Demand Forecast on the Orchard Cold Chain Logistics in Hunan Province Based on Cognitive Neuroscience

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Abstract—How to scientifically and effectively predict the cold chain logistics demand and provide basis for decision making has always been the focus of forestry and orchard logistics research. From the learning environment of neurons, cognitive neuroscience provides a new perspective for forecasting the demand for cold chain logistics. This paper uses the cognitive neuroscience theory to construct a BP neural network model containing two hidden layers to predict the cold chain logistics demand of the forestry and orchard industry in Hunan province in 2017-2021. Suggestions are then given from the aspects of cold chain logistics construction, transportation infrastructure construction, government policy, enterprise and industry according to the prediction results, thus, providing a theoretical basis for the planning of the cold chain logistics system of Hunan province in a certain period of time, as well as references for the development of cold chain logistics in other parts of the country.

Keywords—Fruit industry; Cold chain logistics; Demand forecasting; Cognitive neuroscience; Gray neural network.

I. INTRODUCTION

Hunan province is located in the middle and lower reaches of the Yangtze River and is at 109°~114° E and 20°~30° N. With typical continental subtropical monsoon humid climate, its average annual temperature is 16℃~18℃, and the average annual rainfall is 1200~1700mm [1]. With rich land resources, the province is dominated by middle and low hills with many rivers and lakes, which are suitable for a variety of fruit trees. It is one of the provinces in China with the most abundant fruits and vegetables. There are fruit trees from 14 families, 24 genera and 48 species, dominating by Orange, pear, peach, grape, date, persimmon, pomelo trees and so on. In 2016, the production of garden fruit in Hunan accounted for 5% of the total fruit output of the whole country, of which citrus accounted for 13.2% of the total citrus, ranking the second in the whole country. At present, the fruit industry has become an important part of the gardening industry in Hunan Province, and plays an important role in promoting the increase of farmers' income as well as the efficiency of forestry. According to the data of forestry statistics yearbook of Hunan Province, since 2000, the planting area and production of fruit in the province has been increasing year by year. In 2016, the total output of the fruit was close to 20 billion yuan, ranking the first in terms of the output in all horticultural crops. Therefore, the fruit industry occupies an important position in the first industry of the province.

At present, domestic and foreign research on forest and fruit cold chain logistics can be roughly divided into the following three categories: In terms of cold chain logistics technology and its significance, Alomari et al. [2] proposed that modern information technology is a necessary means to improve the efficiency of cold chain transportation, and digital traceability Technology is an important guarantee for achieving food safety; Suchanek et al. [3] believes that optimizing production logistics can greatly reduce the total cost of enterprises and speed up capital turnover. In terms of cold chain logistics scheduling and optimization, Hsiao et al. [4] found that most of the path optimization problems in cold chain logistics use single vehicle delivery, while Li et al. [5] proposed that in the path optimization problem of cold chain logistics, multiple vehicles are compared with single vehicle delivery. It is more advantageous. In terms of cold-chain logistics demand forecasting, Intarapak et al. [6] used logistic regression forecasting to predict and analyze household debt in Bangkok and Thailand's metropolitan areas; Huang and Wang [7] used a combination model to forecast the cold-chain logistics demand

for fresh agricultural products in my country. Avoid the shortcomings of a single prediction model; Li and Wang [8] found through comparison that the gray neural network model has higher prediction accuracy than the single gray prediction, linear regression and neural network methods.

In a word, the research of the above-mentioned domestic and foreign literature mainly focuses on agricultural products, meat and aquatic products, while there are relatively few discussions specifically on the cold chain logistics of forest and fruit. Therefore, this article will use a combination of gray and neural network methods to predict the demand for forest and fruit cold chain logistics in Hunan Province. It is hoped that through the research of this article, we will understand the general development trend of forest and fruit cold chain logistics in Hunan Province and strengthen relevant infrastructure for the government and enterprises. The construction provides data basis and improves the cold chain logistics management level.

