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Demonstration analysis for the low-carbon factors index system of logistics enterprises

Yuan Tian , Meng Yang

School of Economics and Management, Beijing Jiaotong University (China)

tianmengfei@126.com; meng-926@163.com

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Abstract:

Purpose: In the background of the low-carbon economy, the basic position of the logistics and its high energy consumption, high emission characteristics determine its special status in the low-carbon economy. The purpose of this paper is providing ideas for logistics companies to implement low-carbon management.

Design/methodology/approach: This paper analyses the characteristics and the processes of the logistics enterprises in China. Analyze the low-carbon management factors from the perspective of energy consumption. Then do the demonstration analysis by calculating the connection degree of the indicators and the logistics energy consumption, using the method of grey connection analysis.

Findings: Establish the logistics enterprise's low-carbon management factors index system. And the connection degree is greater than 0.5, indicating that various factors impact significantly on the low-carbon management of logistics enterprises.

Originality/value: The study provides ideas for logistics companies to implement low-carbon management.

Keywords: logistics enterprises, low-carbon, energy consumption, grey connection analysis

1. Introduction

In recent years, the abnormal climate and other environmental issues are becoming increasingly serious. As a result, "low-carbon revolution" of the globalization takes human into the era of low-carbon economy based on "low energy consumption, low pollution and low emissions". The basic position of logistics and its characteristics of high energy consumption, high emissions determine its special status.

The concept of "low carbon" is mainly composed of three core terms: low-carbon economy, carbon productivity and carbon tariff, and low-carbon logistics is one of the sub-concepts derived from them. At present, the academic community hasn't given the standard definition of the low carbon logistics. Some scholars proposed an environmentally responsible logistics system, which paid attention to the protection of the environment in the process of its own operation (Wu & Dunn, 1995). Low-carbon logistics is based on low-carbon economy and green logistics theory, and it takes the concepts of "sustainable development" and "carbon reduction" into the logistics activities, such as transportation, storage, packing, distribution, information processing and so on (Tao, 2010).

In addition, the logistics occupies a special position in the low-carbon economy and low-carbon economy requires the support of modern logistics, so the logistics of low-carbon is the key to develop low-carbon economy (Dai, 2008; Xin, 2010). Some researchers coordinated the relationship between carbon emissions and logistics costs based on multi-objective optimization theory (Kim & Janic, 2009). There are also some scholars discussing the specific relationship of low-carbon economy and logistics industry, and describing the status quo of the logistics' energy consumption in China (Bai & Luo, 2010). In the aspects of logistics enterprises, positive and effective measures should be taken by the government and logistics industry to deal with low-carbon requirements (Jiang, 2010).

Overall, the low-carbon logistics is just developing, and most of the articles about low-carbon logistics describe the necessity of implementing low-carbon management on the macro level. Until mow little has been studied deeply about low-carbon management impact factors on the level of logistics companies.

This article intends to contribute to the development of this field of research by jointly analyzing the low-carbon management impact factors from the perspective of energy consumption on the level of logistics companies. Then establish the logistics enterprises' low-carbon management factors index system and take the demonstration analysis by grey connection theory. So as to find the key low-carbon management impact factors and provide ideas for logistics companies to implement low-carbon management.

2. Logistics Enterprises' Energy Consumption Analysis

In the research of the logistics companies' low-carbon impact factors, it is difficult to study the carbon emissions of the logistics enterprises directly. There are significant difficulties in the index quantification and the quantified data acquisition. So this paper analyzes the energy consumption of the logistics enterprises from the perspective of the energy consumption, thus establishes the low-carbon impact factors index system on the basis of reducing energy consumption.

2.1. Overall Energy Consumption of the Logistics Enterprises

Because logistics enterprises' business processes are very complex involving the entire logistics system, we classify according to the statistical range of the energy consumption when analyzing the logistics enterprises' energy consumption. The energy consumption's statistical range includes energy consumption directly using in production and the secondary energy consumption for production. In accordance with this principle, the energy consumption of the logistics enterprises can be divided into two categories:

Logistics Direct Energy Consumption

Logistics direct energy consumption includes the energy consumption in the logistics processes, such as transport, storage, loading and unloading, packing, processing and information processing, as shown in Figure 1:

