

Research Article

Strategic Planning for Improving Nongreen Impact Factors of Traditional Coal Logistics in China

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ABSTRACT

Based on the nongreen impact factors of coal logistics and traditional coal companies, this study aims to understand the role of such factors in coal supply, production, distribution, recycling, and waste logistics. Porter's five forces model is used to analyze the potential competitors, peer competitors, substitutes, and coal buyers and suppliers in traditional coal logistics enterprises in order to find the key problems in nongreen impact factors affecting traditional coal logistics. Then, Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ) is used to formulate the corresponding six strategies for key problems. Lastly, the interpretative structural model is used to analyze and establish a systematic process for the development of a strategy. Analysis results show that when traditional coal enterprises improve their problems under the influence of nongreen impact factors, they should first establish strategic partnerships with nodes in the supply chain to exchange problems in coal production and coal enterprise operations and help each other achieve mutual benefits. After establishing a cooperative relationship with other enterprises, they can use advanced logistics information technology to establish a logistics system and external communication channels with other cooperative enterprises, thereby helping their own enterprises improve in terms of green production, green scale, and green transportation. Meanwhile, traditional coal enterprises should strengthen product quality supervision, increase production transparency, and improve the quality of coal production. Furthermore, the relationship with suppliers must be maintained for a long time. Market research must also be conducted to understand the needs of the coal market, ensure the development of new products, and maintain the advantages of traditional coal companies in the market competition.

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1. INTRODUCTION

China is a major coal producer and consumer. Coal accounts for approximately 70% of the primary energy structure. As a major energy source and industrial raw material in China, coal is mainly distributed in the northwest and less in the southeast. Major coal production and coal demand areas have a huge spatial difference. In recent years, the volume of coal transportation has increased rapidly due to the rapid growth of coal production in China, thereby promoting the development of the coal logistics industry in China. According to the 2017 China Coal Industry Operation Report, China's coal production in 2017 was 3.52 billion tons, representing a year-on-year increase of 3.3%. In addition, the national railway shipped a total of 2.16 billion tons of coal, representing an increase of 13.3%; the volume of coal shipment at major ports was 730 million tons, representing a year-on-year increase of 12.9% [1]. However, most coal enterprises in China are self-employed enterprises that adopt extensive coal logistics management and mining processes, which range from coal mining, washing, pro-

cessing, storage, transportation, and sales to comprehensive waste utilization; these processes have serious impacts on the environment [2]. Geological disasters in mines occur frequently. The geological collapse caused by improper coal mining, washing, and distribution and the pollution of water and air resources also occur frequently. Therefore, the improvement of traditional coal logistics is imminent.

Coal logistics systems comprise coal supply, production, sales, recycling, and waste logistics [3]; these processes are involved in the development preparation, production process, and sales activities of coal products. Traditional modes of logistics operations have remained to be the mainstream of coal logistics development, although many nongreen impact factors are involved in the process; thus, traditional coal logistics highly pollute the environment.

This study focuses on the nongreen impact of coal logistics and the shortcomings of the operation of traditional coal logistics enterprises. Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ) theory is used to solve the shortcomings [4,5]. Therefore, this study first analyzes the important key problems in traditional coal logistics. Porter's five forces model is used to (1) analyze the competitiveness of coal logistics enterprises using traditional coal logistics methods, (2) analyze the key problems in traditional coal logistics, and

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(3) understand the generation of nongreen impact factors of coal logistics on the basis of the environmental impact of each operation link in the system. In accordance with the identified key problems in traditional coal logistics, an analysis based on TRIZ theory is conducted to propose targeted strategies. Lastly, the Interpretative Structural Model (ISM) is used to establish a systematic process for the development of a traditional coal logistics strategy [6]. The developed strategy can effectively reduce the period of introduction and improve the efficiency of traditional coal logistics enterprises in terms of providing a powerful theoretical reference in the process of improving the enterprise's logistics methods.

2. LITERATURE REVIEW

2.1. Composition of Traditional Coal Logistics

Coal logistics comprises five parts, namely, coal supply, production, distribution, recycling, and waste logistics systems [3,7]. These parts are explained as the following.

2.1.1. Coal supply logistics

Li [8] pointed out that coal supply logistics includes the procurement, transportation, inventory management, and material management of production materials. Therefore, coal supply logistics refers to the physical distribution process between the supply and demand of raw materials, fuels, equipment, and tools during coal production. A coal supply logistics system becomes difficult to control and manage due to the working conditions and location of the mine; with such difficulty, the cost of coal logistics largely increases. Jiang [9] indicated that the cost of coal supply logistics accounts for 60–70% of the total production cost of China's coal enterprises in China. Therefore, reducing the supply logistics costs of coal enterprises can reduce the operating costs of coal enterprises and increase the profitability and market competitiveness of coal enterprises.

2.1.2. Coal production logistics

Coal production logistics refers to the coal mining processes that occur between the coal mining face and the transportation vehicles (trains, cars, etc.). There are two main methods of coal mining. First, a coal mine ground production system includes a ground coal transportation system, a ground gangue system, a material supply system, a coal preparation system, administrative welfare facilities, and other buildings; second, a coal mine underground production system is more complicated than ground production and mainly includes a transportation improvement system, a ventilation system, a drainage system, and a power supply system [10,11]. Overall, all coal production logistics systems include coal mining, warehousing, loading and unloading, transportation, washing, and other operations. For the convenience of these operations in coal production logistics, coal is often stacked in bulk, which will not only cause waste of coal resources but also damage the ecological environment [3].

2.1.3. Coal sales system

Generally, coal production logistics is the flow of materials within a coal enterprise. Coal sales logistics is the flow of external materials of a coal enterprise and is the physical distribution process of coal commodities between the coal enterprise and users. It consists of two important parts, namely, foreign transportation and utilization [10]. The former uses coal transportation to solve the space problem between coal production and demand. The main transportation methods are water and rail transportation. In addition to these two, another method is road transportation, which is one of the important reasons for the nongreen impact on the environment during the process of coal sales and logistics. The latter, through the logistics, to establish the spatial utilization of coal to achieve the use-value of coal. Therefore, research on coal sales logistics has two aspects. On the one hand, it explores external transportation, focusing on the mode and route of external transportation. On the other hand, it investigates coal utilization, including the processing and burning of coal.

