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Dynamic evaluation of enterprise green logistics consciousness and action level

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Abstract: Green logistics has become an important factor and challenge of supply chain management, green logistics and sustainable development under the actual demand, green enterprises from green consciousness to ideology, and then to the strategic concept and action, this development path urgently needs to be monitored, measured and evaluated. In order to carry out the dynamic evaluation of enterprise green logistics awareness and action level, the evaluation index system covering 7 dimensions and 50 measures is constructed, and the set pair analysis is combined with markov chain dynamic analysis to evaluate. The feasibility and practicability of the evaluation method are verified by a case study of a local fresh supply chain enterprise's awareness and action level of green logistics, which provides a scientific decision-making basis for the evaluation of enterprise's awareness and action level of green logistics.

Keywords: Green logistics, Level of consciousness and action, Dynamic evaluation, Set pair analysis, Markov chain.

1. Introduction

Green logistics has become an important factor and challenge of supply chain management. Green logistics is committed to reducing the impact of logistics activities on the environment and ecology, including green procurement, green distribution and marketing, green material management and manufacturing and reverse logistics. Its overall goal is to slow down the impact on the environment, reduce the cost and improve the added value of products, through green logistics to achieve effective use of storage space, reduce logistics costs, improve customer service, enrich the inverse logistics information and ultimately enhance the corporate image.

Effective green logistics activities not only affect the operation and performance of enterprises, but also promote the long-term competitiveness of enterprises. With the transformation of China's economic development mode and the transformation and upgrading of industrial structure, China's green industry is booming, creating new economic growth points and becoming an important part of the new driving force of economic development. Vigorously developing green logistics has become the inevitable choice of logistics industry and related enterprises.

2. Necessity of enterprise green logistics consciousness and action level evaluation

From the perspective of the five development concepts of green development, the implementation of green development is an inevitable requirement to break the constraints of China's resources and environment, accelerate the transformation of economic development mode, optimize the industrial structure and improve the international competitiveness, and is also the premise and basis for the realization of sustainable development of the whole society[1]. From the perspective of green enterprises, the fifth Plenary Session of the 18th CPC Central Committee proposed to adhere to the concept of green development. For enterprises, it means to create green enterprises and develop green economy[2]. From the perspective of green logistics and supply chain, the opinions on promoting high-quality development of Logistics and Forming a Strong Domestic Market clearly put forward that the development of green logistics should be accelerated and the

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endogenous driving force of high-quality development of logistics should be enhanced. The CPC Central Committee and The State Council attach great importance to the construction of green supply chain, which has been included in important strategic arrangements such as supply-side reform. From "Made in China 2025" proposed to build a green supply chain to "Guidance on Promoting Green consumption" to encourage enterprises to promote the construction of green supply chain; Furthermore, specific tasks such as "vigorously advocating green manufacturing", "actively implementing green circulation" and "establishing reverse logistics system" were put forward in the "Guiding Opinions of The General Office of the State Council on Actively Promoting Innovation and Application of Supply Chain". Until the report of the 19th CPC National Congress made it clear that new growth points and new driving forces should be fostered in green and low-carbon areas and modern supply chains.

In order to meet the requirements of the development of The Times, the concept of sustainability combined with the needs of modern logistics development into the definition of green logistics. Green logistics is a process of planning, control, management and implementation of logistics system with the goal of reducing pollutant emission and resource consumption through advanced logistics technology and environment-oriented concept[3].

Under the realistic demand of green logistics and sustainable development, green enterprises rise from green consciousness to ideology, and then to strategic concept and action. The above paths need to be monitored, measured and evaluated urgently.

3. Construction of enterprise green logistics awareness and action level evaluation index system

Combined with the characteristics of the comprehensive evaluation on the awareness and action level of green logistics of local fresh supply chain enterprises in a city, an evaluation index system was established[4], as shown in Table 1. The index system is composed of seven aspects: green behavior and attitude of fresh supply chain enterprises, green supply chain and procurement, green transportation, green packaging, green storage, reverse logistics and the intention to introduce green logistics. The hierarchical structure is constructed by hierarchical analysis. The uppermost layer is the target layer, the second layer is the primary index composed of 7 dimensions, and the third layer is the secondary index composed of 50 criteria corresponding to 7 dimensions. The index system has clear meaning and strong resolution and representativeness.