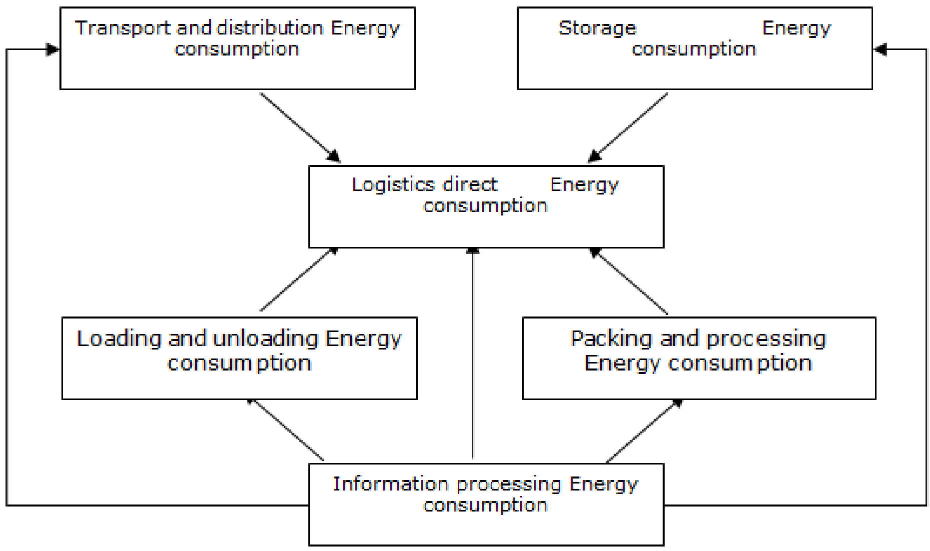

Figure 1. Logistics direct energy consumption chart

Logistics Auxiliary Energy Consumption

Logistics auxiliary energy consumption includes the following aspects: the energy consumption of the transport equipment's manufacture and maintenance; the energy consumption of the logistics line construction, maintenance and running; the energy consumption of the logistics station construction and maintenance. This kind of Energy consumption doesn't create the efficiency directly, but it is the necessary energy consumption that ensures the logistics activities to be normal.

2.2. Energy Consumption in Business Process

Logistics is a joint operating system of many links with the complex characteristics of a variety of energy consumption and factors affecting energy consumption. The type and quantity of the energy consumption by logistics activities, such as transportation, storage, packing, processing, distribution, information processing and other business processes are different.

The Transport Process

Transport is one of the main function elements of logistics, and also the main cause of energy consumption of the logistics system, so it is the important factor of the logistics enterprises' low-carbon management. Its energy consumption consists of two parts: the direct consumption by a variety of transport means or facilities, mainly the burning of gasoline, diesel and other energy sources; the other one is the energy consumption of the services in transportation activities by the transport organization. The transport energy consumption we discuss is the former.In addition, according to the five modes of transport, their main energy-consuming equipment and types of energy consumption are also different, as shown in Table 1:

Mode	Means of transport	Type of energy consumption
Highway	General lorry	Gasoline, diesel, electricity, compressed natural gas, liquefied petroleum gas (LPG), fuel cell, methanol, ethanol
	Van	
Railway	Steam locomotive	Coal
	Diesel locomotive	Fuel (mainly diesel)
	Electric locomotive	Electricity
Water way	Route ships, refrigerated ships, container ships, oil tankers, ore ships, liquefied gas tanker	Diesel, gasoline, heavy oil, electricity
Aviation	A variety of aircraft	Aviation kerosene
Pipeline	/	Oil, electricity, crude oil, gas

Table 1. Energy types of different modes of transport

Warehousing and Handling

This part of energy consumption is about the equipment running. Handling is very frequent in the logistics activities, and the handling machinery includes lifting machinery, continuous transport equipment, loading and unloading vehicles and special loading and unloading machinery. The main energy consumption's storage equipment includes automatic identification and sorting equipment, automatic loading and unloading machinery, automatic shelf, large cranes, roadway stacker, intelligent handling stacking robots and so on. Storage and handling machinery drive and work in different ways, so the form of main energy consumption is different. The energy of the small and medium-sized warehouse is oil, and the energy used by the large and automated warehouse is electricity.

Packaging and Processing

There are mainly three types of packaging machinery: fill packaging machinery, wrapping and banding machinery, packaging technology machinery (shrink packaging machinery, thermoforming packaging machinery and stretch packaging machinery). The types of processing machinery are different too. As a result, different forms of packaging and processing mean different forms of energy consumption.