2.1.4. Recycling and waste logistics of coal

Recycling logistics of coal is the terminal link of coal logistics, which represents the logistics activities of coal enterprises to transport coal materials and products in reverse along the supply chain. It mainly includes three parts: marginal coal, which comes from the recovery of waste materials generated during coal mining; the recovery of waste materials consumed during coal production; and the recovery of coal slag scattered during the internal and external transportation of coal [10]. Because coal has the characteristics of huge usage and strong reusability, the research is focused on the reduction of the generation rate of coal waste and the comprehensive utilization technology of waste logistics, which can save a lot of costs for coal enterprises and reduce the negative impact of coal production on the environment [12].

2.2. Nongreen Impact Factor Analysis of Coal Logistics

Given that coal logistics is a complex system, each system link of the system contains nongreen impact factors [7]. The development of coal logistics has caused various degrees of adverse impacts on the environment and produced a negative influence on sustainable economic and social development. In Figure 1, the nongreen impact factors of coal logistics are presented from the environmental perspective of each operation of the coal logistics system.

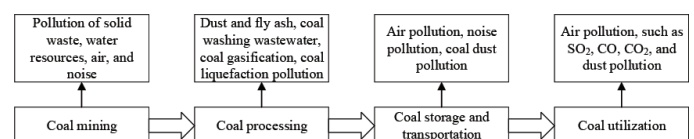


Figure 1 | Nongreen impact factors of coal logistics system.

2.2.1. Nongreen impact factors of coal mining

With coal mining at the front-end of coal logistics, the nongreen impact on the environment is manifested in the pollution of solid waste, water resources, air, and sound [7]. Solid waste pollution mainly includes slime, coal ash, and ash residue, which are discharged during coal mining. Meanwhile, in the process of coal mining and washing, a substantial amount of water is consumed, resulting in a large amount of industrial wastewater. Therefore, the wastewater contains numerous suspended solids, heavy metals, and other toxic substances, which cause serious harm to the environment and human health. Coal mining also causes air pollution, which comes from mine gas, the main component is methane (CH₄) that is 21 times more harmful than CO₂ [9]. In addition, coal mine noise mainly comes from various electromechanical equipment. The noise will pollute the surrounding environment of the coal mine and also cause damage to the miners' auditory organs, which is prone to industrial accidents [13].

2.2.2. Nongreen impact factors of coal processing

The nongreen impact of the coal processing process is mainly manifested in two aspects. The first aspect is reflected during coal storage and transportation when the coal preparation plant filters a large amount of dust and fly ash during the crushing process, which is a loss to the coal itself and is harmful to the human body. Meanwhile, the wear and tear of equipment will be accelerated to reduce the quality of the coal product due to dust and fly [14]. The second aspect is manifested by water pollution and waste of resources due to black coal cleaning during coal washing, the purpose of coal washing is to remove various impurities in the black coal [15].

2.2.3. Nongreen impact factors of coal storage and transportation

Coal storage and transportation largely contribute to environmental problems. Its main pollution is the occurrence of environmental hazards and resource consumption. Environmental hazards mainly come from pollution caused by transportation modes (e.g., atmospheric and noise pollution). Among the various modes of coal transportation, road transportation has the highest pollutant emissions. Coal transportation, especially railway and road transportation, is also a major source of noise pollution. The second is the particularity of coal pollutants logistics, such as air pollution caused by spontaneous combustion or dust generated during coal loading and unloading and transportation [16], or water pollution caused by wastewater discharge. In terms of resource consumption, coal storage and transportation facilities are an important infrastructure; these facilities consume substantial land resources, especially during the construction of railways and highways. Meanwhile, large coal yards along railways and ports also occupy an expanse of arable lands. In addition, the coal transportation industry consumes substantial energy. For example, the backwardness of transportation technology and transportation route planning ability leads to low

energy efficiency [17]. Meanwhile, an average transportation loss of 2–3% is also generated in coal transportation, causing serious waste of coal energy [16].

2.2.4. Nongreen impact factors of coal utilization

China is the world's largest coal producer and consumer. At present, coal provides more than 70% of domestic power generation fuel and more than 80% of domestic fuel; 60% of chemical raw materials also come from coal in China [8]. When using coal, direct coal combustion produces many air pollutants, such as SO₂, CO, CO₂, and dust, which directly cause atmospheric pollution. Such pollution leads to serious environmental destruction and hinders the greening of the coal logistics process.

3. PORTER'S FIVE FORCES MODEL ANALYSIS OF TRADITIONAL COAL LOGISTICS ENTERPRISES

Coal logistics enterprises are the most important carrier of coal logistics operations. The nongreen executors of coal logistics are considered coal logistics enterprises; therefore, the operation status of coal logistics enterprises reflects whether a coal logistics system is operating well. Most traditional coal logistics enterprises are self-operated logistics enterprises. Approximately 80% of coal logistics is borne by coal enterprises and the industry itself [18]. As a result, effective resources, such as various logistics equipment and various logistics practitioners, cannot be reasonably allocated. The existing main services of traditional coal logistics enterprises in China are limited to basic low-level logistics operations, such as freight forwarding, warehousing, and transportation. Only a few logistics service companies provide comprehensive, comprehensive, and integrated modern logistics services [8].

This section uses Porter's five forces model to analyze the competitiveness of China's traditional coal logistics enterprises. As shown in Figure 2, Porter's five forces model believes that five forces prevail in the scale and degree of competition in the industry. These five forces, namely, the competitiveness of existing competitors in the industry, the ability of potential competitors to enter, the ability to substitute alternatives, the bargaining power of suppliers, and the bargaining power of buyers [19], combine to affect the competitiveness of the industry and the competitive strategic decisions of existing companies.

