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Establishment of Systematic Strategic Planning Procedure for China's Green Coal Logistics by Using Interpretative Structure Model

Ching-Kuei Kao
Key Laboratory of LNG Industry Chain,
Fujian University of Technology, Fujian Province, China

Chu-Mei Zhou
Department of Logistics Management,
Beijing Institute of Technology, Zhuhai, China

Chun-Cheng You
Department of Logistics Management,
Fujian University of Technology, Fujian Province, China

Dao-Lin Zheng
Department of Logistics Management,
Fujian University of Technology, Fujian Province, China

Dai-Rui Li
Department of Logistics Management,
Fujian University of Technology, Fujian Province, China

Qian Wan
Department of Logistics Management,
Fujian University of Technology, Fujian Province, China

Zi-Long Wang
Department of Logistics Management,
Fujian University of Technology, Fujian Province, China

ABSTRACT

In today's society with a globalized economy, countries around the world are pursuing efficiency while also pursuing environmentally sustainable development. Therefore, studying green coal logistics for environmental development and optimization is of great significance and practical value. On the basis of the green concept framework of coal logistics, this paper will determine the five main problems in the operation of green coal logistics and then propose seven improvement strategies to these five main problems by using TRIZ theory. Interpretative structural modeling (ISM) is used to establish a systematic development procedure of green coal logistics strategy to

examine the development of green coal logistics. The analysis results of ISM indicate that, when developing green coal logistics, coal enterprises should retain the effective operation of the original operating mechanism. At the same time, enterprises should introduce a green coal logistics system and effectively merge the two to establish a simple and effective logistics system operating mechanism and cultivate employees' awareness of environmental protection. Doing so will establish a green image of coal enterprises and decrease the cost of green logistics of coal enterprises. Next, each department within the coal enterprise should be refined. To enable various departments within the coal enterprise to improve work efficiency through information sharing and exchange, the operation process of each department needs to be standardized and the source and the scope of information of each department must be clarified. Finally, through the production, storage, sharing, and transfer of knowledge of information, coal enterprise employees can be assisted to effectively carry out green awareness popularization courses so they can acquire, produce, store, share, and transfer the knowledge of green coal logistics to enable coal enterprises and employees to understand the relationship between the development of green coal logistics and environmental protection.

Keywords: Coal, Green logistics, TRIZ, Interpretation structure model.

INTRODUCION

Article 4 of the Energy Conservation Law of the People's Republic of China [1] and the Outline of the 11th Five-Year Plan for the National Economic and Social Development of the People's Republic of China [2] propose the development requirements of green logistics, thereby showing that the Chinese government places great importance on the development of green logistics. At present, some enterprises have realized the economic and environmental benefits brought by green coal logistics, but many enterprises have just begun to realize the importance of green logistics because China's logistics industry started relatively late. Therefore, they still aim to reduce costs and improve efficiency and effectiveness. The lack of awareness of environmental sustainability and the lack of value analysis and cost estimation of resources and environment have led most coal enterprises to not actively introduce green coal logistics. These phenomena are a great challenge to the sustainable development of coal logistics and the environment.

Although society has generally recognized the concept of green mining and green consumption of coal, enterprises and the government have not paid enough attention to the transformation of traditional extensive coal logistics to modern green coal logistics. Moreover, the understanding of coal logistics is too narrow. To a certain extent, coal logistics is regarded as equivalent to simple coal transportation, and the development of green logistics is the optimization of coal transportation. For a long time in the past, the development of green logistics mainly focused on new technologies and methods for energy and resource development and utilization. In the process of introducing the green concept to improve the efficiency of resource utilization, few views have been presented on studying coal logistics from the perspective of sustainable development. Therefore, green coal logistics is still essentially a new concept and lacks a mature theoretical system.

In today's society with a globalized economy, countries around the world are pursuing efficiency while pursuing environmentally sustainable development. Therefore, studying green coal logistics for environmental development and optimization is of great significance and practical value. As the most abundant and cheapest energy source in the world, coal has played an important role in social and economic development. As a large country, China has relied on coal to develop many heavy industries since the reform and opening up, but this approach has also caused many environmental problems. The green logistics of coal can realize the intensive development of coal and meet the green development of the environment under high-efficiency coal operations. In this way, China can not only enjoy the economic and environmental benefits brought by improving its own coal logistics methods but also set an example for other developing countries that use coal as their main energy source and establish an image of a country that practices environmental protection.

Therefore, this paper will aim at the green concept framework of coal logistics to identify the problems in the operation of green coal logistics and then use TRIZ theory [3, 4] to propose targeted improvement strategies. Finally, to establish the development of green coal logistics, the interpretative structural model (ISM) [5] is used to establish a systematic development procedure of green coal logistics improvement strategies, which is expected to effectively reduce the introduction time period of improvement strategies, improve the efficiency and effectiveness of coal logistics, and provide a powerful theoretical reference for green coal logistics enterprises as they improve their green logistics methods. This approach enables coal enterprises to coordinate the relationship between logistics development and environmental protection through the development of green coal logistics.

LITERATURE REVIEW

Logistics

In the traditional sense, logistics is transformed from physical distribution to modern logistics. The American Logistics Management Association [6] defines logistics as part of the supply chain process and is the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from the place of origin to the place of consumption for the purpose of conforming to customer requirements.

Green Logistics

The logistics industry has a high awareness of environmental issues. Thus, an increasing number of studies are being conducted on green logistics, mainly because green logistics not only realizes the unification of economic, social, and environmental interests but can also guarantee safe, healthy, and environmentally friendly products and services for consumers. Similar to the concept of logistics, green logistics has no unified definition, and the related research has different descriptions of the concept of green logistics. This paper summarizes the views of the main representative scholars as shown in Table 1.

Therefore, in the process of logistics activities, the methods and processes that can reduce the impact on the ecological environment and reduce resource consumption belong to the category of green logistics. This paper is based on the summary of the above research definition of green logistics. The definition of green logistics is based on the principle of sustainable development, and advanced logistics technology is used to achieve a green economic activity process with the goal of reducing environmental pollution and improving resource utilization.