Information Management

Logistics information platform plays the role of the central nervous system in the logistics activities throughout the whole process of logistics activities, and it has a direct impact on other aspects of energy consumption. The energy consumption is mainly electricity, and the relative consumption is less.

3. Logistics Enterprises' Low-carbon Factors Index System

The analysis about the energy consumption of the logistics system above shows that the logistics business processes and the types of energy consumption involved in logistics enterprises low-carbon impact factors are very complex, and they have a great impact on the development of low-carbon economy. Therefore the establishment of a scientific and rational evaluation system is very important. It can help to analyze the potential of logistics enterprises to implement low-carbon management, and provide the theoretical basis for managers to develop low-carbon and emission reduction measures.

According to the analysis of the characteristics of the logistics system functional elements and its energy consumption, considering the general principles of science, rationality, feasibility, following the sustainability principle of completeness, dynamic testability, ultimately we establish the logistics enterprises low-carbon impact factors index system, shown in Figure 2. It is a complete and independent structural level, which is characterized by the separate and complete lower-level indicators. Consider the energy consumption and utilization of the logistics enterprises mainly from the three aspects of the business process energy consumption, energy constitute and resource efficiency. And then establish the specific refinement indicators.

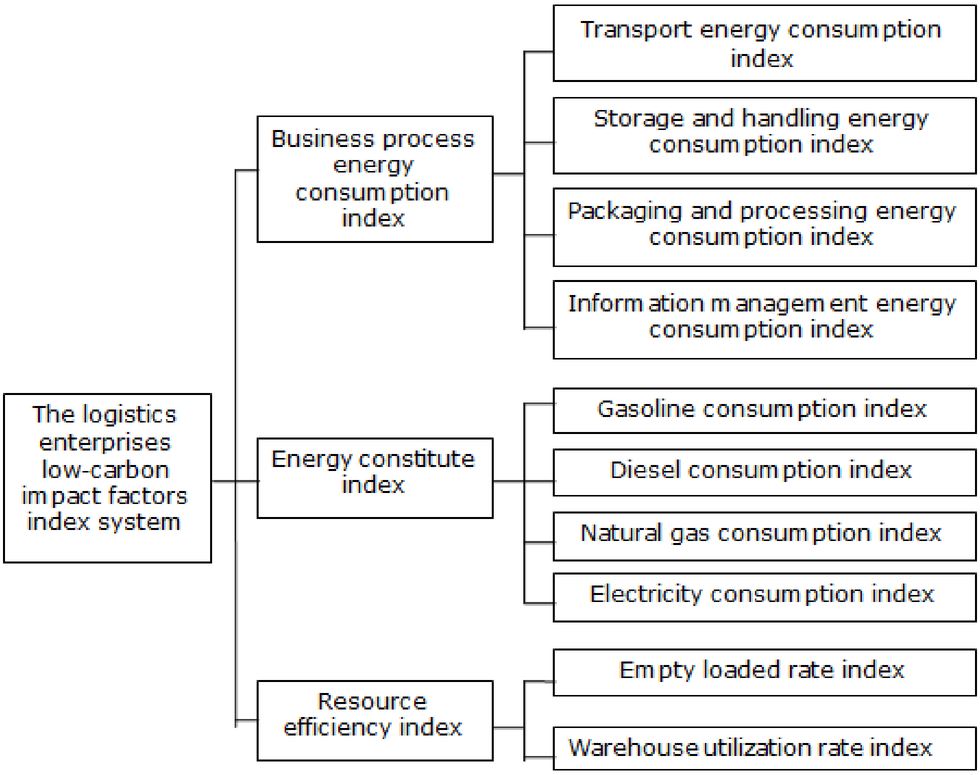

Figure 2. Low-carbon impact factors Index system of logistics enterprises

3.1. Business Process Energy Consumption Index

The establishment of four basic indicators is based on the characteristics of the logistics enterprises' business processes, as well as the energy consumption characteristics of the various business processes. They are transport energy consumption index, storage and handling energy consumption index, packaging and processing energy consumption index and information management energy consumption index. Among these four indicators, the most important one is the transport energy consumption index. According to the analysis above we know that the transport energy consumption is the largest in all business activities of the logistics enterprises. The main consumption is fuel and carbon emission is the most. Facilities and equipment's energy consumption plays an important role in the storage and handling, and also a small amount of fuel consumption. Packaging and processing is also the main facilities and equipment's energy consumption. Information management mainly consumes electricity.