II. STATUS OF COLD CHAIN LOGISTICS OF FRUIT INDUSTRY IN HUNAN PROVINCE

A. Status of infrastructure devices

60% of the total cold storage in Hunan is concentrated in Chang-zhu-tan, Zhangsha. According to the statistics of the provincial development and reform commission, the total cold storage capacity of Chang-zhu-tan has reached 219300 tons till 2015, and 51 enterprises engaged in cold chain related businesses. Therefore, according to researches on the main cold storage of Hongxing, Wulipai, Shangdalong, Heishipu, Yangjiashan in Changsha and some supermrkets, the status of the cold storage in Hunan are listed as follows: Wulipai, upper big ridge, black stone shop and Yang Jiashan, and some supermarkets. 1) In terms of the classification of cold storage, the current urban operational cold storage, such as commercial refrigerators, is the most, while cold storehouses for processing are few. Low temperature cold storehouses occupy more than 90%, while the high temperature ones are few. 2) As for the types of goods stored, most of the cold stores in the province are used for meat, aquatic products and dairy products storage. Cold stores for fruit account for less than 10%, most of which are in supermarkets, and most of them are for high-grade fruits. Less than 20% locally produced fruits are refrigerated. 3) As for the construction of the cold stores, large cold stores in the province are dominated by traditional multi-layer large warehouse, which accounts for more than 90% of the total amount of cold stores in the province. This kind of cold store is in saves land and is often equipped with a trading market, for example, Hongxing. 4) In terms of the heat preservation facilities of the cold storage, the cold stores used in Hunan province now is mainly the old cold storage in the 60s and 70s of last century. The means of heat preservation of these cold stores are relatively backward, the rice husk is still used for heat preservation, while new polyamine PU and the extruded board XPS are rarely used.

B. The current situation of cold chain logistics enterprises

At present, 452 enterprises engaged in cold chain logistics in the province, most of which are small and medium-sized enterprises with small business scale and different service standards. Regional and large service network has not been formed; therefore, it is difficult to provide comprehensive integrated cold chain logistics services. According to the competition for " top 100 China's cold chain logistics enterprises in 2015" hold by China Federation of Logistics and Procurement, only one company in Hunan Province - Hunan Huinong Agricultural Logistics Co., Ltd. has been named [9].

C. Human resources in cold chain industry

At present, professionals in the cold chain logistics in Hunan are scarce, and the existing employees in the industry are mostly from the related industries. Being lacking of professional knowledge, they are not familiar with the characteristics of cold chain logistics and the operation specifications. According to the analysis of the curriculum standards and syllabus of the logistics professional colleges and universities in our province, there is no cold chain logistics specialty and no special courses for cold chain logistics at present. Although some schools provide classes for cold chain design as well as some courses for refrigeration technology, there is still no perfect training system.

III. ANALYSIS OF RELEVANCE INDEX OF THE DEMAND INDEX SYSTEM OF FRUIT COLD CHAIN LOGISTICS

A. The construction of the demand index system

According to the related data and the analysis of the present situation of the fruit in Hunan Province, the factors affecting the cold chain logistics can be divided into two categories: economic index and non-economic index [10]. Considering that non-economic indicators can not be expressed with quantitative data, this paper will mainly analyze the economic indicators in the construction of the logistics demand index system based on the principles of operability, authenticity and objectivity [11].

The index system for forecasting the demand for cold chain logistics in Hunan province is as follows:

B. The establishment of cold chain logistics index system for garden fruits

In order to make the prediction results more authentic and accurate, combined with the actual situation of Hunan Province, the paper corrected some of the influencing factors in the index system. This paper studies the cold chain logistics demand of garden fruits produced within the province and the indexes of garden fruit production are revised. The formula is: the output of self-produced garden fruit=total fruit output*85%*65% of fruit and fruit. Since the data of per-capita consumption of garden fruits is difficult to collect, the national per-capita consumption of fruit is used for replacement. Therefore, the demand for garden fruits=the national per-capita consumption of garden * the number of permanent residents in Hunan province. In view of the various influencing factors in the logistics index system, relative statistics on the above 12 indexes and the total logistics demand (billion yuan) for the cold chain are collected according the statistical yearbook of Hunan Province, the statistical bulletin of Hunan Province, the

Chinese Statistical Yearbook, the Chinese Rural Statistical Yearbook and the Chinese logistics yearbook, The data collected was shown in the following tables (Table 1).

