Prediction on Cold Chain Logistics Demand of Urban Residents in Jiangsu Province during the Twelfth Five-Year Plan Period——Based on Estimates of GM(1,1) Model

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Abstract This paper takes the total yield of products that need refrigerated transport as the impact factors of transport aggregate of cold chain logistics, such as meat, aquatic products, quick-frozen noodle, fruits, vegetables, dairy, and medicine. Through selecting the consumption data of urban residents on transported products via cold chain in Jiangsu Province from 2005 to 2000 as sample, this paper establishes grey prediction model GM(1,1) of cold chain logistics demand and uses DPS7.05 software for test, to predict the cold chain logistics demand of urban residents in Jiangsu Province during the Twelfth Five-Year Plan period. The results show that in the period 2010－2015, the cold chain logistics demand of urban residents in Jiangsu Province is 1 151.589 1, 1 185.136 6, 1 219.661 3, 1 255.191 8, 1 291.757 3, 1 329.388 1 t respectively; in the period 2005－2010, the cold chain logistics demand of urban residents in Jiangsu Province increases at annual growth rate of 3.9%; in the period 2011－2015, the growth rate declines to some extent, increasing slowly at rate of 2.9%.

Key words Cold chain logistics demand, The Twelfth Five-Year Plan, Jiangsu Province, Grey prediction model, China

In 1894, the American Albert Barrier and the British Ruddich first proposed the concept of " Cold Chain"[1]. In the 1940s, cold chain got enough attention and developed rapidly. China's cold chain logistics originated from the meat export trade in the 1950s. In 1982, China promulgated *Food Sanitation Law*, thus promoting the burgeoning and development of the cold chain of food. In recent years, with the improvement of living standards of urban and rural residents, and change of people's spending habits, the cold chain logistics represented by aquatic products, livestock products, fruits and vegetables, and flowers, is burgeoning, and the industry of cold chain logistics also develops increasingly along with the growing market demand.

For the time being, the development of national economy gradually gets rid of extensive pattern, and the awareness of quality and benefit is gradually promoted, cold chain captures more and more attention from economic circle and industry circle. Many scholars emphasize the great significance of development of cold chain logistics to China's economy, and problems and countermeasures existing in the process of development. A handful of scholars use mathematical statistical methods to predict the demand of cold chain logistics, for example, Lan Hongjie uses neural network technology to predict and analyse cold chain logistics demand of Olympic food[2]. Taking cold chain logistics demand of aquatic products in China as an example, Li Junbo uses multiple linear regression analysis method to establish prediction equation of cold chain logistics demand, and uses Eviews software to conduct test[3]. We find that although a large number of documents use multivariate linear method, neural network method, support vector machine method, grey forecasting method and other methods to predict and research the logistics demand[4-5], the predictions and researches on cold chain logistics are extremely rare.

Accurately predicting the future cold chain logistics demand is of great significance to the development of the national economy. However, the loading and unloading operation of perishable domestic food and medicine at present is completed mostly in the open air rather than warm place and cold storage. 80% to 90% of the vehicles are common trucks, and there is no guarantee of transportation quality. The losses of food in China arising from circulation and transport of reach hundreds of billions yuan. The direct factor responsible for this predicament is in that currently in China, the cold chain facilities and cold chain equipments are seriously short, and the former equipments and facilities are stale, with imbalanced development and distribution, which cannot provide low temperature guarantee systematically for circulation of perishable food. As we all know, facilities and equipments must be provided in accordance with demand, while the cold chain logistics demand in Jiangsu Province cannot be ascertained. The grey prediction model of cold chain logistics demand in Jiangsu Province established in this paper, can predict the demand amount and demand trend of future cold chain logistics, so as to provide the basis for building and input of facilities and equipments of cold chain logistics.

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1 Index selection, data source and research method

1.1 Index selection and data source The cold chain logistics demand is the requirement on goods and materials in terms of time, space and cost, arising from the role of a given period of economic activities in allocating raw materials, semi-finished products, finished goods and waste materials in the fields of production, circulation and consumption, which involves transport, packaging, inventory, loading, unloading and hauling, distribution, circulation, processing, information processing and other aspects of the logistics activities. The index system of measuring cold chain logistics demand includes: to consider volume of freight traffic, rotation volume of freight transport, storage, processing capacity and other indices from quantity of goods produced; to consider the total costs of social logistics, the total income of social logistics, increase in value of supply chain and other indices from magnitude of value; to consider the number of workers engaging in cold chain logistics, the ratio of the number of workers engaging in cold chain logistics and total number of employees from employment and other indices[4]. The commodities that are applicable to cold chain logistics are generally divided into three categories: first, the primary agricultural products, including vegetables, fruits, meat, poultry, eggs, aquatic products, flowers, *etc.*; second, the processed foods, such as quick-frozen food, meat, aquatic products and other cooked food packaged, ice cream and dairy products, *etc.*; third, special commodities, such as medicine and vaccines, *etc*[6].