4. Set pair analysis and Markov chain dynamic analysis

4.1 Set pair analysis method

The basic idea of Set Pair Analysis (SPA) is as follows: For A specific problem background, given two sets A and B, and Set H= (A, B) formed by these two sets, N features can be obtained by analyzing the characteristics of Set Pair H. Among them, S features are common to A and B in the set pair, P features are opposite to each other on sets A and B, and the rest Q= N-S-P features are neither opposite nor common on sets A and B, then the correlation degree of the corresponding problem can be expressed as:

$$\mu = \frac{S}{N} + \frac{Q}{N}i + \frac{P}{N}j = a + bi + cj \quad (1)$$

The formula represents the degree of connection between two sets. a is the same degree of two sets, b is the difference degree of two sets, and c is the opposition degree of two sets. $a + b + c = 1$,i is the coefficient of difference degree, $i \in [-1,1]$, j is the coefficient of opposition, generally $j = -1$. If $c \neq 0$, the ratio of the same degree a to the opposition degree c is the set pair potential of the corresponding set pair under the specified problem background, which is expressed by shi. When

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$shi=\frac{a}{c}$。$\frac{a}{c}>1$，$\frac{a}{c}=1$，$\frac{a}{c}<1$,they are called set pair isopotential, set pair equilibrium and set pair inverse potential respectively. The set pair potential expresses the tendency for two sets of set pairs to relate. The values of a, b and c can also determine the strength of the trend. In the analysis of the trend of similarity and difference reaction of the degree of connection, if the trend of strong homogeneity represents the same trend as the main direction of the system, the level of green logistics consciousness and action can be considered as "excellent". If the situation is strong balance, it means that the same and opposite trend of the system is obviously equal, the level of action of green logistics consciousness can be considered as "good". If the situation is strongly negative, it means that the opposition trend of the system is determined, and the corresponding evaluation grade can be considered as "poor".

In the process of comprehensive evaluation of green logistics awareness and action level of fresh supply chain enterprises, AHP is used to determine the index weight W_k,k=1,2,…，N，$\sum_{k=1}^{N}W_k=1$, then the degree of connection can be expressed as:

$$\mu=a+bi+cj=\sum_{k=1}^{S}W_k+\sum_{k=S+1}^{S+Q}W_k i+\sum_{k=S+Q+1}^{N}W_k j \tag{2}$$

4.2 Dynamic analysis of SPA combined with Markov chain

Markov chain method describes the rule of system state transition and is a method to analyze the future change rule of random events and possible results. The comprehensive evaluation of enterprise green logistics awareness and action level can be considered in multiple periods.Assuming that at time t, there are N indicators satisfying $S_t+Q_t+P_t=N$, then the degree of connection at time t is:

$$\mu=a(t)+b(t)i+c(t)j=\sum_{k=1}^{S_t}W_k(t)+\sum_{k=S_t+1}^{S_t+Q_t}W_k(t)i+\sum_{k=S_t+Q_t+1}^{N}W_k(t)j \tag{3}$$

Among them:

$$\sum_{k=1}^{S_t}W_k(t)+\sum_{k=S_t+1}^{S_t+Q_t}W_k(t)+\sum_{k=S_t+Q_t+1}^{N}W_k(t)=1 \tag{4}$$

Because, the fresh supply chain enterprise system is in the process of dynamic change, after △t time, the evaluation index of enterprise green logistics awareness and action level will change, some change to other levels, some keep the same level.Assume that at time t+△t, In S_t features, S_{t1}, S_{t2},and S_{t3} represent unchanged, become neither identical nor opposite, and become opposite, respectively. And $S_t=S_{t1}+S_{t2}+S_{t3}$, then S_t belongs to [t，t+△t], the normalized transfer vector can be expressed as:

$$\vec{S}=(F_{11}+F_{12}+F_{13})=[\sum_{k=1}^{S_{t1}}W_k(t)+\sum_{k=S_{t1}+1}^{S_{t1}+S_{t2}}W_k(t)+\sum_{k=S_{t1}+S_{t2}+1}^{S_t}W_k(t)]\times\frac{1}{\sum_{k=1}^{S_t}W_k(t)} \tag{5}$$