The competitiveness of traditional coal enterprises is analyzed in accordance with Porter's five forces model. This study summarizes the problems faced by traditional coal enterprises and then analyzes them in detail, as shown in Table 1.

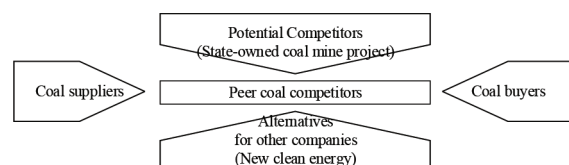


Figure 2 | Porter's five-force model analysis of traditional coal enterprises.

Table 1 | Problems faced by traditional coal companies

Aspects of five forces model	Problems
Coal suppliers	Suppliers are scattered, and coal companies have low bargaining power with suppliers.
Coal buyers	The higher the user's requirements for coal quality, and the oversupply of coal in China, the coal market is in a buyer's market.
Potential competitors	The market entry threshold for coal is low, and local self-employed individuals who are motivated by profit mine coal privately, thereby disrupting market order and causing disorderly competition.
Alternatives for other companies	The popularization of green concepts and the social and environmental requirements for green coal have increased. Moreover, the wide use of new energy sources, such as wind and solar energy, has emerged.
Peer competitors	Excessive competition between peers has an adverse effect on the development of the coal industry.

3.1. Coal Suppliers

Suppliers of upstream production equipment hold resources and equipment that are closely related to coal production and product processing [20], and the purchase costs of coal enterprises for these resources and equipment account for a high proportion of the total product cost [21]. Therefore, the main key technologies and equipment needed for coal production (e.g., hoisting systems) can be purchased through international bidding. The materials required for daily production are steel, cement, equipment, and electricity. Given that the number of suppliers involved is large and scattered, coal companies have weak bargaining power over suppliers. However, production materials are abundant, and the supply of most commodities has various choices and is in an excess state due to the transition from the planned economy to the market economy. In this case, coal companies can adopt a comparative purchase method, which greatly reduces procurement costs [22].

3.2. Coal Buyers

The bargaining power of buyers is greatly affected by market supply and demand [23]. Moreover, as society's environmental protection requirements and users' requirements for coal quality increase, the bargaining power of buyers for coal products also becomes stronger. Coal itself is a standardized product with almost no difference; thus, the buyer can shop around for the best product. In recent years, a buyer's market has been formed due to the oversupply of coal in China [24]. As a result, buyers have imposed stricter requirements on the quality, price, and after-sales service of coal products.

3.3. Potential Competitors

Two major situations regarding potential competitors prevail. One is the emergence of new coal mine projects under the guidance of national industrial policies and regulations. The other is the development of coal mines that are privately mined by local and individual households, i.e., small coal mines that are being reproduced

and driven by increased market improvement [23]. The latter has remarkably disturbed the order of the coal market, leading to a disorderly competition among coal mining enterprises. With the expansion of the small coal mines' ability to control the market, coal mine entry barriers have been formed. Thus, the concentration of the coal industry and the market discourse power and control have gradually higher [25], but the competitiveness of the coal industry has gradually weakened.

3.4. Alternatives for Other Companies

In China's primary energy consumption pattern, the competitive strength of alternative products has increased, and the proportion of coal consumption has declined. According to the development of science and technology and environmental protection requirements, new green energy sources, such as solar energy, atomic power, wind and power, are widely used [23]. Moreover, the development of coal enterprises is facing severe challenges because of the low thermal efficiency and high pollution rate of coal.

3.5. Peer Competitors

For the domestic coal industry, import and export tariff barriers are low, entry barriers are high, and market share is low. These reasons result in the current coal market in the case of oversupply [26]. The fierce competition between individual local private households with different interests and state-owned coal enterprises has an adverse impact on the development of the coal industry.

In accordance with Porter's five forces model, an in-depth external analysis of the competitiveness of traditional coal enterprises is conducted. Results from the analysis of the five aspects reveal that the current problems of coal enterprises can be classified into four problems, namely bargaining power, balance of supply and demand, over-competition, and new energy penetration. The TRIZ analysis method is then used to propose strategies for these four problems.

4. ESTABLISHMENT OF IMPROVEMENT STRATEGIES TO ADDRESS TRADITIONAL COAL LOGISTICS PROBLEMS

This section aims to control coal logistics pollution effectively, reduce the nongreen impact of coal logistics, and improve the competitiveness of coal enterprises. In accordance with the above nongreen impact of coal logistics and Porter's five forces model analysis of the competitiveness of traditional coal enterprises, the TRIZ analysis method is used to propose improvement strategies.

4.1. Analysis Steps of TRIZ

Savransky [27] proposed four steps of TRIZ analysis for the application of the contradiction matrix and 40 innovation principles: (1) identifying the problem, (2) determining the improving and worsening parameters, (3) searching for the intentions of the innovative principles, and (4) constructing strategies on the basis of innovative principles [28].

4.2. TRIZ Strategy Formulation

4.2.1. Bargaining power

Step 1. Identifying the problem

Although coal-related equipment can be purchased through international bidding, many related suppliers can produce large amounts of steel, cement, equipment, electricity, and other common materials. Thus, the price competitiveness of coal enterprises becomes weak. The higher the bargaining power of coal companies over suppliers, the more beneficial it is to reduce the cost of the daily expenditure of enterprises. By contrast, the low bargaining power of coal companies over suppliers is detrimental to the daily cost of coal enterprises.