Problems in the Operation of Green Coal Logistics

This section explains the definition and objectives of green coal logistics and discusses the necessity of developing green coal logistics. The problems in the operation of green coal logistics are proposed.

Definition and Objectives of Green Coal Logistics

Definition of green coal logistics

In accordance with the definition and expression of green logistics (Table 1), this paper defines green coal logistics as follows: The premise of green coal logistics is the coordinated development of economic activities and ecological environment, and modern logistics management methods and logistics technologies are used as the method of implementation to reduce logistics costs and environmental pollution. Logistics systems and facilities are unified, planned, and controlled to maximize the benefits of logistics activities.

Table 1. Definition of green logistics.

Researcher	Definition of Green Logistics
Cheng and Liu [7]	With the goal of reducing environmental pollution and resource consumption, green logistics adopts advanced logistics technology to plan and implement logistics activities such as transportation, warehousing, loading and unloading, distribution processing, distribution, packaging, and other logistics activities.
Wu et al. [8]	In the logistics process, all means, methods, and goals of reducing the impact on the ecological environment and reducing resource consumption belong to the category of green logistics.
Wei [9]	Green logistics refers to economic management activities that rationally and effectively allocate social resources, meet and improve human welfare, connect green demand and supply subjects, and quickly and effectively overcome the obstacles to the time and space of green goods and services. Specifically, green logistics is aimed at reducing environmental pollution and resource consumption, and it involves the use of advanced logistics technology to plan and implement logistics activities such as transportation, warehousing, loading and unloading, distribution processing, distribution, and packaging.
Xie et al. [10]	By improving the efficiency of logistics operations and reducing costs and through logistics technologies and management methods, green logistics can reduce the external costs of logistics (mainly including greenhouse gas emissions, noise, and accidents, etc.) to achieve economic, environmental, and socially sustainable development.
Zhang and Zhang [11]	Green logistics refers to the process of planning, controlling, managing, and implementing logistics systems through advanced logistics technologies and environmental management concepts to reduce pollutant emissions and resource consumption.

Goal of green coal logistics

The general logistics activities of coal are aimed at realizing the economic benefits of coal enterprises and making coal logistics more efficient and cost-effective. However, the goal of green coal logistics is to pursue economic benefits and social conservation to save resources and protect the environment. The purpose is to reduce pollution to the environment and reduce resource consumption to achieve the harmonious development of the coal logistics system and the environment. Therefore, green coal logistics is a modern logistics concept that combines the principles of sustainable development and coal logistics.

Necessity of Developing Green Coal Logistics

Requirements for sustainable development of coal

The green development of coal enterprises is related to resource conservation and recycling to achieve the sustainable development of the coal economy and realize the repeated reuse of coal

resources, which can form a virtuous cycle of coal resource utilization to achieve the purpose of protecting the environment, rationally allocating resources, improving resource utilization, and reducing waste emissions. Therefore, through the development of green coal logistics, a helpful approach is to solve the environmental pollution problems caused by coal resource consumption and waste discharge, save land resources, and improve the economic benefits of enterprises. Doing so not only ensures the enjoyment of the economic benefits brought by the green development of coal resources but also achieves the requirements of sustainable development of the environment.

Connecting green mining and green consumption

Green coal logistics is a channel that connects green mining and green consumption, that is to say, green coal logistics is an important way for coal commodities to pass from the producer to the consumer through the market, which closely connects coal production and consumption. The coordinated development of coal producers, consumers, and green coal logistics jointly builds a resource-saving and environmentally friendly coal green economic recycling system.

Realizing the sustainable development of coal enterprises

Coal enterprises cause damage to the environment due to the waste of resources in the production process. However, when the concept of environmental protection gradually penetrates the hearts of people and becomes the mainstream of today's social development, green logistics can become one of the main trends in the development of modern logistics. Therefore, the development of coal enterprise logistics must also begin to adjust the relationship between coal utilization and resources. This situation requires consideration of the integration of resource reuse and environmental protection, and the establishment of a mature green coal logistics system to enhance the sustainable production capacity of coal enterprises.

Problems in the Operation of Green Coal Logistics

The importance of green coal logistics is increasing. Many larger coal enterprises that have allowed the conditions have begun to formally introduce green coal logistics. However, many difficult problems in the actual operation process still exist, such as the lack of a complete green coal logistics system, obstruction of logistics information exchange, weak awareness of coal enterprises with regard to implementing green logistics, outdated technical equipment, unreasonable use of logistics methods, high energy consumption for enterprise logistics operations, serious environmental pollution, and high control costs of the logistics end. The details of these problems are summarized in Table 2.

Establishment of Improving Strategies

In accordance with the previous section, this paper defines the problems encountered in the operation of green coal logistics as (1) system integrity, (2) information circulation, (3) green awareness, (4) technical support, and (5) control cost. In this section, the TRIZ analysis method is used to propose strategies for these five problems.

Analysis steps of TRIZ

Four steps of TRIZ analysis for the application of the contradiction matrix and 40 innovation principles were proposed by Savransky [21]: (1) identifying the problem, (2) determining the improving and worsening parameters, (3) searching for the intentions of the innovative principles, and (4) constructing strategies based on innovative principles.

Table 2. Problems in the operation of green coal logistics.