In the same way, Q_t， P_t belongs to [t,t+△t], the normalized transfer vector can be expressed as:

$$\vec{Q}=(F_{21}+F_{22}+F_{23})=[\sum_{k=S_t+1}^{S_t+Q_{t1}}W_k(t)+\sum_{k=S_t+Q_{t1}+1}^{S_t+Q_{t1}+Q_{t2}}W_k(t)+\sum_{k=S_t+Q_{t1}+Q_{t2}+1}^{S_t+Q_t}W_k(t)]\times\frac{1}{\sum_{k=S_t+1}^{S_t+Q_t}W_k(t)} \tag{6}$$

$$\vec{P}=(F_{31}+F_{32}+F_{33})=[\sum_{k=S_t+Q_t+1}^{S_t+Q_t+P_{t1}}W_k(t)+\sum_{k=S_t+Q_t+P_{t1}+1}^{S_t+Q_t+P_{t1}+P_{t2}}W_k(t)+\sum_{k=S_t+Q_t+P_{t1}+P_{t2}+1}^{N}W_k(t)]\times\frac{1}{\sum_{k=S_t+Q_t+1}^{N}W_k(t)} \tag{7}$$

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$$F^{\Delta t}=\begin{bmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{bmatrix} \tag{8}$$

To sum up, after △t time, the correlation degree at the t+△t moment is:

$$\mu(t+\Delta t)=a(t+\Delta t)+b(t+\Delta t)i+c(t+\Delta t)j=(a(t),b(t),c(t))\circ F^{\Delta t}\circ(1,i,j) \tag{9}$$

Where, $F^{\Delta t}$ is the identity and difference inverse transition matrix of set pair A and B in the evolution of time[t，t+△t][5].

5. Empirical Analysis

In order to understand the level of green logistics awareness and action of enterprises, a comprehensive evaluation was carried out based on the SPA method. First, AHP[6] was used to calculate the weights of the first and second level indicators, as shown in Table 1. Secondly, based on the evaluation grades of each indicator in each time period (I represents score [8,10], II represents score [6, 8]), and III represents score below 5), the connection degree of each period was calculated, as shown in Table 2.

Table 1. Comprehensive evaluation index system of enterprise green logistics awareness and action level

Primary indicators	Weight of first-level indicators	Secondary indicators	Weight of secondary indicators	2015	2016	2017	2018	2019
Green behavior attitude of enterprises	0.06	Environmental policies and targets have been formulated	0.02	III	II	II	II	II
		Conduct environmental education activities for employees	0.02	III	III	II	II	II
		Understand all kinds of government support measures for green logistics, and use and promote	0.02	III	III	II	II	II
Green supply chain and procurement	0.24	Consider the packaging reduction of the product	0.02	III	III	II	II	II
		Consider vehicle load capacity	0.02	II	II	II	I	I
		Consider the efficiency of transportation	0.02	II	II	II	II	I
		Promote green logistics by cooperating with upstream and downstream industries	0.02	III	III	III	II	II
		Training on environmental factors has been carried out for cooperative companies	0.02	III	III	III	II	II
		Adjust transaction criteria with partners to facilitate logistics operations	0.02	II	II	II	I	I
		Motivate logistics suppliers to improve transport units by providing incentives	0.02	I	II	I	II	II
		We will adjust the delivery time with our trading partners to avoid the peak delivery time	0.02	II	II	I	I	I
		Adjust delivery times to reduce rush hour congestion	0.02	II	II	I	I	I
		Improve the accuracy of demand forecasting to reduce wasteful	0.02	III	III	II	II	I