Step 2. Determining the improving and worsening parameters

According to the definition of the bargaining power problem, a reduction in the cost of the daily expenditure of coal enterprises can bring great benefits for the development of the enterprises. Under the condition wherein the prices of coal products in the coal market do not greatly vary, reduced corporate expenditure is another benefit for coal companies. Therefore, the improving parameter is “21. Power” by searching 39 engineering parameters [29], that is, the amount of change in the cost of coal companies’ expenditures. However, in the process of reducing costs, it may affect the supplier’s enthusiasm for cooperation. The lack of attention to the supply directly affects the normal supply of goods; thus, the worsening parameter is “9. Speed” by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

According to the contradiction matrix [29], the improving parameter “21. Power,” and the worsening parameter “9. Speed,” the innovation principles of bargaining power include “Principle 2: Taking out,” “Principle 15: Dynamics,” and “Principle 35: Parameter change”.

In accordance with the explanation of 40 innovative principles, “Principle 15: Dynamics” and “Principle 35: Parameter change” are obtained.

Step 4. Constructing strategies on the basis of the innovative principles

In “Principle 15: Dynamics,” the characteristics of the object or its external environment can be adjusted to the most suitable operating state. The decentralization of suppliers has caused coal companies to have low bargaining power. Therefore, coal companies should adjust supplier cooperation methods. They can change decentralized cooperation methods to centralized ones or choose suppliers with stable supply and guaranteed quality to establish a long-term cooperative relationship and thus reduce the cost of procurement.

“Principle 35: Parameter change” refers to changing the degree of flexibility. The original supply mode is too fragmented; thus, coal enterprises should make corresponding adjustments. For coal enterprises, a long-term

cooperation with suppliers can reduce the inventory level of coal enterprises’ equipment and parts and eventually reduce inventory management fees and increase capital turnover. In addition, during the process of strengthening supplier communication, the order processing process, the accuracy of the required equipment, the technological and innovative achievements of the supplier, and the quality of coal must be improved.

4.2.2. Balance of supply and demand

Step 1. Identifying the problem

Coal products do not have much differences; thus, the major means of profit of coal enterprises is impulse. With the increase in coal enterprises, the market has been saturated, China has an oversupply of coal, and the coal market is in a buyer’s market state. With the development of society and the improvement of the quality of coal purchase groups, coal buyers have become increasingly demanding on the quality of coal products, and their willingness to purchase ordinary coal products has decreased. This situation results in an imbalance between coal supply and demand.

Step 2. Determining the improving and worsening parameters

According to the definition of balance of supply and demand, the oversupply of coal companies and the neglect of coal product quality cause an oversupply in the coal market. Therefore, coal companies should supply the actual market demand to improve the oversupply of coal; thus, the improving parameter is “39. Productivity” by searching 39 engineering parameters. However, the market has too many instability factors, deviations occur in the judgment of market demand; thus, the worsening parameter is “29. Accuracy of manufacturing” by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

According to the improving parameter “39. Productivity” and the worsening parameter “29. Accuracy of manufacturing,” the innovation principles of the balance of supply and demand include “Principle 1: Segmentation,” “Principle 10: Preliminary actions,” “Principle 18: Mechanical vibration,” and “Principle 32: Color changes” according to the contradiction matrix.

In accordance with the explanation of 40 innovative principles, “Principle 10: Preliminary actions” and “Principle 32: Color changes” are obtained.

Step 4. Constructing strategies on the basis of the innovative principles

“Principle 10: Preliminary action” refers to ensuring the change in the demand of the object or system before execution. Before large-scale coal production, coal companies should study the market well and fully understand the needs of the market to avoid unnecessary losses.

“Principle 32: Color changes” refers to changing the transparency of the external environment of the object

or system. To make the coal production process transparent, coal buyers should be able to understand directly the environment-friendly production of coal to strengthen the supervision of the quality of commercial coal. Meanwhile, the coal company must strengthen the evaluation of coal quality indicators to improve the quality of coal products.

4.2.3. Over-competition

Step 1. Identifying the problem

The barrier to entry in the coal market is low, and local individuals driven by personal interests seem to have joined the coal market competition. The fierce competition among their peers has caused chaotic order in the coal market. Disorderly competition is serious and unfavorable to the development of the coal industry.

Step 2. Determining the improving and worsening parameters

According to the definition of the excessive competition problem, the coal market is overcompetitive due to the influx of coal companies of different sizes and individual private households into the coal market. Therefore, the improving parameter is defined as “2. Weight of non-moving object” by searching 39 engineering parameters. However, the market share of coal companies is also greatly affected because of too many competitors; thus, the worsening parameter is defined as “8. Volume of non-moving object” by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

According to the improving parameter “2. Weight of non-moving object” and the worsening parameter “8. Volume of nonmoving object”, the innovation principles of over-competition include “Principle 2: Taking out,” “Principle 5: Merge,” “Principle 14: Spheroidality,” and “Principle 35: Parameter change” according to the contradiction matrix.

In accordance with the explanation of 40 innovative principles, “Principle 5: Merge” is obtained.

Step 4. Constructing strategies on the basis of the innovative principles

“Principle 5: Merge” refers to combining homogeneous objects or systems with each other. In response to the phenomenon of excessive competition, coal companies can choose to cooperate with other coal companies, exchange experiences in coal production and coal company operations, and help each other achieve mutual benefits.

4.2.4. New energy penetration

Step 1. Identifying the problem

Coal is an indispensable part of China’s energy consumption structure. However, with the social requirements for greening and the popularization of green concepts, the

green requirements for coal have increased. Moreover, with the development of science and technology and the requirements of environmental protection, the wide use of new energy sources, such as solar, nuclear, and wind energy, have emerged, and the development of coal enterprises is facing severe challenges.

Step 2. Determining the improving and worsening parameters

China’s coal production is still in an extensive state, and the use of information technology in the management of coal logistics remains lacking [30]. The salient features of coal logistics information are wide information range, numerous sources, dynamism, time sensitivity, and high risk. With the development of science and technology, logistics information technology has been greatly improved. The use of logistics information technology for coal production and operation has great benefits for the development of coal enterprises. Therefore, the improving parameter is defined as “38. Level of automation” by searching 39 engineering parameters. However, the coal market has little experience in the use of logistics information technology in the new era; therefore, even if coal enterprises introduce logistics information technology, improper operation may occur. Thus, the worsening parameter is defined as “37. Complexity of control” by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

According to the improving parameter “38. Level of automation” and the worsening parameter “37. Complexity of control”, the innovation principles of new energy penetration include “Principle 25: Self-service,” “Principle 27: Cheap short-living objects,” and “Principle 34: Discarding and recovering” according to the contradiction matrix.