Problem	Explanation of problem
1. System integrity: lack of complete green coal logistics system [12]	The entire process of coal logistics from mining, production, transportation, sales, and waste discharge often only focuses on the transportation link, and systematic planning for production is lacking, especially waste disposal links, which results in the waste of resources in the entire logistics process and ineffectiveness of resource allocation.
2. Information circulation: obstruction of logistics information exchange [13]	A huge information flow occurs between each process and node of green coal logistics, including procurement information, logistics warehousing port information, sales information, and information between coal enterprises. The lack of information exchange and sharing platforms among various links in coal logistics results in information blocking, thereby interrupting the logistics information exchange process and wasting a large amount of manpower, material resources, and financial resources. The inconsistency of information systems causes obstacles to information transmission.
3. Green awareness: weakness of coal enterprises awareness of implementing green logistics [12, 14]	Under the guidance of the concept of sustainable development, many enterprises in China began to form a sense of social responsibility. Some enterprises have noticed the importance of the environment, and the main business of the company has changed to the production of green products. However, most enterprises generally feel that green logistics is actually doing environmental protection work and that the significance of implementing green logistics is to obtain environmental protection certificates. In the actual situation, no practical change has occurred in coal production, and the realization of green logistics is just empty talk. The main reason is that enterprises have not correctly realized the importance of green logistics and believe that the implementation of green logistics will not only increase costs but also bring no gains. However, international coal enterprises have set the implementation of green logistics as their strategic goal for rapid development and even feel that one of the biggest strategic challenges for coal enterprises is green logistics, whether from the market demand or from the standpoint of their own development.
4. Technical support: outdated technical equipment and unreasonable use of logistics methods [15, 16]	The implementation and promotion of green logistics require not only the establishment of green logistics concepts and corresponding plans but also the support of green logistics information technology equipment. The backward construction of the logistics information system has caused the slow development of deep-level logistics services such as inventory control, distribution processing, and logistics information services. Therefore, there is no way to achieve timely delivery and processing of logistics information such as loading and unloading, transportation, and circulation.
5. Control costs: high energy consumption for enterprise logistics operations, serious environmental pollution, and high control costs of the logistics end [17, 18, 19, 20]	Only the end of the logistics is considered, which is why enterprises have invested a large amount of money to purchase pollution treatment equipment and their own pollution control technology is limited. Thus, some resources that can be recycled cannot be used well, thereby increasing the raw material consumption and costs of coal enterprises. But it cannot completely eliminate pollution. Some enterprises pay special attention to the cost of waste recycling during their operations and often convert the costs of environmental pollution caused by enterprises into social costs, thereby affecting public interests and causing the environmental level of the region to decline.

TRIZ STRATEGY FORMULATION

System integrity

Step 1. Identifying the problem

The process of coal logistics includes mining, production, transportation, sales, and waste discharge. The interaction between the links is interrelated. At present, third-party logistics began to provide logistics services for coal companies, but most of the third-party logistics companies lacked modern logistics management concepts, lagging behind in logistics technology and single service functions [12], and systematic planning for production is lacking, especially waste disposal

links. The lack of a complete system results in the inability of the entire logistics process to be effectively connected, resulting in the waste of resources and the inefficient use of excess energy. The overall planning of coal logistics is chaotic, which prevents resources from being effectively allocated.

Step 2. Determining the improving and worsening parameters

In accordance with the definition of the problem of system integrity, a complete and standardized logistics system is extremely important for the development of green coal logistics. Therefore, this paper defines the improving parameters of system integrity as "11. Tension, pressure" by searching 39 engineering parameters, that is, the effect of new operation mechanism. However, even if a complete logistics system is established, the stability of the system still needs to be investigated and requires time to be verified. Thus, this paper defines the worsening parameter of system integrity as "13. Stability of object" by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

In accordance with the improving parameter "11. Tension, pressure" and the worsening parameter "13. Stability of object", the innovation principles of new energy penetration include "Principle 2: Taking Out", "Principle 35: Parameter Change", and "Principle 40: Composite Structure" according to the contradiction matrix. In accordance with the explanation of 40 innovative principles, "Principle 2: Taking Out" and "Principle 40: Composite Structure" are selected.

Step 4. Constructing strategies based on innovative principles

In accordance with the explanation of the TRIZ innovation principle, "Principle 2: Taking Out" is to remove the obstructed part from the object or system, that is to say, removing the part of the original green coal logistics operation process that has little effect or easily causes losses can establish a simple and effective logistics system operation mechanism.

In accordance with the explanation of the TRIZ innovation principle, "Principle 40: Composite Structure" is to replace the composite structure with a composite structure. The layers involved in the system of coal logistics are intricate. If the original operating mechanism is eliminated to run the new logistics system at once, then it will inevitably affect the normal operation of coal enterprises. Therefore, the effective operation part of the original operation mechanism of the coal logistics system should be retained and, at the same time, a new green coal logistics system can be introduced to effectively merge the two. Therefore, the fourth-party logistics operation model can be adopted to solve the limitations of the development of third-party logistics, and provide an overall systematic planning scheme for all links of the coal logistics process [22]. For example, the process of coal logistics implements an effective carbon emission management plan, designs and produces environmentally friendly coal services and products for customers, or introduces environmental standards for procurement to establish environmental performance assessments for coal suppliers.

Information circulation

Step 1. Identifying the problem

Huge information flow occurs between each process of green coal logistics and nodes. The lack of a platform for information exchange and sharing among all links of coal logistics results in information blockage, thereby resulting in an absence of effective communication between various

links and enterprises, which then interrupts the logistics information exchange process and causes considerable waste of manpower, material resources, and financial resources. Moreover, the inconsistency of the information system causes obstacles to information transmission [13].

Step 2. Determining the improving and worsening parameters

According to the definition of the information circulation problem, the degree of effective circulation of information within the enterprise not only affects the normal operation of each link but also plays a role in saving additional expenditures of coal enterprises. Therefore, the improving parameter of information circulation is defined as "3. Length of moving parts" by searching 39 engineering parameters, which is to improve the enterprise information transmission and communication method so that the information in the enterprise can effectively be transmitted. However, in the process of actual operation, the situation in which information cannot be transmitted in time may occur. Thus, the worsening parameter of information circulation is defined as "24. Loss of information" by searching 39 engineering parameters.

Step 3. Searching for the intentions of the innovative principles

In accordance with the improving parameter "3. Length of moving parts" and the worsening parameter "24. Loss of information", the innovation principles of new energy penetration include "Principle 1: Segmentation" and "Principle 26: Copying" according to the contradiction matrix. In accordance with the explanation of 40 innovative principles, "Principle 1: Segmentation" is selected.