C. Analysis of association degree of logistics index system of garden fruit cold chain of fruit

It can be seen from Table 2 that there are 13 quantitative indicators, of which are 12 independent variables, and y is dependent variables. Considering the different influence of the factors on the logistics demand in the garden fruit cold chain in Hunan Province, the relationship between the 12 independent variables and the dependent variable is different. Therefore, it is necessary to analyze the association degree of these quantitative indexes which affect the logistics demand of the

cold chain of garden fruits, and then the association degree between the 12 independent variables and the dependent variable can be obtained.

At present, many methods are used to analyze the association degree. Considering the correlation and timing between the two systems, and the complexity and interlacing of the relationship between the logistics demand of the cold chain and the related economic indicators, this paper will use the gray relational degree model to quantitatively analyze the relationship between the index system and the cold chain logistics of garden fruits. The association degrees between the 12 independent variables and the dependent variable can be obtained [12], as shown in the Table 3.

Table 1. Indexes for logistics demand forecast of garden fruit

Primary Index	Secondary Index	No.	Third-level Index	Unit
Logistics demand of cold chain of garden fruit in Hunan	Supply	X1	Fruit yield	ten thousand tons
		X2	Planting area	thousand hectares
		X3	Total value of out-put	ten thousand yuan
	Demand	X4	Consumption of fruit	ten thousand tons
		X5	Retail price index of fruit	%
		X6	Disposable income of residents	yuan
	Transportation	X7	Road mileage	kilometer
		X8	Railway operating mileage	kilometer
		X9	Highway freight volume	ten thousand tons
		X10	Proportion of logistics to GDP	%
	Construction Level	X11	Flow rate of cold chain	%
		X12	Investment in fixed assets	100 million yuan

Table 2. Forecast data of garden fruit cold chain logistics demand over the years

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	Y
2006	203.6	450.6	212667	238.9	102.2	6203	171848	2806	72457	18.5	4	396.9	36.9
2007	228.2	480.8	475962	242.2	117.9	7255	175415	2779	85432	18.4	4.5	551.61	42.5
2008	229.0	430.8	591540	230	102.2	8349	184568	2795	92148	18.2	4.6	775.92	46.7
2009	250.9	469.2	673791	240.2	107.1	9098	191405	2894.8	111351	18.1	4.9	1024.94	49.1
2010	261.4	519.7	1067748	245.1	114.3	11825	227998	3695	127635	17.8	5	1273.96	55.4
2011	281.3	537.1	1160152	244.1	115.9	13403	232190	3693	144241	17.8	5.6	1267.65	63.7
2012	325.0	546	1587014	267.6	99.7	14609	234051	3825	166670	17.9	6.2	1313.21	86.4
2013	280.7	583.9	1656663	272.2	106	16004.9	235396	4038	185073.2	18	6.5	1474.93	82.5
2014	294.2	563.9	1756311	279.6	114	17621.7	236250	4532	172612.7	16.6	7	1681.03	96.1
2015	309.1	533.1	1823316	288.3	97.4	19317.5	236886	4521	184830.9	16.3	7.2	2076.37	113
2016	336.6	538.9	2011023	305.2	98.3	21115	238142	4716	192039.3	16	7.9	2242.7	138.4

Table 3. Association degree

Variables	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
γ_{ij}	0.789	0.675	0.762	0.853	0.566	0.843	0.701	0.814	0.750	0.463	0.857	0.831

From the above table, we can see that the total logistics demand of cold chain are highly associated with the flow rate of cold chain x11 and the consumption of fruit x4. The the association degrees are 0.857 and 0.853, respectively. The residents' disposable income x6, fixed assets input x12, railway operating mileage x8, fruit output x1, total output value x3, highway freight volume x9, road mileage x7 and fruit planting area x2 are highli associated with the total demand for garden fruit cold chain logistics. The price index x5 is weakly associated with the proportion of the logistics to the total GDP x4 and the logistics demand of the cold chain of Hunan province compared with other indexes, even though the

association degree has been regarded as moderate.