In accordance with the explanation of 40 innovative principles, “Principle 34: Discarding and recovering” is obtained.

Step 4. Constructing strategies on the basis of the innovative principles

“Principle 34: Discarding and recovering” refers to discarding or revising an object or system when its function has failed. The original coal production model no longer meets the requirements of sustainable development. Coal enterprises should adopt advanced logistics information technology for green production, green sales, and green transportation. Some advanced abroad logistics companies have begun to apply e-commerce and Internet of Things technologies, including Electronic Data Interchange (EDI), Geographic Information Systems (GIS), Global Positioning System (GPS), barcode technology, radio frequency identification, and other communication technologies.

In summary, this study uses the TRIZ theoretical analysis method to propose six corresponding strategies to the problems existing in traditional coal enterprises. These strategies are described in [Table 2](#).

Table 2 | Improvement strategies for traditional coal logistics problems

Problems	Improving parameter	Worsening parameter	Innovative principle	Strategy
Bargaining power	21. Power	9. Speed	Principle 15: Dynamics	S1. Adjust supplier cooperation methods, change decentralized cooperation methods to centralized cooperation methods, and choose suppliers with stable supply and guarantee quality to establish long-term cooperative relations.
Balance of supply and demand	39. Productivity	29. Accuracy of manufacturing	Principle 35: Parameter Change	S2. For traditional coal companies, long-term cooperation with suppliers can reduce the inventory level of coal companies' equipment and parts, reduce management fees, and make a quick capital turnover. In the process of strengthening supplier communication, the order processing process, the accuracy of required equipment, the technological and innovative achievements of suppliers, and the quality of coal must be improved.
Over-competition	2. Weight of nonmoving object	8. Volume of nonmoving object	Principle 10: Preliminary Action	S3. Traditional coal companies should conduct market research and fully understand the coal market demand before officially investing in coal production.
New energy penetration	38. Level of automation	37. Complexity of control	Principle 32: Color Changes	S4. Making the coal production process transparent allows coal buyers to understand the environment-friendly local coal production and strengthen the supervision of commercial coal quality. Furthermore, enterprises must strengthen the evaluation of coal quality indicators to improve coal quality.
			Principle 5: Merge	S5. Traditional coal enterprises may choose to cooperate with other coal enterprises to exchange experiences in coal production and coal enterprise operations and help each other achieve mutual benefits.
			Principle 34: Discarding and Recovering	S6. Use advanced logistics information technology for green production, green sales, green transportation, and other links.

5. EXECUTION PLANNING OF STRATEGIES

Although TRIZ is used to establish improvement strategies for traditional coal logistics problems, the order of strategy implementation must be formulated. Before large-scale coal production, coal companies should conduct market research (S3) to understand the coal market demand and produce coal products that meet the quality of demand (related to S1 and S2); moreover, the supervision of the quality of commercial coal (S4 in Table 2), which is related to the quality of production materials (S1 and S2), must be strengthened. In addition, the use of advanced logistics information technology for green production, green sales, green transportation, and other links (S6) is related to S1, S2, and S5, that is, a correlation exists among the strategies. Thus, highly relevant strategies must be analyzed and then parallelized to establish the hierarchical relationship of the strategies and eventually ascertain a systematic development process of traditional coal logistics strategies.

5.1. Questionnaire Design

This study uses a questionnaire survey to conduct a correlation survey among strategies. The purpose is to find the subordinate relationship between pairwise strategies. Then, the ISM is used to analyze the data collected by the questionnaire and establish a systematic strategy development process system on the basis of the data analysis results. The questionnaire, which is distributed using snowball sampling, is filled out by coal logistics-related companies.

The questionnaire on the correlation between traditional coal logistics problem improvement strategies uses a single-choice question to ask the correlation between the pairwise improvement strategies in Table 2 and judges the correlation between the pairwise improvement strategies on the basis of the proportion of the answers “yes” or “no,” where “0” indicates no correlation, and “1” indicates otherwise. The question is “Do you think “improvement strategy A” is closely related to each of the following improvement strategies?” If a certain indicator has a correlation, check “Yes”; select “No” if otherwise (Table 3).

5.2. Analysis Steps of the ISM

To judge the subordination relationship between the pairwise strategies for solving traditional coal logistics problems, the ISM is used as an analysis tool because it is widely used in modern engineering systems. Using the ISM can decompose a complex system into several subsystem elements. Then, good experience and knowledge, with the aid of a computer, are used to form a systematic execution

Table 3 | Interpretation of questions in the questionnaire

Improvement strategies	Yes	No
1. Do you think “improvement strategy A” is closely related to each of the following improvement strategies?		
S2	<input type="radio"/>	<input type="radio"/>
S3	<input type="radio"/>	<input type="radio"/>
S4	<input type="radio"/>	<input type="radio"/>
S5	<input type="radio"/>	<input type="radio"/>
S6	<input type="radio"/>	<input type="radio"/>

(URL of the complete questionnaire: <https://www.wjx.cn/m/53653562.aspx>)

program. That is, using the ISM can decompose and transform vague ideas and opinions in the system into intuitive hierarchical relationships and graph. The hierarchy-related graph can provide a specific structure to provide systematic execution steps and reduce the errors and risks in the decision-making and planning processes. Therefore, this study uses the ISM to construct a standard operating procedure for the improvement strategy that would address traditional coal logistics problems; the development of such strategy is beneficial to the coal logistics industry. The procedure is based on the research results and serves as a reference and implementation basis for the development of traditional coal logistics.