Step 4. Constructing strategies based on innovative principles

In accordance with the explanation of the TRIZ innovation principle, "Principle 1: Segmentation" is transformed into a micro level to strengthen the degree of division. Therefore, each department within the coal enterprise should be refined, and each department needs to determine the scope of the responsible information and clarify the source of the information. For example, coal enterprises can introduce ERP systems to integrate the work processes of information generated by various departments and then unify the internal information processing procedures of each department [13]. This approach can ensure the communication and sharing of information of each department with each other, reduce information duplication, improve the accuracy and real-time nature of the information, and then strengthen the operating efficiency and competitive advantage of the enterprise.

Green awareness

Step 1. Identifying the problem

Green awareness has been popularized with the development of society, but many people still lack a complete understanding of green concepts in practice. The bottom line is that the popularity of green awareness is not high enough, and the popularity of green concepts is still at a relatively superficial level. Thus, the realization of green logistics is limited to the promotion of slogans [12, 14].

Step 2. Determining the improving and worsening parameters

The definition of the green awareness problem suggests that only when the concept of green logistics is deeply rooted in the development of a coal enterprise or coal industry can the coal enterprise or coal industry really promote the operation of green coal logistics. Therefore, the

improving parameter of green awareness is defined as "1. Weight of moving object" by searching 39 engineering parameters, which means to strengthen the awareness of green logistics in the enterprise, promote the implementation of green logistics, guide enterprises to develop in the direction of green environmental protection, and create the importance of green logistics for enterprises.

However, new ideas and old ideas will always have some conflicts in actual operation, which will inevitably lead to conflicts in actual operation. If an enterprise only promotes the slogan of environmental protection but does not really implement the relevant environmental protection regulations in the operation of the enterprise, then it will cause a certain negative impact on the goodwill of the enterprise. Thus, the worsening parameter of green awareness is defined as "12. Shape" by searching 39 engineering parameters, that is, if green awareness exists only on paper, then it will impair the corporate image or goodwill.

Step 3. Searching for the intentions of the innovative principles

In accordance with the improving parameter "1. Weight of moving object" and the worsening parameter "12. Shape", the innovation principles of new energy penetration include "Principle 8: Anti-Weight", "Principle 10: Preliminary Action", "Principle 20: Continuity of Useful Action", and "Principle 40: Composite Structure" according to the contradiction matrix. In accordance with the explanation of 40 innovative principles, "Principle 10: Preliminary Action" and "Principle 20: Continuity of Useful Action" are selected.

Step 4. Constructing strategies based on innovative principles

In accordance with the explanation of the TRIZ innovation principle "Principle 10: Preliminary Action" is to arrange objects or systems in advance to reduce wasted time. Before the actual operation of green coal logistics, coal enterprises should first have a deep understanding and analysis of the concept of green coal logistics to understand the importance of green coal logistics implementation. Meanwhile, coal enterprises should focus on the operation process to reduce unnecessary time costs. For example, coal enterprises can collect domestic and foreign green logistics theories, management experience, and successful cases to combine with the current situation of China's green coal logistics industry for planning enterprise training materials and implementing enterprise training education to allow employees to learn and understand the concept of green coal logistics [14].

In accordance with the explanation of the TRIZ innovation principle, "Principle 20: Continuity of Useful Action" is a continuous action. Thus, all objects and systems can be fully loaded from time to time. The popularity of green awareness will probably not succeed the first time. Long-term and continuous in-depth study is needed for improved green coal logistics. Therefore, coal enterprises should regularly conduct education and training courses on green awareness. First, such courses should enable employees of the coal enterprise to understand the importance of green logistics and then learn the actual operation of green logistics, which entails doing more with less.

Technical support

Step 1. Identifying the problem

The development of green logistics in China is relatively later compared with that in foreign countries, which is why the application of related logistics information technology is relatively

backward. Most enterprises still lack a correct understanding of logistics informatization management. They believe that as long as Internet information technology is used in the daily logistics office, the logistics information management of the enterprise can be realized. However, they do not really understand the information logistics management system required by enterprises to build and develop, which is also the main reason for the low level of logistics information management and service level [15]. This situation causes coal enterprises to lack information and data support in logistics warehousing and transportation decision-making, which affects the efficiency of logistics operations, thereby resulting in the emergence of non-green factors in the logistics process. For example, the coal transportation industry consumes a large amount of energy, and the backwardness of transportation technology and route planning capabilities will lead to low energy efficiency [16]. Moreover, the cost of equipment and systems of logistics information technology is difficult for small coal logistics companies to bear, which hinders the operation of green coal logistics.

Step 2. Determining the improving and worsening parameters

In accordance with the definition of the technical support, the biggest problem faced by coal logistics companies in terms of technology is the degree of information automation. When the enterprise fully adopts information automation, it can reduce repeated manual processes, improve productivity, reduce operation errors, and make corresponding intelligent decisions in the process of logistics operations based on these information data to realize the intelligent logistics operation system of transportation, storage, packaging, and loading and unloading in the logistics process. The improvement of the degree of information automation in the logistics process is a critical step for coal enterprises to implement green coal logistics. Therefore, the improving parameter of technical support is defined as “38. Level of Automation”.

However, when a coal enterprise introduces logistics automation information technology, a case of loss may be caused by improper operation. Thus, the worsening parameter of technical support is defined as “32. Manufacturability,” that is, the degree of understanding of the maturity of the technology or method.

Step 3. Searching for the intentions of the innovative principles

In accordance with the improving parameter “38. Level of automation” and the worsening parameter “32. Manufacturability,” the innovation principles of new energy penetration include “Principle 8: Anti-Weight”, “Principle 1: Segmentation”, “Principle 8: Anti-Weight”, and “Principle 28: Mechanics Substitution” according to the contradiction matrix. In accordance with the explanation of 40 innovative principles, “Principle 28: Mechanics Substitution” is selected.