3.2. Energy Constitute Index

According to the analysis above we know that the energy consumed by the logistics companies is gasoline, diesel, natural gas, electricity and so on. And different companies' proportion of energy consumption is different because of different types of business. Therefore, the energy constitute index analyzes the amount of different energy consumption based on the types of enterprise energy consumption

3.3. Resource Efficiency Index

Resource efficiency also played a certain effect in the low-carbon management of the logistics companies. The efficiency of resource use will directly affect the consumption of corporate resources, but also the relationship to the low-carbon management. This article analyzes the enterprise resource use efficiency in two aspects: Empty loaded rate index and warehouse utilization rate index. It is to see whether enterprise resource is being effectively utilized and whether the phenomenon of the waste of resources is existed.

4. Grey Relational Analysis of Low-carbon Factors Index System

4.1. Grey Relational Analysis

The basic idea of grey relational analysis is to determine whether closely linked according to the degree of similarity of the sequence of curve geometry. The closer the curve, the greater the degree of connection between the corresponding sequence, on the contrary, the smaller. Analyzing an abstract system, firstly we must choose the correct data sequence which accurately reflects the system's behavior characteristics, the mapping of system behavior. With the system's behavior characteristic data and the data of the relevant factors, we can make the graphics of each sequence and analyze intuitively.

After system analysis and selecting the right mapping of the system's behavior characteristics, we need to further clarify the impact factors of the system's main behavior. Then the quantitative analysis needs to do justice to the mapping of system behavior and other impact factors. By means of the role of the operator, make them into dimensionless data of a broadly similar order of magnitude, then turn the negative correlation factors into positive correlation factors.

Grey relational analysis is a method to describe and compare the trend of a system's development and change quantitatively. Its essence is a collection of relations of time-series data, and the purpose is to seek the key relationships between the various elements in the system, to identify the important factors affecting the target, finally to analyze and determine the degree of influence between the elements and the contribution of elements to the system's master behavior.

4.2. Grey Relational Calculation Steps

When we apply the grey relational analysis, the calculation analysis steps can be followed:

1) Seek the beginning to value of the sequence: Because the dimension (or unit) of the various factors in the index system is not necessarily the same, the data is difficult to directly compare, and the proportion of geometric curves are also different. Therefore, the dimension

(or units) of the raw data need to be eliminated, in order to be converted to a sequence of comparable data.

$$x_i^{'} = x_i / x_i(1) = \left\{ x_i^{'}(1), x_i^{'}(2), \ldots, x_i^{'}(n) \right\}$$
$$i = 1, 2, \ldots, m$$

Among them, "x_i" means the i-th impact factors; "x_0" means the benchmark index; "m" represents the number of the impact factors. In this article m=10; "n" represents the year, n=5.

2) Seek the Sequence Difference:

$$\Delta_i(k) = \left| x_0^{'}(k) - x_i^{'}(k) \right|$$
$$\Delta_i = \left\{ \Delta_i(1), \Delta_i(2), \ldots, \Delta_i(n) \right\}$$
$$i = 1, 2, \ldots, m; k = 1, 2, \ldots, n$$

Among them, "$\Delta_i(k)$" means the sequence difference corresponding to the i-th element in the k-th year, and "Δ_i"means the horizontal amount of the sequence difference.

3) Seek the maximum and the minimum differential of the poles:

$$M = \max_i \max_k \Delta_i(k) \qquad i = 1, 2, \ldots, m; k = 1, 2, \ldots, n$$
$$m = \min_i \min_k \Delta_i(k)$$

4) Seek the correlation coefficient:

$$r_i(k) = \frac{m + \varepsilon M}{\Delta_i(k) + \varepsilon M} \qquad i = 1, 2, \ldots, m; k = 1, 2, \ldots, n$$

Among them, ""$r_i(k)$"means the correlation coefficient of the i-th element and the benchmark index in the k-th year, and set "ε"=0.5.

5) Calculate the correlation degree:

$$r_i = \frac{1}{n} \sum_{k=1}^{n} r_i(k) \qquad i = 1, 2, \ldots, m; k = 1, 2, \ldots, n$$

Among them, "r_i"means the correlation degree of the i-th element and the benchmark index.