IV. PREDICTION MODEL CONSTRUCTION OF THE GARDEN FRUIT COLD CHAIN LOGISTICS DEMAND IN HUNAN PROVINCE BASED ON COGNITIVE NEUROSCIENCE

Cognitive neuroscience is a discipline that uses neuroscience to study cognitive processes [13-16], including social cognition, decision-making, evolution, and some neuroimmunological and cognitive related research directions [17]. Based on the learning environment of neurons, gray neural network is used to study the prediction of cold chain logistics demand in Hunan province.

A. Validity test of gray prediction model

Gray prediction model is mainly used to predict independent variables [18-23]. Taking into account the number of independent variables, this paper takes the output of garden fruits in Hunan Province as an example to verify the gray prediction model. The training sample is the per capita GDP of Hunan province in 2006-2013. The test sample of forecast is the fruit yield in Hunan province in 2014-2016. The comparison of the forecast results of 2014-2016 output by the MTALAB gray model [24], the actual data is shown in Table 4:

Table 4. Gray forecast model results

Year	Forecast value (ten thousand tons)	Actual value (ten thousand tons)	Relative error %
2014	306.8	294.2	4.30%
2015	319.2	309.1	3.28%
2016	332.1	336.6	-1.33%

The above table shows that the relative error between the predicted value and the actual value is within 5%, and the error is within the acceptable range, so it is effective to predict the independent variable by using the gray prediction model. Therefore, this model can be used to predict the development of the impact factors of the logistics demand forecast of the cold chain in Hunan province for the next five years (Tables 5-8).

Table 5. Gray prediction results of independent variables

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
2017	345.6	584.9	2540300	303.8	100.3	24395	259420	5190.9	225310	16.2	8.4	2565.4
2018	359.5	597.7	2900700	312.5	99.1	27262	267660	5522.7	244760	15.9	8.9	2907.5
2019	374.1	610.8	3312200	321.5	97.9	30465	276170	5875.7	265900	15.7	9.6	3295.3
2020	389.2	624.2	3782200	330.8	96.7	34046	284940	6251.3	288870	15.5	10.3	3734.8
2021	404.9	637.8	4318800	340.4	95.6	38047	294000	6650.9	313820	15.3	10.9	4232.8

B. Validity test of gray neural network model

The predictions on the logistics demand of the cold chain in 2006-2014 and its influencing factors were selected as the training samples; the predictions on the logistics demand of the cold chain in 2013-2014 was chosen as the verifying sample; the predictions on the logistics demand of the cold chain in 2015-2016 was the test sample. Based on the training samples, verifying samples and test samples, relevant statistics of 2006-2016 were taken to build a BP neural network model containing two hidden layers [25], and MSE (Mean Square Error) was used to measure the training error, MSE is mean square error. The training process and the fitting results are shown in Figures 1-3.

Fig. 2 Gray neural network training diagram
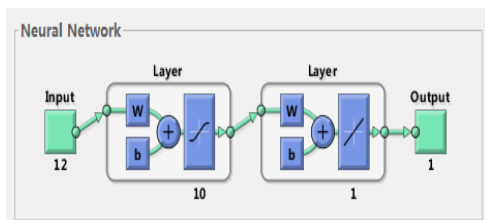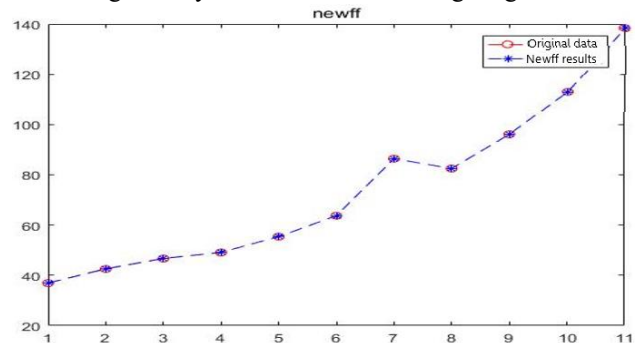