The analysis results of the ISM can be summarized as the hierarchical relationships and graph of each element. These hierarchical relationships can be used to propose a systematic execution procedure. The seven calculation steps of the ISM proposed by Olsen [31] are introduced in order as follows:

- Step 1. Identify the factors related to the research. The researcher can collect the related factors in accordance with the theme of the research. These factors are expressed mathematically as a_i , $i = 1, 2, 3, \dots, k$, where k stands for the number of factors.
- Step 2. Determine the subordination relationship between the pairwise factors. Such relationship and their mutual influence can be measured in accordance with the opinions of experts and scholars through questionnaires or qualitative research.
- Step 3. Determine the relation matrix. After determining the subordination relationship between the pairwise factors, the result is expressed mathematically. The four cases are as follows:
- (1) If factor i directly affects factor j , then $a_{ij} = 1$, and $a_{ji} = 0$.
 - (2) If factor j directly affects factor i , then $a_{ji} = 0$, and $a_{ij} = 1$.
 - (3) If factor i and factor j interact with each other, then $a_{ij} = 1$, and $a_{ji} = 1$.
 - (4) If factor i and factor j do not affect each other, then $a_{ij} = 0$, and $a_{ji} = 0$.

The relationship matrix is represented by \mathbf{A} , as shown in Equation (1).

$$\mathbf{A} = \begin{matrix} \begin{bmatrix} a_{11} & \cdots & a_{1k} \\ \vdots & \ddots & \vdots \\ a_{k1} & \cdots & a_{kk} \end{bmatrix} \\ i = 1, 2, 3, \dots, k \\ j = 1, 2, 3, \dots, k \end{matrix} = \begin{bmatrix} 0 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 0 \end{bmatrix} = [a_{ij}] \quad (1)$$

- Step 4. Decide on the adjacent matrix. Add the relationship matrix (\mathbf{A}) in Step 3 and the identity matrix (\mathbf{I}) to obtain the adjacent matrix (\mathbf{M}).
- Step 5. Convert the adjacent matrix into a reachable matrix. The ISM has a transitivity relationship, that is, if factor i is related to factor j , and factor j is related to factor k , then factor i and factor k are also related. Therefore, the adjacent matrix can be referred to as reachable matrix (\mathbf{M}) after satisfying the transitivity.
- Step 6. Convert the reachable matrix into a hierarchy matrix. The hierarchy matrix contains a reachability and an antecedent set; the representative symbols of the two are $\mathbf{R}(a_i)$ and $\mathbf{A}(a_i)$, and the set is called the intersection set ($\mathbf{R}(a_i) \cap \mathbf{A}(a_i)$).

- (1) Reachable set ($\mathbf{R}(a_i)$): With the horizontal axis taken as the main axis, the corresponding factors are extracted if the intersection value of the horizontal and vertical axis factors in the reachable matrix is 1.
- (2) Antecedent set ($\mathbf{A}(a_i)$): With the vertical axis taken as the main axis, the corresponding factors are extracted if the intersection value of the horizontal and vertical axis factors in the reachable matrix is 1.

Step 7. Use the hierarchical matrix to draw an ISM hierarchy-related graph. First, extract the same factors as the reachable set ($\mathbf{R}(a_i)$) and intersection set ($\mathbf{R}(a_i) \cap \mathbf{A}(a_i)$), and place them on the first layer. Then, delete the extracted factors from the reachable and intersection sets. Afterward, find the factors of the second layer in the same manner. After finding the factors of each layer by analogy, draw the arrows to show the subordinate relationship of each factor in accordance with the subordination relationship between the pairwise factors presented in the relationship matrix (\mathbf{A}), that is, an ISM hierarchy-related graphic can be completed.

5.3. ISM Data Analysis

In this section, the ISM, which comprises seven steps, is used to analyze the data recovered from the questionnaire. The first step is to identify the relevant factors of the study, that is, the improvement strategy to address the traditional coal logistics problem (Table 2). The remaining six steps are explained as follows:

5.3.1. Determine the subordination relationship between the pairwise factors

Wu et al. [32] acknowledged the subordination relationship of the pairwise factors if over 50% of the respondents indicate the said subordination relationship of the factors. Thus, this study uses a questionnaire to investigate the opinions of coal logistics-related companies, confirming the affiliation between the pairwise factors and analyzing the results of the questionnaire, with 60% as the threshold. That is, a value more than 60% proves that the pairwise factors have a subordinate relationship. A total of 12 valid questionnaires are retrieved from the respondents. If eight (more than 60%) of the respondents thought that the pairwise factors had a subordination relationship, the pairwise factors are deemed to have a subordination relationship.

According to the statistical results in Table 4, strategic factor S2 affects strategic factor S3, strategic factor S3 affects strategic factor S2, strategic factor S4 affects strategic factor S2, strategic factor S4 affects strategic factor S6, strategic factor S5 affects strategic factor S1, strategic factor S5 affects strategic factor S6, and strategic factor S6 affects strategic factor S4. After collating the results, a subordination relationship is obtained, as shown in Table 5.

5.3.2. Determine the relation matrix

From Table 5, the subordination relationship between the pairwise strategic factors can be obtained. Result is then converted into the relation matrix, as shown in Table 6.

