

Cold Chain Logistics Demand Forecasting for Fresh Agricultural Foods in Fujian Province, China

Yuanyuan Chen¹, Mohammad Affendy Arip² and Nor Afiza Abu Bakar³

Abstract

China's current cold chain infrastructure for fresh agricultural products faces numerous challenges, particularly within the context of Fujian Province. The cold chain logistics sector in the region is characterized by limited development and requires immediate improvements in its foundational supporting infrastructure. The establishment of a comprehensive cold chain logistics system tailored for fresh agricultural goods remains incomplete, resulting in inefficiencies within the supply network. An in-depth examination of the necessity for refrigerated transportation networks for fresh agricultural products through scientific inquiry reveals the potential for strategic investments in the industry. To address this gap, a study employing the GM (1,1) model is conducted to forecast the future demand for cold chain logistics in fresh agricultural items specifically within Fujian Province, China, over the next five years. The findings of the study indicate that by 2027, the demand for cold chain logistics services for fresh produce in Fujian Province is projected to reach 4765.6 million tons. These insights furnish valuable information for optimizing investment planning in cold chain logistics infrastructure and formulating pertinent legislative measures to stimulate industry growth. In summary, the integration of these findings into the context of Fujian Province underscores the significance of enhancing cold chain logistics capabilities to address existing challenges and capitalize on future opportunities within the region's fresh agricultural sector.

Keywords: Fresh Agricultural Foods, Cold Chain Logistics, Forecast, Demand, GM (1,1) Model, Fu Jian

INTRODUCTION

Agricultural items that are fresh are highly susceptible to time and temperature (Han et al., 2021b). When the temperature circumstances are not appropriate, microbes or mold can undergo biochemical processes, leading to rapid food spoilage and impacting people's ability to consume it normally (Preetha & Narayanan, 2020). The preservation of fresh agricultural foods relies on cold chain logistics, which effectively inhibits the growth of germs or molds in raw agricultural items, resulting in reduced loss and long-term preservation (Giannakourou & Tsironi, 2021). Fujian Province, as one of the significant agricultural production regions in China, has consistently witnessed a robust demand for cold chain logistics in the fresh agricultural food sector. However, inadequate handling during transportation and deficiencies in the cold chain process have led to substantial losses of fresh agricultural foods during transit, posing considerable challenges to the supply chain. Therefore, it is imperative to scientifically and reasonably forecast the demand for cold chain logistics in Fujian Province's fresh agricultural food sector and implement effective measures to address this issue (He & Yin, 2021).

LITERATURE REVIEW

Types of Fresh Agricultural Foods

Sun (2021) proposed specific categories of fresh agricultural items suitable for research, including fruits, vegetables, meat and poultry, eggs, milk, and aquatic foods. Wang (2017) selected five distinct categories, comprising fresh fruits and vegetables, aquatic foods, meat foods, poultry and egg foods, and dairy foods, as representative of the sector. Li (2022) classified fresh agricultural items into six key groups while examining cold chain logistics requirements during the COVID-19 pandemic: fresh vegetables, aquatic foods, fruits, poultry and egg foods, meat foods, and dairy foods. Kasza et al. (2024) conducted a study on fresh agricultural items, focusing specifically on vegetables, fruits, meat and poultry, egg foods, dairy foods, and aquatic foods.

¹ Faculty of Economics and Business, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia. Fujian Business University, 350012, Fu Zhou, Fu Jian, China.

² Faculty of Economics and Business, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia

³ Faculty of Economics and Business, Universiti Malaysia Sarawak, 94300, Kota Samarahan, Sarawak, Malaysia E-mail: 21010347@siswa.unimas.my

Zhou & Zeng (2023) specifically investigated the prediction of cold chain logistics demand for fresh agricultural items in Jiujiang City, located in Jiangxi Province. They specifically included fruits, seafood, vegetables, and meat as fresh agricultural foods. In Meishan City, Zhou et al. (2023) identified four categories of agricultural items—vegetables, aquatic foods, meat, and fruits—to be used as indicators for predicting cold chain logistics, based on the specific requirements of cold chain logistics in the city and the availability of relevant data.

Aligning with the scholarly classification framework for fresh agricultural foods, and aiming to ensure the comprehensiveness and precision of the research outcomes, this study categorizes fresh agricultural foods into six distinct groups: fruits, vegetables, meat, aquatic foods, eggs, and dairy foods.

Measurement Indicators for Cold Chain Logistics of Fresh Agricultural Foods

Wang (2017b) stated that some parts of the fresh product distribution chain lack cold chain facilities. Nevertheless, the development history of industrialized countries indicated that the future market trend was moving towards the widespread implementation of cold chain logistics. The China Cold Chain Logistics Development Report (2010) highlighted the necessity of doing a more thorough evaluation of the total demand for cold chain logistics. The proposal suggested including the overall output of refrigerated commodities, such as meat, seafood, frozen pasta, fruits, vegetables, milk, and other perishable things, as a determinant of cold chain logistics transportation. Zhang (2020) conducted a study on demand forecasting for cold chain logistics in Hebei Province. The total demand for cold chain logistics for fresh agricultural foods was calculated based on the combined production of vegetables, fruits, meat, poultry, eggs, milk, aquatic goods, and other perishable foods that need cold chain transportation. Zeng and Zhu (2022) created a Gray GM (1,1) model to forecast the future demand for cold chain logistics of agricultural foods in Hunan Province. The researchers used historical data on the output of fresh agricultural goods in Hunan Province from 2010 to 2021 as input for their model. The projection covers the period from 2022 to 2026. The study selects the production of newly harvested agricultural items as the dependent variable.