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		production, inventory and transportation						
		Willing to carry out common transportation with other enterprises	0.02	III	III	III	II	II
		Willing to use common logistics locations with other companies	0.02	III	III	III	II	II
Green transportation (distribution)	0.14	Distribution depends on quantity of goods, number of vehicles, type of distribution route, check delivery order and reflect in scheduling plan	0.02	II	II	I	I	I
		According to the distribution destination, direct supply through the differentiation of bases, so as to improve the overall transport efficiency	0.02	II	II	I	I	I
		Purchase logistics using daily distribution operation system	0.02	III	II	II	I	I
		Continue to implement environmentally friendly driving activities	0.02	III	III	III	II	II
		Advance the introduction of regulations to address the latest emissions legislation	0.02	III	III	III	III	III
		Distribution vehicles already use environmentally friendly tyres	0.02	III	III	III	III	III
		Distribution vehicles must use new energy	0.02	III	III	III	III	II
Green packaging	0.2	Reduce the use of packaging materials	0.02	III	III	III	III	II
		Simplified the packaging form	0.02	II	II	II	II	II
		Integrate in large boxes and remove small box packaging	0.02	II	II	II	II	II
		Use packaging materials that are easy to reduce volume when not in use	0.02	III	III	II	II	II
		Make unpackaged cuts	0.02	III	III	II	II	II
		The reuse of transport containers and pallets (pallets) is regulated	0.02	III	III	II	II	II
		The transport containers used are recyclable and reusable	0.02	III	III	III	III	II
		Considering its recycling treatment, the packaging material is flexible and reusable	0.02	III	III	II	II	II
		The packaging used is made from recycled materials	0.02	III	III	III	III	II
		Energy-saving and low-emission packaging equipment	0.02	III	III	III	III	III
Green warehousing	0.2	Use energy saving and low pollution logistics equipment to reduce the impact on the environment	0.02	III	III	III	III	III
		Efficient staffing and equipment operation, resulting in reduced operating time	0.02	III	III	II	II	II
		Change the storage layout or inventory layout, as well as improve the work line to reduce internal	0.02	II	II	II	II	I

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		handling						
		There is a driver dispatch waiting room to prevent idle delay due to loading and unloading of vehicles	0.02	II	II	II	II	II
		Import energy-saving power equipment, lighting, air conditioning	0.02	III	III	II	II	II
		Design to increase the number of stacks to improve storage efficiency	0.02	II	II	II	II	II
		In cold storage, refrigerated storage, as far as possible to make the outside air impenetrable	0.02	II	I	I	I	I
		Store products at desired temperatures in different stratospheric layers to avoid excessive cooling	0.02	III	II	II	II	I
		Actuarial input, output, average inventory to reduce storage space	0.02	III	II	II	II	I
		Reduce unmarketable goods, stationary inventory and inventory of wasted space, etc., to reduce storage space	0.02	II	II	II	II	I
The reverse logistics	0.08	Efforts are being made to recycle waste generated as a result of logistics activities	0.02	III	III	II	II	II
		Reduce return logistics to reduce logistics costs	0.02	III	III	II	II	I
		Record and return to reduce return logistics	0.02	III	III	II	II	I
		Reduce the occurrence of returns and reduce the return logistics	0.02	III	III	II	II	I
Willingness to use green logistics	0.08	Be willing to pay more	0.02	III	III	II	II	II
		Be willing to pay unexpected costs	0.02	III	III	II	II	II
		Willingness to change IT systems (including traceability)	0.02	III	III	II	II	I
		Be willing to pay for inventory changes	0.02	II	II	II	II	II

Table 2. Calculation of association degree of enterprise green logistics awareness and action level in 5 time periods

Degree of connection in 5 periods		i	j	μ value	Shi=a/c	Situational
	a	b	c	i=0.5，j=-1		
Y1:2015	0.02	0.3	0.68	μ1=-0.51(Very poor)	0.029	Weakly inverse situation
Y2:2016	0.02	0.38	0.6	μ2=-0.39(Poor)	0.033	Weakly inverse situation
Y3:2017	0.12	0.62	0.26	μ3=0.17(General)	0.46	Micro inverse situation
Y4:2018	0.16	0.68	0.16	μ4=0.34(Good)	1	Micro equilibrium situation
Y5:2019	0.36	0.56	0.08	μ5=0.56(Excellent)	4.5	Slightly homogeneity situation
Average level of connection	0.136	0.508	0.356	0.034General)	0.382	Micro inverse situation
μpre=μ6	0.22	0.58	0.2	μ6=0.311(Good)	1.1	Slightly homogeneity situation