Fig. 3 Gray neural network fitting diagram

Fig. 1 Schematic diagram of BP neural network element model

The transfer function of the first hidden layer is set to be Tansig function. The number of neurons is set to be 10. The transfer function of the second hidden layer is set to be purelin function, and the number of neurons is set to be 1. The number of iterations and the accuracy of the operation are reduced to the lowest, and the error of the fitting has been reduced to 0.01 through 147 iterations. Therefore, the gray neural network has been basically fitted [26], and the numbers of the training samples, verifying samples and the testing samples as well as the error statistics are:
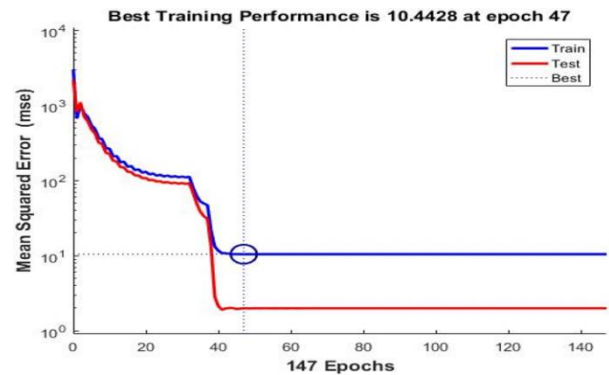
Table 6. Error prediction of neural network prediction model

	Number of samples	MSE
Training	7	3.443
Verifying	2	0.235
Testing	2	1.995

On this basis, the verifying results of the 2013-2014, the testing results of 2015-2016 and the actual values are compared.

Table 7. Comparison between training results and actual values of neural network prediction models

Year	Training results	Actual values	Errors
2013	82.1	82.5	-0.48%
2014	95.5	96.1	-0.62%
2015	114.2	113	1.06%
2016	140.7	138.4	1.67%

According to the above table, the error of the training and test samples are both within 2%, the error is within the acceptable range, and the accuracy is higher than that of a single gray prediction model.

C. Gray neural network prediction model

According to the previous analysis, the effect of the gray neural network prediction model has been verified, therefore, the logistics demand of garden fruits cold chain in Hunan province of the next five years can be predicted by the gray neural network prediction model. The forecast results are as follows:

Table 8. Forecast of total garden fruit cold chain logistics demand in Hunan province

Year	Total Garden Fruit Cold Chain Logistics Demand in Hunan Province Y (100 million)
2017	151.1
2018	173.2
2019	198.7
2020	227.9
2021	261.4

D. Suggestions on the development of the garden fruit cold chain logistics in Hunan province

According to the previous prediction results, the logistics demand of the garden fruit cold chain will show an upward trend in the next five years, which puts higher development requirements for the cold chain logistics. Based on the analysis of the factors affecting the logistics demand, suggestions are listed as follows:

(1) Increase investment in the facilities of garden fruit cold chain logistics

According to the previous analysis of the correlations between the 12 factors and the total logistics demand of the cold chain, the flow rate x_{11} is of the highest correlation with the total demand, and the correlation degree was 0.857. Moreover, fixed assets investment x_{12} was highly associated with the total demand, which ranks the third. Therefore, the construction of cold chain logistics plays a vital role in the development of garden fruit cold chain logistics in Hunan province.

Based on the degree of relevance of the above indicators and combined with the problems existing in the cold chain logistics of forest and fruit in Hunan Province, the following suggestions are made:

First, increase the construction of refrigerated warehouses in production areas. Starting from the source, build cold storage in the fruit production areas, taking into account that the main fruit planting areas in Hunan Province are Taoyuan County, Shimen County, Yongxing County, Mayang Autonomous County, Qiyang County, and Yongshun County. Therefore, relying on the above six forest and fruit production areas to build a cold storage in the local area, and build a single-storey fresh-keeping cold storage warehouse. In addition, some processing places need to be planned in the cold storage warehouse for pre-cooling and preliminary processing of forest fruits.

Second, increase capital investment in distribution centers on cold chain logistics nodes. On the one hand, focus on improving the cold chain warehousing system, and build a batch of low-temperature distribution and processing centers for forest and fruit on the cold chain logistics nodes; on the other hand, accelerate the construction of the cold chain transportation system and vigorously develop third-party and fourth-party cold-chain logistics enterprises , Encourage and support third-party and fourth-party logistics enterprises to increase investment in the purchase of refrigerated transport vehicles, and encourage enterprises to upgrade and transform existing cold-chain vehicles.