Step 4. Constructing strategies based on innovative principles

In accordance with the explanation of the TRIZ innovation principle, “Principle 28: Mechanics Substitution” is to change from static to dynamic or to change from being unstructured to structured. Coal enterprises can establish a logistics information management system according to relevant logistics information technology and formulate a standard operation process of the logistics information management system, thus ensuring its safe, efficient, and systematic operation. Then, the original data and related information of each link operation of coal logistics are archived and regularly monitored and inspected. Afterward, the data can be analyzed periodically to understand the performance of each link of coal logistics operations and determine

the reasons for the lack of performance improvement, thus enabling coal companies to take measures to improve logistics performance and achieve green coal logistics [23].

Control cost

Step 1. Identifying the problem

As a result of an improper operation process, the logistics process in the coal supply chain will definitely cause related pollution, thus resulting in pollution control and waste recycling costs. For example, the main environmental pollution in coal mining includes solid waste pollution, water resource pollution, atmospheric pollution, and noise pollution [17]. During the process of coal production, the main pollution is dust and fly ash pollution [18], as well as water pollution and resource waste [19]. Air pollution is caused mainly by dust during coal loading, unloading, and transportation [20]. Air pollutants such as SO_2, CO, CO_2, and dust will also be generated due to the burning of coal in the process of using coal. To develop the logistics of coal supply chain sustainable development, companies need to invest more resources in coal pollution control and the recycling of coal waste, thus affecting their economic benefits.

Step 2. Determining the improving and worsening parameters

In accordance with the definition of control cost, the cost of pollution control in the process of coal logistics is necessary; thus, the focus should be on reducing and reasonably controlling the cost of pollution control caused by coal logistics. Therefore, the improving parameter of control cost is defined as "20. Energy Spent by Nonmoving Object" by searching 39 engineering parameters.
Reasonable control of the cost of pollution control generated by coal logistics can reduce the cost of pollution control, and the intensity of pollution control may also be reduced, which will increase the loss and waste of coal in the process of coal logistics. Therefore, the worsening parameter of control cost is defined as "23. Waste of Substance" by searching 39 engineering parameters, that is, unreasonable waste or loss.

Step 3. Searching for the intentions of the innovative principles

In accordance with the improving parameter "20. Energy Spent by nonmoving object" and the worsening parameter "23. Waste of Substance", the innovation principles of new energy penetration include "Principle 12: Equipotentiality", "Principle 27: Cheap Short-Living Objects", "Principle 28: Mechanics Substitution", and "Principle 31: Porous Materials" according to the contradiction matrix. In accordance with the explanation of 40 innovative principles, "Principle 27: Cheap Short-Living Objects" is selected.

Step 4. Constructing strategies based on innovative principles

In accordance with the explanation of the TRIZ innovation principle, "Principle 27: Cheap Short-Living Objects" involves the use of multiple inexpensive objects or systems to replace expensive ones and to ensure the same quality. Therefore, the inspiration for this paper is that coal companies can use low-cost and environmentally friendly materials or methods to produce or deal with the pollution caused by waste logistics and recycling logistics to minimize control costs. For example, the use of carbon capture and storage (CCS) technology [24] seeks a cleaner way to burn coal to reduce the emissions of coal-fired exhaust gas and air pollution. However, the biggest challenge for CCS technology is economic benefits, not technical issues. If the scale of the commercial application of CCS technology can be expanded, then the production costs of the entire coal industry and enterprises can be reduced and corresponding benefits can be obtained.

In summary, this paper uses the TRIZ analysis method to propose seven corresponding strategies to the problems that exist in the actual operation of green coal logistics and describes them in Table 3.

Table 3. Improving strategies of green coal logistics problems.

Problem	Improving parameter	Worsening parameter	Innovative principle	Strategy
System integrity	11. Tension, pressure	13. Stability of object	Principle 2: Taking Out	S1. The parts of the original green coal logistics operation process that have little utility or are likely to cause losses are removed to establish a simple and effective logistics system operation mechanism.
			Principle 40: Composite Structure	S2. The effective part of the original operation mechanism is retained, while a new green coal logistics system is introduced to effectively merge the two.
Information circulation	3. Length of moving parts	24. Loss of information	Principle 1: Segmentation	S3. The various departments within the coal enterprise are refined, and then each department needs to be responsible for determining the scope of information to clarify the source of information.
Green awareness	1. Weight of moving object	12. Shape	Principle 10: Preliminary Action	S4. An in-depth understanding of the concept of green coal logistics is obtained to understand the key points of the implementation of green coal logistics and focus on the operation process, thereby reducing unnecessary time costs.
			Principle 20: Continuity of Useful Action	S5. Green awareness popularization courses are conducted regularly so that employees understand the importance of green coal logistics and learn the actual operation of green coal logistics.
Technical support	38. Level of automation	32. Manufacturability	Principle 28: Mechanics Substitution	S6. The relevant logistics information technology can be specified to formulate relevant operation procedures and standardize the operation process for coal logistics.
Control cost	20. Energy spent by nonmoving object	23. Waste of substance	Principle 27: Cheap Short-Living Objects	S7. Low-cost and environmentally friendly materials or methods are used to produce or deal with the pollution caused by waste logistics and recycling logistics processes for minimizing the control cost due to coal pollution.

Execution Planning of Strategies

Establishing strategies for solving green coal logistics problems is important; however, another necessary task is to formulate the order in which these strategies are executed. The strategy of information technology (S6) plays an important role in the reorganization and reengineering of green coal logistics operations (S1, S2). For example, a database or information system with shared functions can be created by using information technology. The efficiency of individual operations or activities of coal enterprises will improve by integrating the operation functions of these enterprises. The database or information system can also be effectively used for business process information collection and analysis. Moreover, when coal companies make an effort to strengthen awareness of environmental issues, they can reduce waste logistics control costs (S7) by applying the strategy of green awareness (S4). In summary, the strategies that are used to solve the operation problem of green coal logistics are related. Therefore, the highly correlated strategies need to be analyzed to parallelize and establish their hierarchical relationship. Doing so will

institute a procedure of systematically development a green coal logistics strategy and effectively shorten the time period in which the strategy is introduced, ultimately improving efficiency.