In terms of selection of logistics demand forecasting indicators, formerly the scholars use single indicator approach, but as a matter of fact, there are many factors affecting cold chain logistics demand. Therefore, in order to more comprehensively describe the total cold chain logistics demand, this paper takes the total output of products which need refrigerated transport, such as meat, aquatic products, quick-frozen noodle, fruits, vegetables, dairy, and medicine, as impact factor of the total volume of transport of cold chain logistics, to be incorporated into the model. We use grey prediction model to predict the total volume of transport of cold chain logistics in Jiangsu Province during the Twelfth Five-Year Plan period.

Considering the data availability, as well as differences in statistical caliber of urban residents and rural residents' food spending in Jiangsu Province, this paper selects the data concerning urban residents in Jiangsu Province from 2005 to 2009 as sample, and the data is from *Statistical Yearbook of Jiangsu Province* (2006 – 2010). The specific values can be shown in Table 1.

Table 1 The total product consumption of urban residents transported via cold chain in Jiangsu Province from 2005 to 2009 kg

Name	2005	2006	2007	2008	2009
Edible vegetable oil	32537.25	35 812.26	36 627.76	38 850.23	37 880.31
Pork	79 191.58	80 518.8	74 918.57	80 826.83	87 743.21
Beef	6 492.351	6 582.559	6 855.029	6 169.35	6 528.129
Mutton	2 453.505	2 429.278	2 758.236	2 751.197	3 221.117
Chicken and duck	44 465.05	44 158	37 479.57	39 016.97	39 813
Fresh eggs	40 426.21	42 590.73	42752.66	45 186.32	45 782.8
Fish	47 145.04	50 427.11	55 975.97	56 399.53	58 366.63
Shrimp	10 606.69	11 441.11	13 182.75	12 088.59	13 872.28
Fresh vegetables	395 203	428 219	459 652	482 835	500 647.4
Tea	603.939 6	666.092 3	730.1214	750.326 4	944.860 8
Fresh fruits	108 293.9	113 627.5	130 042.7	127 638.9	136 876
Fresh melon	87 495.75	104 145.5	87 574.01	77 408.67	89 547.04
Pastry	14 079.34	15 163.4	15 900.42	18 716.48	20 228.61
Fresh dairy	72 397.26	79 539.26	81 449.1	76 241.5	71 208.15
Yoghurt	10 644.44	13 282.66	13 507.25	11 713.43	12 540.88
Total	952 035.3	1 028 603	1 059 406	1 076 593	1 125 200

Data source: *Statistical Yearbook of Jiangsu Province*(2006 –2010).

1.2 Grey prediction model The grey system theory gradually developed from the 1980s takes uncertain system as the study object. Through the known information to study and predict the unknown fields, it has achieved significant benefits since it is applied to industry, agriculture, society, economy and many other fields[7]. The basic grey prediction model GM (1,1) based on grey system theory has good prediction accuracy and practicality.

1.2.1 Grey prediction principle. The grey system model, in essence, through a certain method, processes the original data sequence, so that it presents regularity to a certain degree, and then uses differential equations for fitting, and conduct prediction via the extension[8]. The predicted value we get by the grey model generating data, must undergo the reverse generation process. The commonly used grey prediction model is GM (1,1). The setting of the model is as follows:

Step 1, let the time sequence have n observational values:

$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \cdots, X^{(0)}(n)\}$

By cumulative summation, it generates new sequence:

$X^{(1)} = \{X^{(1)}(1), X^{(1)}(2), \cdots, X^{(1)}(n)\}$

Step 2, establish GM(1,1) model. The corresponding differential equation is as follows: $\frac{dX^{(1)}}{dt} + aX^{(1)} = \mu$

where a is called development grey number; μ is called endogenous control grey number.