Third, build a forest and fruit cold chain logistics information sharing platform. Using the "Internet +" thinking, with the help of advanced logistics technologies such as big data and cloud computing technology, GIS/GPS technology, and RFID technology, build a multi-channel, multi-level, and wide-coverage forest and fruit cold chain logistics information sharing platform. The forest fruit cold chain logistics information platform mainly includes three functional modules: forest fruit cold chain logistics information interaction platform, forest fruit cold chain logistics operation process platform and external interface management. Relying on the Linguo cold chain logistics information exchange platform, it realizes the sharing of information on the supply and demand of the forest and fruit between the "fruit purchaser and the forest and fruit retailer". Tracking the whole process from orchard to table; relying on the forest fruit cold chain logistics operation process platform, realize the sharing of vehicle information, warehousing information and location information of "forest fruit purchasers, logistics providers and forest fruit retailers" to promote resources Efficient use and reasonable configuration.

(2) Strengthen the construction of transportation infrastructure between the fruit producing areas and the consuming areas

By consulting relevant literatures and statistical yearbooks, the garden fruit producers are distributed in Huaihua, Yongzhou, Xiangxi Autonomous Prefecture, Chenzhou, Changde, Shaoyang and other hilly areas, accounting for nearly 58.44% of the total area of Hunan Province. However, the transportation infrastructure in these areas is relatively weak. The proportion of road total mileage and highway mileage to the total road mileage and highway mileage in the province are 49.4% and 50.4% respectively. The total highway mileage per unit area and the highway mileage are 0.95 and 0.023 respectively. Compared with 1.36 and 0.054 of Chang-zhu-tan area, there is a big gap. Therefore, first, increase the investment in the construction of transportation infrastructure between the

producers and the markets, especially to increase the investment in the highway construction connecting them so that to ensure the smooth and rapid transportation of the fruit from the farmers to the markets. In this way, cases of unsalable fruits such as the Xiangxi's citrus can be reduced. Second, strengthen the construction of the expressways around the distribution center, rely on which, develop a garden fruit supply chain which integrates fruit packaging, transportation and sales, and thus form a batch of cold chain logistics bases covering a wide range with strong processing capacities.

(3) Policy improvement and cold chain standardization

Considering that the investment in infrastructure construction of cold chain logistics has the characteristics of long cycle and large scale, support from the government departments and industries including funds and policies are in needed. Specifically, first, preferential policies of garden fruit cold chain logistics should be promoted including reducing tax and fees, implementing land concessions, improving the financing environment of enterprises and other measures to reduce the operational pressure of enterprises. Second, promote the standardization of garden fruit cold chain logistics. Standards for storage temperature, transportation, packaging, packaging materials and quality testing should be carried out and the state ensured to be implemented with strict professional certification system and market access system.

(4) Promote co-ordinate development of production, learning and research through joint efforts of enterprises and the universities

Since the fresh fruits have short preservation time and are prone to be rot, the co-ordinate development of the production, learning and the research brooks no delay. According to the needs of users, relying on the university resources in the province to set up a special project group, insulation system, transportation route and storage strategy should be formulated to reduce the traditional circulation from production to consumption as much as possible, and thus to establish a sound, efficient and coherent logistics network. Only in this way can the fresh fruits and vegetables be quickly and safely transferred in to the final consumption link so that to benefit the end-users. Promote the development of the cold chain logistics industry association and erect a bridge of communication between enterprises and government through the combination of production, learning and research. Reduce vicious competitions in the industry and other bad phenomena by formulating corresponding standards for cold chain logistics market.

V. CONCLUSION

Through the research of this article, it provides data support for the construction of forest and fruit cold chain logistics in Hunan Province, so as to accelerate the high-quality development of cold chain logistics, and also provide reference for the development of cold chain logistics in other regions.

This article also has certain shortcomings, such as the extensiveness of data to be strengthened, and the selection of quantitative and qualitative index systems can be further improved. Therefore, in future research, we will focus on improving these two aspects to ensure higher prediction accuracy.

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