4.3. Demonstration Analysis of the Logistics Enterprise

According to the low-carbon impact factors index system established previously, we set the explanatory variables: "Y_i" means the transport energy consumption, "Y_2"means the storage and handling energy consumption, "Y_3"means packaging and processing energy consumption, "Y_4" means the information management energy consumption, "Y_5" means the gasoline consumption, "Y_6" means the diesel consumption, "Y_7" means the natural gas consumption, "Y_8" means the electricity consumption, "Y_9" means the empty loaded rate, "Y_{10}" means the warehouse utilization rate. Then establish the grey system composed of the explanatory variables above based on the statistical data of one logistics enterprise, as shown in Table 2. Finally calculate the degree of influence of the explanatory variables to the logistics energy consumption, as shown in Table 3.

Time / Index	2006	2007	2008	2009	2010
Logistics energy consumption (million tons standard coal) X	50	61	70	88	94
Transport energy consumption (million tons) Y_1	26	29	30	37	41
Storage and handling energy consumption (million tons standard coal) Y_2	10	12	15	20	30
Packaging and processing energy consumption(million tons standard coal) Y_3	7	10	16	20	25
Information management energy consumption(million tons standard coal) Y_4	4	5	11	23	25
Gasoline consumption (million tons) Y_5	20	25	26	35	37
Diesel consumption (million tons) Y_6	4	3	3	3	3
Gas consumption (million m^3) Y_7	5	6	5	7	9
Electricity consumption (Million kilowatt-hour) Y_8	150	172	180	188	193
Empty loaded rate (%)Y_9	50%	50%	43%	41%	37%
Warehouse utilization rate (%)Y_{10}	70%	75%	80%	77%	79%

Tab.2 the original data table of logistics energy consumption and its related factors

Index	Grey correlation degree	Grey correlation sequence
Transport energy consumption (million tons) Y_1	0.987253	1
Storage and handling energy consumption (million tons standard coal) Y_2	0.863970	4
Packaging and processing energy consumption(million tons standard coal) Y_3	0.759352	6
Information management energy consumption(million tons standard coal) Y_4	0.735629	7
Gasoline consumption (million tons) Y_5	0.583928	9
Diesel consumption (million tons) Y_6	0.925786	2
Gas consumption (million m^3) Y_7	0.557462	10
Electricity consumption (Million kilowatt-hour) Y_8	0.713694	8
Empty loaded rate (%)Y_9	0.872591	3
Warehouse utilization rate (%)Y_{10}	0.834276	5

Tab.3 the connection degree of logistics energy consumption and its related factors

The calculation result of the grey correlation degree of this logistics enterprise's low-carbon impact factors index system is that: transport energy consumption Y_1> diesel consumption Y_6> empty loaded rate Y_9> storage and handling energy consumption Y_2> warehouse utilization rate Y_{10}> packaging and processing energy consumption Y_3> information management energy consumption Y_4> electricity consumption Y_8> gasoline consumption Y_5> gas consumption Y_7.

From the Table 3, we can find the following characteristics of the logistics enterprises' low-carbon impact factors:

1) The grey correlation degrees of all the indexes of the low-carbon impact factors index system are greater than 0.5, which indicates that the index system is scientific and instructive.

2) The grey correlation degree of the transport energy consumption is the highest in the logistics enterprises' low-carbon impact factors index system, which means that transport plays a key role in the carbon management of the logistics enterprises. In addition, logistics' transport activities consume mainly the diesel, and the grey correlation degree of diesel fuel consumption is also high, which further validates the importance of transport energy consumption index.

3) The resource's use efficiency also has a huge impact on the low-carbon management of the logistics enterprises, such as empty loaded rate and warehouse utilization rate listed in the table. Therefore, the logistics enterprises should improve management efficiency and avoid waste of the resources.

5. Conclusions

By analyzing the situation of the logistics enterprises' energy consumption, as well as the types and characteristics of the energy consumption in the logistics business processes, this paper establishes the logistics enterprises' low-carbon impact factors index system and takes the grey relational analysis. Then take the demonstration analysis by grey connection theory based on one logistics enterprise's data to further validate the scientific nature of the index system. From the study in this paper, we know that transport energy consumption and resource efficiency play a very important role in the low-carbon management of the logistics enterprises, which are the key indicators of the index system.

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