Questionnaire Design

A questionnaire is used to conduct a correlation survey between strategies to identify the subordination relationship between pairwise strategies. Then, ISM is used to further analyze the data that were gathered by the questionnaire, after which a systematic strategy development procedure system is established based on the data analysis results. Snowball sampling was used to distribute the questionnaire among coal logistics-related companies.

The questionnaire on the correlation between green coal logistics problem improving strategies uses a single-choice question to ask about the correlation between the pairwise improving strategies in Table 3. The correlation between the pairwise improving strategies is judged based on the proportion of "yes" or "no" answers, where "0" indicates no correlation and "1" indicates a correlation. The question is stated as "Strategic factor S1 is closely associated with which of the following strategic factors?" The respondents should check "yes" if a certain indicator has a correlation and "no" otherwise, as shown in Table 4.

Table 4. Questions in the questionnaire.

1. Strategic factor S1 is closely associated with which of the following strategic factors?		
Strategic factor options	Yes	No
S2	☐	☐
S3	☐	☐
S4	☐	☐
S5	☐	☐
S6	☐	☐
S7	☐	☐

（URL of the complete questionnaire： https://www.wjx.cn/m/53657055.aspx）

ANALYSIS STEPS OF ISM

ISM is used as an analysis tool to judge the subordination relationship between the pairwise strategies for solving green coal logistics problems. ISM was selected because of its wide usage in modern system engineering. Using ISM can decompose a complex system into several subsystem elements, after which one can use their own good experience and knowledge and the assistance of a computer to form a systematic execution program.

In short, ISM can derive intuitive hierarchical relationships and graph by decomposing and transforming vague ideas and opinions in the system. The hierarchy-related graph can provide a specific structure to provide systematic execution steps and reduce the errors and risks during decision-making and planning. Therefore, this paper uses ISM to construct a standard operating procedure for strategies to address the green coal logistics problem. Such a procedure is beneficial to the coal logistics industry, as indicated by the research results, and can serve as an implementation basis to enable the development of green coal logistics to solve problems simultaneously.

ISM analysis can summarize the hierarchical relationships and graph of each element and then utilize these hierarchical relationships to propose a systematic execution procedure. The seven calculation steps of the ISM proposed by Olsen [25] are as follows:

1. Identify the factors associated with the research: The researcher can gather the related factors according to the research theme. These factors are expressed mathematically as a_i, i = 1, 2, 3 ..., k, where k denotes the number of factors.
2. Determine the subordination relationship between the pairwise factors: The subordination relationship between the pairwise factors and their mutual influence are measurable in accordance with the opinions of experts and scholars through questionnaire or qualitative research.
3. Determine the relation matrix: After the subordination relationship between the pairwise factors is determined through Step 2, the result is converted into the following mathematical expressions:
   (a) If Factor i directly affects Factor j, then a_{ij} = 1 and a_{ji} = 0.
   (b) If Factor j directly affects Factor i, then a_{ji} = 0 and a_{ij} = 1.
   (c) If Factor i and Factor j interact with each other, then a_{ij} = 1 and a_{ij} = 1.
   (d) If Factor i and Factor j do not affect each other, then a_{ij} = 0 and a_{ij} = 0.

   The relationship matrix is represented by **A**, as shown in Equation (1).

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

4. Decide the adjacent matrix: The relationship matrix (**A**) of Step 3 and the identity matrix (**I**) is added to derive the adjacent matrix (**M**).
5. Convert the adjacent matrix into the reachable matrix: ISM exhibits a transitive relationship, that is, if Factor i is associated with Factor j and Factor j is associated with Factor k, then Factors i and j are also associated. Therefore, the adjacent matrix can be referred to as the reachable matrix (**M***) after the transitivity is satisfied.
6. Convert the reachable matrix into a hierarchy matrix: The hierarchy matrix contains the reachability set and the antecedent set. The representative symbols of the two are **R**(a_i) and **A**(a_i), and the set of the two is the intersection set (**R**(a_i)∩**A**(a_i)).
   (a) Reachable set (**R**(a_i)): With the horizontal axis taken as the main axis, if the intersection value of the horizontal axis factor and the vertical axis factor in the reachable matrix are 1, then the corresponding factors are extracted.
   (b) Antecedent set (**A**(a_i)): With the vertical axis taken as the main axis, if the intersection value of the horizontal axis factor and the vertical axis factor in the reachable matrix is 1, then the corresponding factors are extracted.
7. Use the hierarchical matrix to draw the ISM hierarchy-related graph: First, the same factors as the reachable set (**R**(a_i)) and intersection set (**R**(a_i)∩**A**(a_i)) are extracted and placed in the first layer. Then, the extracted factors are deleted from the reachable and intersection sets. The factors of the second layer are obtained in the same way. After the factors of each layer are determined through analogy, arrows are drawn to show the subordination relationship of each factor according to the subordination relationship between the pairwise factors presented in the relationship matrix (**A**), that is, an ISM hierarchy-related graphic can be completed.

ISM DATA ANALYSIS

In this section, ISM is used to analyze the data obtained by the questionnaire.

Result of ISM analysis

ISM consists of seven steps. Step 1 is to find out the relevant factors of the study, which are the green coal logistics problem improvement strategies, as shown in Table 3.

Step 2 of the ISM analysis is to determine the subordination relationship between the pairwise factors. Wu et al. (2011) proposed that a subordination relationship exists between the pairwise factors if more than 50% of the respondents indicated that these factors have a subordination relationship. Thus, this study uses a questionnaire to examine the opinions of coal logistics-related companies. This approach confirmed the affiliation between the pairwise factors, and then the questionnaire results were analyzed, with 60% set as the threshold, that is, more than 60% of the respondents stated that a subordination relationship exists between the pairwise factors. Fourteen valid questionnaires were extracted. The pairwise factors were considered to have a subordination relationship if nine (more than 60%) of the respondents stated that this was the case.