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The evaluation grade of enterprise green logistics consciousness and action level corresponding to the degree of connection is shown in Table 3. From the set pair connection degree of the fresh supply chain enterprise in each period, when the neutral attitude is adopted for evaluation, i=0.5, j=-1, the level of consciousness and action of enterprise green logistics in 2015 and 2016 is very poor and poor respectively, and the level of consciousness and action of enterprise green logistics in 2017-2018 is from average to good. In 2019, the level of enterprise green logistics awareness and action was excellent. From the period of 2015-2019, the level of green logistics awareness and action of the enterprise is an increasingly good development trend.

Table 3. The degree of connection corresponds to the evaluation level of enterprise green logistics consciousness and action level

The value range of μ	Corresponding level
[0.5,1]	Excellent
[0.3,0.5)	Good
[-0.3,0.3)	General
[-0.5,-0.3)	Poor
[-1,-0.5)	Very poor

Calculate the transfer matrix of each period:

$$Y_{1-2}=\begin{bmatrix}0 & 1 & 0\\ 0.07 & 0.93 & 0\\ 0 & 0.12 & 0.88\end{bmatrix} \tag{10}$$

$$Y_{2-3}=\begin{bmatrix}1 & 0 & 0\\ 0.26 & 0.74 & 0\\ 0 & 0.57 & 0.43\end{bmatrix} \tag{11}$$

$$Y_{3-4}=\begin{bmatrix}0.83 & 0.17 & 0\\ 0.10 & 0.9 & 0\\ 0 & 0.38 & 0.62\end{bmatrix} \tag{12}$$

$$Y_{4-5}=\begin{bmatrix}1 & 0 & 0\\ 0.29 & 0.71 & 0\\ 0 & 0.5 & 0.5\end{bmatrix} \tag{13}$$

In accordance with the principle that the more recent the weight of the connection degree is, the weight of the transfer matrix of each period is set as (0.1, 0.2, 0.3, 0.4), then the weighted average transfer matrix of these five periods is:

$$\overline{Y}=\begin{bmatrix}0.85 & 0.15 & 0\\ 0.21 & 0.79 & 0\\ 0 & 0.44 & 0.56\end{bmatrix} \tag{14}$$

Calculate and predict the relation degree of Y6:2019-2020 in the next period is $\mu_{\text{pre}}=\mu_6=0.22+0.58i+0.2j$, and Shi6=1.106.

To sum up, the evaluation level of enterprise green logistics consciousness and action level in the past five periods to predict its future stable state is good, and its set pair potential is slightly homogeneity situation. Through the change of the set pair potential as you can see, the fresh green logistics of supply chain enterprise consciousness action levels tend to be stable, the set pair potential from weakly inverse situation gradually into slightly homogeneity situation, indicated that the fresh supply chain enterprises relying on the national regional economic and social development in the process of urbanization and the improvement of people's living standard, increasing fresh (cold chain logistics investment, and improve operational efficiency, So as to better meet the needs of the people for a better life. However, combined with the above calculation, it is found that the corresponding set pair potential is not strong homogeneity situation, but slightly homogeneity situation, which is at the fourth level of homogeneity, indicating that the situation is not stable. If you do not pay attention to it, it will become equilibrium or counter-potential, thus weakening the

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work performance level. In particular, China has entered the new normal of economic development, and in the process of rapid urbanization, fresh cold chain logistics has put forward higher requirements for safety, efficiency, green and sustainable.

Therefore, we should continue to change our thinking, strengthen the concept of sustainable development, establish the consciousness of green development and turn it into concrete implementation actions, so as to make the convergence trend in the stable time become a strong same trend, among which green packaging and energy saving and consumption reduction are also the development direction of green economy that needs attention.

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