Table 4 | Related proportions between the pairwise strategic factors


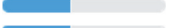



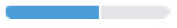


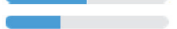





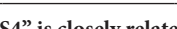





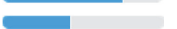
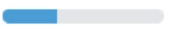








Strategic factor options	Subtotal	Proportion
1. Do you think “Improving strategic S1” is closely related to each of the following improvement strategies?		
S2	7	 58.33%
S3	5	 41.67%
S4	5	 41.67%
S5	7	 58.33%
S6	7	 58.33%
2. Do you think “Improving strategic S2” is closely related to each of the following improvement strategies?		
S1	7	 58.33%
S3	8	 66.67%
S4	4	 33.33%
S5	6	 50%
S6	4	 33.33%
3. Do you think “Improving strategic S3” is closely related to each of the following improvement strategies?		
S1	6	 50%
S2	9	 75%
S4	7	 58.33%
S5	5	 41.67%
S6	6	 50%
4. Do you think “Improving strategic S4” is closely related to each of the following improvement strategies?		
S1	4	 33.33%
S2	8	 66.67%
S3	7	 58.33%
S5	3	 25%
S6	8	 66.67%
5. Do you think “Improving strategic S5” is closely related to each of the following improvement strategies?		
S1	9	 75%
S2	5	 41.67%
S3	4	 33.33%
S4	5	 41.67%
S6	8	 66.67%
6. Do you think “Improving strategic S6” is closely related to each of the following improvement strategies?		
S1	6	 50%
S2	7	 58.33%
S3	5	 41.67%
S4	8	 66.67%
S5	5	 41.67%

Table 5 | Result of subordination relationship of pairwise strategy factors

S2 ¹ ↔ S3 ³	S4 → S2 ²	S4 → S6	S5 → S1	S5 → S6
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Remarks: ¹Refer to Table 2 for the number of each strategic factor; ²A→B means that strategic factor A affects strategic factor B; ³A↔B means that strategic factors A and B affect each other.

5.3.3. Determine the adjacent matrix

The relation matrix in Table 6 and the identity matrix are combined to form an adjacent matrix, as shown in Table 7.

Table 6 | Relation matrix

Strategic factor ¹	S1	S2	S3	S4	S5	S6
S1		0 ²	0	0	0	0
S2	0		1 ³	0	0	0
S3	0	1		0	0	0
S4	0	1	0		0	1
S5	1	0	0	0		1
S6	0	0	0	1	0	

Remarks: ¹Refer to Table 2 for the number of each strategic factor; ²Value 0 means that strategic factor A do not affect strategic factor B; ³Value 1 means that strategic factor A affects strategic factor B.

Table 7 | Adjacent matrix

Strategic factor ¹	S1	S2	S3	S4	S5	S6
S1	1	0 ²	0	0	0	0
S2	0	1	1 ³	0	0	0
S3	0	1	1	0	0	0
S4	0	1	0	1	0	1
S5	1	0	0	0	1	1
S6	0	0	0	1	0	1

Remarks: ¹Refer to Table 2 for the number of each strategic factor; ²Value 0 means that strategic factor A do not affect strategic factor B; ³Value 1 means that strategic factor A affects strategic factor B.

Table 8 | Reachable matrix

Strategic factor ¹	S1	S2	S3	S4	S5	S6
S1	1	0 ²	0	0	0	0
S2	0	1	1 ³	0	0	0
S3	0	1	1	0	0	0
S4	0	1	1*	1	0	1
S5	1	1*	1*	1*	1	1
S6	0	1*	1*	1	0	1

Remarks: ¹Refer to Table 2 for the number of each strategic factor; ²Value 0 means that strategic factor A do not affect strategic factor B; ³Value 1 means that strategic factor A affects strategic factor B, Symbol * means that the transitivity relationship.

5.3.4. Convert the adjacent matrix into a reachable matrix

The ISM needs to conform to the transitivity relationship, that is, if factor A affects factor B, and factor B affects factor C, then factor A can affect factor C. Therefore, changing the value between the factors conforming to the transitivity relationship to 1, can obtain the reachable matrix in Table 8.

5.3.5. Convert the reachable matrix into a hierarchical matrix

Converting the reachable matrix into a hierarchical matrix entails the identification of the reachable, antecedent, and intersection sets of various strategic factors in accordance with Table 8, as shown in Table 9. Among them, the reachable set means that each

strategic factor finds the corresponding strategic factor with a value of 1 in the row of the reachable matrix. The antecedent set means that each strategic factor finds the corresponding strategic factor with a value of 1 in the column of the reachable matrix. The intersection set refers to the strategic factors common to the reachable and antecedent sets.

5.3.6. Hierarchy-related graph and analysis

Table 9 reveals that the reachable set of strategic factors S1, S2, and S3 is exactly the same as the intersection set; thus, strategic factors S1, S2, and S3 are selected as the first layer of the hierarchy-related graph. Then, after deleting the selected strategic factors S1, S2, and S3 in Table 8, the same method is used to select the strategic factors that are the same as the reachable set and the intersection set as the second layer; thus, strategic factors S4 and S6 are selected as the second layer of the hierarchy-related graph. Lastly, only strategic factor S5 remains as the third layer of the hierarchy-related graph. With the results of the subordination relationship in Table 5 combined, arrows are used to indicate the subordination relationship between the pairwise strategic factors in the hierarchy-related graph, and the ISM hierarchy-related graph in Figure 3 is obtained.

According to Figure 3, when establishing a systematic development process for a traditional coal logistics strategy, the first stage of strategic factor S5 should be built first to cooperate with other enterprises, learn from each other's strengths, and benefit each other because the relationship between strategic factor S5 and other strategic factors is relatively simple. With strategic factor S5, coal companies can choose to cooperate with other coal companies, exchange experiences in coal production and coal company operations, and help each other to achieve mutual benefits.