The statistical results in Table 5 show the following results: strategic factor S1 affects strategic factor S4, strategic factor S1 affects strategic factor S7, strategic factor S2 affects strategic factor S1, strategic factor S3 affects strategic factor S5, strategic factor S5 affects strategic factor S6, strategic factor S6 affects strategic factor S5, and strategic factor S7 affects strategic factor S4. The results were collated and the subordination relationship was obtained, as shown in Table 6.

Step 3 of the ISM analysis is to determine the relation matrix. The subordination relationship between the pairwise strategic factors can be derived from Table 6. This result is then converted into a relation matrix, as shown in Table 7. Step 4 of the ISM analysis is to determine the adjacent matrix. The relation matrix of Table 7 and the identity matrix are added to form an adjacent matrix, as shown in Table 8. Step 5 of the ISM analysis is to convert the adjacent matrix into the reachable matrix. The ISM needs to conform to the transitive relationship, that is, if Factor A affects Factor B and Factor B affects Factor C, then Factor A can affect Factor C.

Therefore, the reachable matrix in Table 9 can be obtained when the value between the factors that conform to the transitive relationship is changed to 1. Step 6 of the ISM analysis is to convert the reachable matrix into a hierarchical matrix. As indicated in Table 10, such conversion involves finding the reachable, antecedent, and intersection sets of different strategic factors according to Table 9. In the reachable set, each strategic factor finds the corresponding strategic factor with a value of 1 in the row of the reachable matrix. In the antecedent set, 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 that both the reachable set and the antecedent set have.

Table 5. Related proportions between the pair-wise strategic factors.

1. Strategic factor S1 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S2	8	57.14%
S3	7	50%
S4	9	64.29%
S5	3	21.43%
S6	7	50%
S7	11	78.57%
2. Strategic factor S2 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	9	64.29%
S3	4	28.57%
S4	8	57.14%
S5	7	50%
S6	5	35.71%
S7	6	42.86%
3. Strategic factor S3 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	7	50%
S2	4	28.57%
S4	6	42.86%
S5	9	64.29%
S6	6	42.86%
S7	4	28.57%
4. Strategic factor S4 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	8	57.14%
S2	7	50%
S3	7	50%
S5	6	42.86%
S6	5	35.71%
S7	3	21.43%
5. Strategic factor S5 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	2	14.29%
S2	6	42.86%
S3	8	57.14%
S4	6	42.86%
S6	9	64.29%
S7	3	21.43%
6. Strategic factor S6 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	6	42.86%
S2	3	21.43%
S3	4	28.57%
S4	4	28.57%
S5	9	64.29%
S7	4	28.57%
7. Strategic factor S7 is closely associated with which of the following strategic factors?		
Strategic factor options	Subtotal	Proportion
S1	8	57.14%
S2	5	35.71%

S3	3	21.43%
S4	10	71.43%
S5	6	42.86%
S6	7	50%

Table 6. Result of subordination relationship of pair-wise strategy factors.

S1[1]→S4[2]	S1→S7	S2→S1	S3→S5	S5↔S6[3]	S7→S4

Remarks: [1]Refer to Table 3 for the number of each strategic factor; [2]A→B means that strategic factor A affects strategic factor B; [3]A↔B means that strategic factors A and B affect each other

Table 7. Relation matrix.

Strategic factor[1]	S1	S2	S3	S4	S5	S6	S7
S1		0	0	1	0	0	1
S2	1[2]		0[3]	0	0	0	0
S3	0	0		0	1	0	0
S4	0	0	0		0	0	0
S5	0	0	0	0		1	0
S6	0	0	0	0	1		0
S7	0	0	0	1	0	0	

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

Table 8. Adjacent matrix.

Strategic factor[1]	S1	S2	S3	S4	S5	S6	S7
S1	1	0	0	1	0	0	1
S2	1[2]	1	0[3]	0	0	0	0
S3	0	0	1	0	1	0	0
S4	0	0	0	1	0	0	0
S5	0	0	0	0	1	1	0
S6	0	0	0	0	1	1	0
S7	0	0	0	1	0	0	1

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

Table 9. Reachable matrix.

Strategic factor[1]	S1	S2	S3	S4	S5	S6	S7
S1	1	0	0	1	0	0	1
S2	1[2]	1	0[3]	1*	0	0	1*
S3	0	0	1	0	1	1*	0
S4	0	0	0	1	0	0	0
S5	0	0	0	0	1	1	0
S6	0	0	0	0	1	1	0
S7	0	0	0	1	0	0	1

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

Table 10. Hierarchical matrix.

Strategic factor	Reachable set	Antecedent set	Intersection set
S1	S1、S4、S7	S1、S2	S1
S2	S1、S2、S4、S7	S2	S2
S3	S3、S5、S6	S3	S3
S4	S4	S1、S2、S4、S7	S4
S5	S5、S6	S3、S5、S6	S5、S6
S6	S5、S6	S3、S5、S6	S5、S6
S7	S4、S7	S1、S2、S7	S7

Step 7 of the ISM analysis is to draw the hierarchy-related graph. First, Table 10 shows that the reachable set of strategic factors S5 and S6 is exactly the same as the intersection set. Thus, S5 and S6 are selected as the first layer of the hierarchy-related graph. Then, after S5 and S6 that were selected in Table 10 is deleted, the same method is applied to choose the same factors as the reachable set and the intersection set as the second layer. Thus, strategic factor S3 is chosen as the second layer. Finally, only strategic factors S1, S2, S4, and S7 remain as the third layer. With the results of the affiliation relationship combined in Table 6, arrows are used in the hierarchy-related graph to indicate the subordination relationship between the pairwise strategic factors, and the ISM hierarchy-related graph is obtained as shown in Figure 1.