Let $\hat{a}$ be parameter vector to be estimated, $\hat{a}=\begin{pmatrix} a \\ \mu \end{pmatrix}$, we can use least square method for solving. We get the result as follows:

$$\begin{bmatrix} a \\ \mu \end{bmatrix} = (B^T B)^{-1} B^T Y_n$$

where, $B=\begin{bmatrix} -\frac{1}{2}[x^{(1)}(2)+x^{(1)}(1)] & 1 \\ -\frac{1}{2}[x^{(1)}(3)+x^{(1)}(2)] & 1 \\ \cdots & \\ -\frac{1}{2}[x^{(1)}(3)+x^{(1)}(2)] & 1 \end{bmatrix}$; $Y_n=\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \cdots \\ x^{(0)}(n) \end{bmatrix}$.

Step 3, calculate the response equation of the model:

$$\hat{x}_1^{(1)}(k+1)\left[x^0(1)-\frac{\mu}{a}\right]e^{-ak},\ k=1,2,\cdots,n-1$$

Step 4, conduct the residual correction. The residual is written as $d^{(0)}(k)=x^{(0)}(k)-x_1^{(0)}(k)$, $k=2,3,\cdots,n$

Similar to Step 1 – 3, we establish grey prediction model to residual $d^{(0)}(k)$ as follows:

$$\hat{x}_2^{(1)}(k+1)\left[x^0(1)-\frac{\mu}{a}\right]e^{-ak}+\frac{\mu}{\alpha}+\eta(k-i)\hat{d}^{(0)}(k+1),$$

$k=1,2,\cdots,n-1$

where, $\eta(k-i)=1(k>i)$ or $\eta(k-i)=0(k\leqslant i)$, i is the number of residuals that have not participated in establishment of model. Similarly, conduct cumulative subtraction and restoration, namely

$x^{(0)}(k)=x_2^{(1)}(k)-x_2^{(1)}(k)$, to get the final prediction result.

1.2.2 Precision test. The grey prediction model generally uses relative error $e(k)$, posterior error ratio C and frequency of small error P to assess the precision of the model. The calculation expression is as follows:

First, relative error

$$q^{(0)}(k)=x^{(0)}(k)-\hat{x}^{(0)}(k)$$

$$e(k)=q^{(0)}(k)/x^{(0)}(k)$$

Second, posterior error ratio

$$C=S_2/S_1$$

$$S_1^2=\frac{1}{n}\sum_{k=1}^{n}[q^{(0)}(k)-\bar{x}]^2,\ \bar{x}=\frac{1}{n}\sum_{k=1}^{n}[x^{(0)}(k)]$$

where, $P=f[\ |q^{(0)}(k)-\bar{q}|<0.067\,45S_1]$

$$S_1^2=\frac{1}{n}\sum_{k=1}^{n}[x^{(0)}(k)-\bar{x}]^2,\ \bar{x}=\frac{1}{n}\sum_{k=1}^{n}[x^{(0)}(k)]$$

Third, frequency of small error

$$P=f[\ |q^{(0)}(k)-\bar{q}|<0.067\,45S_1]$$

For a good prediction model, the smaller the C value, the better. It is generally required to be smaller than 0.35, and the maximal value is not more than 0.65. Another indicator of predicting quality of model is probability of small error P, which is required to be bigger than 0.95, and not less than 0.70. The specific precision level can be seen in Table 2.

Table 2 Reference table of precision test level

Prediction precision level	Relative error $e(k)$	Small error probability P	Ratio of mean square error C
Good	0.01	>0.95	<0.35
Qualified	0.05	(0.8, 0.95]	[0.35, 0.50)
Barely enough	0.10	(0.7, 0.8]	[0.50, 0.65)
Unqualified	0.20	≤0.7	≥0.65

2 Results and analysis

We use the basic grey model to calculate the urban residents' total demand of cold chain logistics in Jiangsu Province by DPS7.05 software, and the prediction model is x(t+1) = 35 241 329.743 873ex(0.028 715 t) – 34 289 294.443 873. The model parameter a = –0.028 715, b = 984 623.28106 5. The test value of model precision C = 0.112 0, P = 1.000 0. The level of model prediction precision is good, and the prediction results can be seen in Table 3.