Strategic factors S4 and S6 should be implemented in the second stage. The main content should be to strengthen the quality of supervision of commercial coal and then make the production

Table 9 | Hierarchical matrix

Strategic factor	Reachable set	Antecedent set	Intersection set
S1	S1	S1, S5	S1
S2	S2, S3	S2, S3, S4, S5, S6	S2, S3
S3	S2, S3	S2, S3, S4, S5, S6	S2, S3
S4	S2, S3, S4, S6	S4, S5, S6	S4, S6
S5	S1, S2, S3, S4, S5, S6	S5	S5
S6	S2, S3, S4, S6	S4, S5, S6	S4, S6

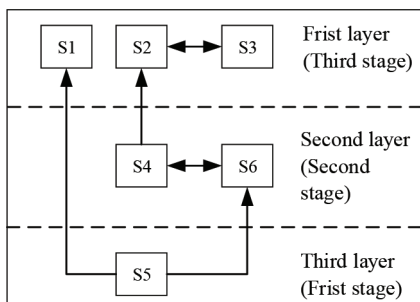


Figure 3 | Hierarchy-related graph.

process of commercial coal transparent; moreover, the evaluation of coal quality indicators within the enterprise must be strengthened to improve coal quality. Meanwhile, advanced logistics information technology is used in green production, green sales, green transportation, and other links. As shown in Figure 3, strategic factor S5 of the first stage directly affects strategic factor S6 of the second stage. Today, logistics information technology (such as warehouse, distribution, customer relationship, and supply chain management systems; EDI/Internet; GIS; GPS; and other logistics information technologies) plays a key role in improving the operating efficiency of logistics systems. Therefore, after establishing a cooperative relationship with other enterprises, traditional coal logistics enterprises can use advanced logistics information technology to establish a logistics system and communication channels with other cooperative enterprises, thereby helping their own enterprises improve green production, green sales, green transportation, and other links.

In the second stage, strategic factors S4 and S6 affect each other. When traditional coal logistics companies establish advanced logistics technologies to improve all aspects of coal logistics (S6), coal production links are included; thus, the coal production process can be made transparent through the information system so that coal buyers can clearly understand the process of environmental protection production to strengthen the supervision of commercial coal quality. It can also strengthen the evaluation of coal quality indicators within the coal enterprise to improve coal quality (S4). By contrast, for coal buyers to understand the environment-friendly production process of coal clearly and transparently, they must be able to query coal production information through the information system during the coal sales process so that they can provide feedback on the quality of coal commodities; such feedback can serve as an internal assessment indicator for coal production quality. Thus, every link in coal logistics must establish an information system for the management of coal quality in the production process.

Strategic factors S1, S2, and S3 should be implemented in the third stage. As shown in Figure 3, strategic factor S4 of the second stage directly affects strategic factor S2 of the third stage. When traditional coal logistics companies implement strategic factor S4 to improve coal quality, coal production must cooperate with good quality raw materials; thus, coal logistics companies must establish good partnerships with suppliers to promote the stability of the quality and price of purchased raw materials and components and improve the quality of coal production. When the quality of coal production improves, the inventory level and inventory management costs of equipment and parts of traditional coal enterprises can naturally be reduced, thus allowing for the company's quick capital turnover. Therefore, strategic factor S4 directly affects strategic factor S2.

Strategic factors S2 and S3 affect each other in the third stage. Traditional coal logistics companies implement strategic factor S2 to establish a good partnership with suppliers, promote the quality and price stability of the purchased raw materials and components, and improve the quality of coal production. However, commercial coal products are diverse, and the raw materials and components required for different types of commercial coal products may vary. Therefore, the production planning of commercial coal product types of traditional coal production enterprises requires market research to understand the needs of the coal market. Afterward, it

is officially placed into the production of commercial coal products (S3). Conversely, when traditional coal enterprises conduct research and development on coal products through market research, they must also fully understand whether the supplier can provide the raw materials and components needed for the new commercial coal products and whether the quality and price of the raw materials and components can meet the requirements of traditional coal enterprises. Therefore, strategic factors S2 and S3 affect each other.

Lastly, strategic factor S1 in the third stage is affected by strategic factor S5 in the first stage. The focus of future competition in the coal industry is mainly on supply chain management and market control. When traditional coal enterprises implement strategic factor S5, the primary goal is to cooperate with other coal enterprises, exchange experiences in coal production and coal enterprise operation, and help each other achieve a situation of mutual benefit and benefit from market competition. However, the cooperation with suppliers must be further adjusted, and decentralized cooperation must be changed to a centralized one to maintain the advantages of market competition. That is, suppliers with stable supply and guaranteed quality must be selected to establish long-term partnerships and a competitive advantage in supply chain cooperation (S1).

6. CONCLUSION

Coal resources play an indispensable role in the development of China's national economy. The development of all walks of life is inseparable from the support for coal. Thus, the development of coal logistics provides convenient conditions for the development of regional economies and the circulation of various social resources. However, coal logistics activities are accompanied by serious environmental pollution and resource wastage, which are caused by the existing conditions in the process of coal mining and transportation. In recent years, China has paid increasing attention to the greening of coal enterprises, and the direction of policy guidance has become increasingly clear. The development trend of the coal industry is green mining, green storage, and green transportation. The green development of coal logistics has ushered in the best development opportunities.

Therefore, this study focuses on the nongreen impact factors of coal logistics and the shortcomings of the operation of traditional coal logistics enterprises. Porter's five forces model is used to analyze and summarize the five problems faced by traditional coal enterprises. Then, on the basis of TRIZ theory, six improvement strategies are proposed to address these five problems. Lastly, the ISM is used to establish a systematic development process of these traditional coal logistics strategies.

According to the ISM hierarchy-related graph, when traditional coal companies improve their problems under the influence of nongreen impact factors, they should first establish strategic partnerships with various nodes in the supply chain, exchange experiences on coal production and coal company operations, and then help each other achieve mutual benefits. After establishing cooperative relations with other enterprises, traditional coal enterprises can use advanced logistics information technology to establish logistics systems and communication channels with other cooperative enterprises to facilitate the improvement of green production,

green sales, and green transportation. In addition, it can strengthen quality supervision within the enterprise to increase production transparency and improve the quality of coal production. Lastly, the supply relationship with suppliers must be maintained for a long time, and market research must be conducted to understand the needs of the coal market and thus ensure the development of new products and maintain the advantages of traditional coal companies in the market competition.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest.

AUTHORS' CONTRIBUTION

CK and CZ study conceptualization and writing (review & editing) the manuscript, CK and CZ data curation, formal analysis and writing (original draft), CK, CY, DZ and DL funding acquisition and project administration, CK and CY supervised the project, CZ, CY, DZ, DL, QW and ZW formal analysis and writing (original draft) the manuscript.

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