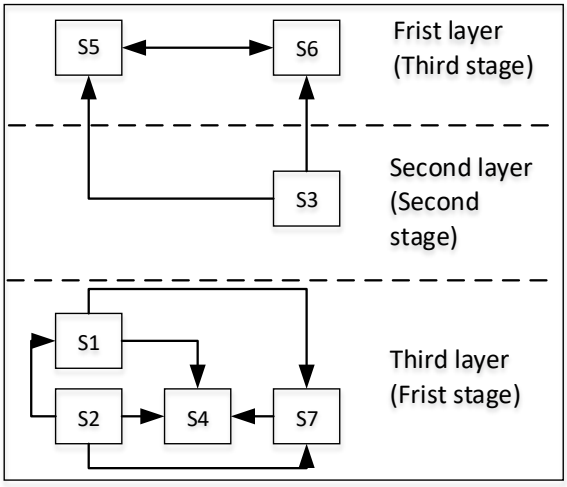


Figure 1. ISM Hierarchy-related graph

Explanation of ISM hierarchy-related graph

According to Figure 1, when a systematic green coal logistics strategy development procedure is established, the strategic factors that should be established in the first stage are S1, S2, S4, and S7, and S2 will directly affect S1, S4, and S7. Therefore, S2 should be implemented first in the first stage, that is, coal enterprises should retain the effective operation part of the original operation mechanism and at the same time introduce the green coal logistics system and effectively merge the two. After merging with the green logistics system, S1 should be implemented to streamline the combined green coal logistics operation process and establish a simple and effective logistics system operation mechanism. When S2 and S1 are implemented, S7 can be implemented to reduce the cost of green logistics of coal enterprises by using low-cost environmentally friendly materials

or methods to produce or deal with the pollution generated by waste logistics and recycling logistics.

Green coal logistics is a new topic. From the perspective of environment and sustainable development, coal companies are expected to be able to establish a logistics management system that is symbiotic with the environment to reduce the impact of coal mining, production, circulation, and sales on environmental pollution, thus improving environmental friendliness. However, the establishment of environmental protection awareness is a long-term cultivation process. Therefore, through the implementation of S1, S2, and S7, coal companies are expected to be able to actively participate in environmental remediation activities and cultivate employees' environmental awareness, thus establishing a green image of coal companies. Through the implementation of S4, coal companies and their employees can have a deep understanding of the concept of green coal logistics to understand the key points of green coal logistics implementation. Ultimately, coal companies can focus on the operation process of green coal logistics to reduce unnecessary time cost.

The strategic factor that should be implemented in the second stage is S3. Figure 1 shows that S6 in the third stage will be directly affected by S3 in the second stage. When the coal company implements S6, a large amount of data will be generated. The information sharing and communication of various departments within the coal company can be facilitated by using S3 to first refine the various departments within the coal company. Each department needs to be responsible for determining the scope of information to clarify the source of information. In this way, various departments within the coal enterprise can improve work efficiency through information sharing and exchange. S5 of the third stage will also be directly affected by S3 of the second stage. S3 is used to determine the scope of information that each department needs to be responsible for to clearly convey the information required by each department. This approach allows each employee to clarify the content and goals of the work to strengthen their self-learning and establish the awareness of green logistics work (S5).

Finally, the strategic factors implemented in the third stage are S5 and S6, which affect each other. When the coal company implements S5 to regularly carry out green awareness popularization courses, it can enable internal employees to understand the importance of green logistics and learn the actual operation of green logistics. The efficiency and service quality of green logistics operations can be improved by using S6 to specify the relevant logistics information technology to formulate relevant operation procedures and standardize the operation process for coal logistics. Conversely, the establishment of specific relevant logistics information technology based on S6 can assist coal enterprise employees to produce, store, share, and transfer knowledge. Thus, S5 can be implemented to conduct green awareness popularization courses to allow internal employees of coal enterprises to access, generate, store, share, and transfer green logistics knowledge.

CONCLUSIONS

The development of green coal logistics has become unstoppable. This occurrence is not only a manifestation of social progress but also a major milestone in the development of human society. As we all know, logistics has become one of the sources of economic benefits in the contemporary economic structure, and green coal logistics management is an area of high research significance. In the long run, room for the development of efficient, professional, and low-cost green coal

logistics will increase. Judging from the problems in the actual operation of green coal logistics, the main problems are system integrity, information circulation, green awareness, technical support, and control cost. In response to these problems, this article uses TRIZ to propose seven improvement strategies and then uses ISM to construct a set of standard operating procedures for green coal logistics problem improvement strategies. The ISM analysis results show that the strategic factors that should be built in the first stage are S1, S2, S4, and S7. The strategic factor that should be implemented in the second phase is S3. Finally, S5 and S6 should be implemented in the third stage.

In accordance with the ISM hierarchy-related graph, when developing green coal logistics, coal enterprises should retain the parts of the original operating mechanism that are effectively operating and delete the parts of the original green coal logistics operation process that have little utility or are likely to cause losses. At the same time, a new green coal logistics system is introduced, and then the two are effectively merged to establish a simple and effective logistics system operation mechanism (S1 and S2). Furthermore, low-cost and environmentally friendly materials or methods are used to produce or deal with the pollution caused by waste logistics and recycling logistics to reduce green logistics costs (S7) and allow coal enterprises and employees to have an in-depth understanding of the concept of green coal logistics to understand the key points of the implementation of green coal logistics and focus on the operation process, thereby reducing unnecessary time costs. (S4).

Next, coal enterprises can refine their various departments, each of which needs to be responsible for determining the scope of information to clarify the source of information (S3). Finally, with the use of the related logistics information technology, the relevant operating procedures and process for coal logistics can be formulated and standardized (S6), and coal enterprise employees can be assisted in effectively carrying out green awareness courses so that they can access, generate, store, share, and transfer green logistics knowledge (S5).

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