Table 3 Grey prediction result of urban residents' cold chain logistics demand in Jiangsu Province

No.	Observational value//kg	Fitted value//kg	Error//kg	Error rate//%
X(2006)	1 028 603.000 0	1 026 630.545 0	1 972.455 0	0.191 8
X(2007)	1 059 406.000 0	1 056 537.767 1	2 868.232 9	0.270 7
X(2008)	1 076 593.000 0	1 087 316.229 5	–10 723.229 5	–0.996 0
X(2009)	1 125 200.000 0	1 118 991.312 7	6 208.687 3	0.551 8

The prediction value in the next six time points is as follows: X(2010) = 1151589.13664; X(2011) = 1 185 136.581 97; X(2012) = 1 219 661.312 56; X(2013) = 1 255 191.798 13; X(2014) = 1 291 757.337 77; X(2015) = 1 329 388.084 09.

Therefore, the prediction result of the model is basically consistent with the actual value, and adopting the grey prediction model for future prediction is basically correct.

By combining the prediction data in the period 2010 – 2015 and the data in the period 2005 – 2009, we calculate growth rate of urban residents' demand of cold chain logistics in Jiangsu Province from 2005 to 2015. From Table 4, we can find that in 11 years, the annual demand in the period 2005 – 2010 increases at growth rate of 3.9%, and the growth rate declines to some extent in the period 2011 – 2015, increasing slowly at rate of 2.9%.

Table 4 Growth rate of urban residents' cold chain logistics demand in Jiangsu Province from 2005 to 2015

Year	Demand//t	Growth//%	Average growth rate//%
2005	952.035 3	–	3.904
2006	1 028.603 0	0.080 425 54	
2007	1 059.406 0	0.029 946 325	
2008	1 076.593 0	0.016 223 407	
2009	1 125.200 0	0.045 148 983	
2010	1 151.589 1	0.023 452 462	
2011	1 185.136 6	0.029 131 436	2.913
2012	1 219.661 3	0.029 131 436	
2013	1 255.191 8	0.029 131 436	
2014	1 291.757 3	0.029 131 436	
2015	1 329.388 1	0.029 131 436	

(To page 45)

protection product, its property protection will have legal safeguard and its industrialization will have a regional brand platform. Along with people's recognition of Liupao Tea and its functions and effects, Liupao Tea industry will have a greater expansion.

In the course of industrial development of Liupao Tea, following quality-related problems exist: low processing threshold, scattered and small scale of processing enterprises; low product quality and production indexes, not favorable to survival of the fittest enterprises; most processing enterprises do not have their own tea garden base, not favorable to improving quality of Liupao Tea and controlling abuse of pesticide; and low ability of research and development and technology popularization, as well as lack of public research and development and popularization platform.

4.2 Suggestions for quality and industrial supervision of Liupao Tea To fully utilize effect and resource of GI product Liupao Tea, and promote development of Liupao Tea industry without losing its special features, it is proposed to take proper measures and establish appropriate system to supervise the industry according to influence of Liupao Tea and the connection between Liupao Tea and the production regions. First, we recommend applying for formulation of national standard *GI Product – Liupao Tea* to State Administration of China for Standardization, to raise indexes of product standard. Second, it is proposed to popularize the industrial mode of " market + association (enterprise) + base" , and establish demonstration areas for protection of GI product Liupao Tea, to raise utilization efficiency of technology and cut down use of pesticide. Third, government may take the lead in establishing special product inspection and research and development institutions, and increasing frequency of periodical random inspection and market supervision. Fourth, we should raise the production and processing threshold, standardize production and stabilize quality of Liupao Tea enterprises, cultivate and support leading enterprises, and speed up financial, technical, talent, and brand gathering of Liupao Tea. Fifth, we suggest setting up independent supervision institution, reinforce and perfect supervision functions of Liupao Tea industry.

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(From page 40)

3 Conclusion

This paper uses grey prediction model to conduct prediction analysis on the total volume of goods and materials that need cold chain transport during the Twelfth Five-Year Plan period. The results show that during the whole period of the Twelfth Five-Year Plan, the total volume of goods and materials of urban residents in Jiangsu Province that need cold chain transport will increase at an annual growth rate of 2.9%, which will bring good opportunities for enterprises engaging in cold chain logistics.

Based on the current situation, most producers have insufficient refrigerated trucks, not enough to confront the increase in cold chain logistics demand. Consequently, the relevant cold chain logistics service providers need to consider whether to purchase refrigerated trucks or cooperate with the third – party logistics companies for distribution. Based on the analysis in this paper, in the future, we can conduct research on cold chain logistics from the following aspects: first, what kind of distribution model should the cold chain logistics adopt; second, how to design the information management system of cold chain logistics to ensure the safe transport of goods.

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