Reviews on the Demand Forecasting Method

Wang and Yan (2018) employed a variety of quantitative techniques, including neural network models, GM (1,1) models, and other methodologies, to assess China's logistics demand. Their study revealed the advantages of the Gray model, such as independence from assumptions regarding data statistical features, absence of sample size limitations, and high prediction accuracy. The Gray model, being a univariate model, relies solely on information from the dependent variable during the modeling process. Describing the influence of additional factors on the need for cold chain logistics in the agricultural goods system poses a challenge. While the neural network approach yields highly accurate predictions, its performance becomes erratic with limited datasets.

Yang et al. (2021) applied the Gray model and the exponential smoothing model to develop a combined logistics demand forecast model. Zhou et al. (2021) utilized a genetic algorithm and support vector regression machine to forecast logistics demand in specific regions. Li (2017) utilized the GM (1,1) Gray forecasting model to predict the demand for cold chain logistics of fresh agricultural foods in Chongqing. This study provided a scientific basis for determining the requirement for cold chain facilities and equipment in the logistics of fresh agricultural foods. Li(2022b) utilized Gray correlation analysis to establish a demand forecasting index system for cold chain logistics of fresh agricultural foods in Guangdong Province. Subsequently, a Gray GM (1, N) model was developed to forecast cold chain logistics demand for fresh agricultural foods in Guangdong Province, with the model's validity confirmed.

Various scholars employ distinct forecasting methodologies to predict demand. This study adopts the GM (1,1) model to forecast the demand for cold chain logistics concerning fresh agricultural items of Fu Jian province.

METHODS

GM (1, 1) Model

The Grey Model GM (1, 1) is a specialized type of grey system model used for predicting time series data with limited observations. It is particularly suitable for situations where the data lacks sufficient prior information to

utilize more complex forecasting algorithms. The model aims to generate forecasts by considering the underlying growth pattern and the initial value of the time series data.

Here's the basic formulae for the GM (1,1) model:

Let $Q_{FAP}^{(0)} = \{Q_{FAP}^{(0)}(i), i = 1, 2, \dots, n\}$ be the original time series data, Where $Q_{FAP}^{(0)}$ represent the original values.

Perform the Accumulated Generating Operation (AGO) on the original data to obtain the accumulated series $Q_{FAP}^{(1)}$:

$Q_{FAP}^{(1)} = \{Q_{FAP}^{(1)}(k), k = 1, 2, \dots, n\}$	(1)
$Q_{FAP}^{(1)}(k) = \sum_{i=1}^k Q_{FAP}^{(0)}(i), k = 1, 2, \dots, n$	(2)

Calculate the first-difference series $Q_{FAP}^{(1)}$ to obtain $\Delta Q_{FAP}^{(1)}$:

$\Delta Q_{FAP}^{(1)}(k) = Q_{FAP}^{(1)}(k) - Q_{FAP}^{(1)}(k - 1)$	(3)
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The first-order differential equation for GM (1, 1) is:

$\Delta Q_{FAP}^{(1)}(k) + a * Q_{FAP}^{(1)}(k) = u$	(4)
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Where:

a and u are constants, and a represents the development coefficient and u represents the influence degree of the initial value.

The solution of the differential equation is given by:

$\Delta Q_{FAP}^{(1)}(k) = \frac{u}{a} + (x^{(1)}(1) - \frac{u}{a}) \cdot e^{-a \cdot (k-1)}$	(5)
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After obtaining $Q_{FAP}^{(1)}(k)$, you can reconstruct the forecasted values for the original series $Q_{FAP}^{(0)}$:

$\hat{Q}_{FAP}^{(0)}(k) = Q_{FAP}^{(1)}(k) - Q_{FAP}^{(1)}(k - 1)$	(6)
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These forecasted values $\hat{Q}_{FAP}^{(0)}(k)$ represent the predicted values for the future data points.

Forecast Accuracy Test

Huo (2014) utilized both the mean square ratio and small error probability as metrics to assess the accuracy of forecasting the demand for aquatic foods in cold chain logistics. The study concluded that the forecasting accuracy was satisfactory. According to Zhang (2021), the accuracy of forecasting the demand for fresh

agricultural items in the cold chain logistics in Chongqing city was assessed using the mean square ratio and small error probability. When the mean square ratio falls below 0.35, it signifies a high prediction accuracy and good reliability of the forecasted results. To ensure a standardized measure, this study incorporates the mean square error ratio to evaluate the model’s accuracy.

$e(i) = Q_{FAPi} - \hat{Q}_{FAPi}$	(7)
$\bar{e} = \frac{1}{n} \sum_{i=1}^n e(i)$	(8)
$S_1 = \sqrt{\frac{1}{n} \sum_{i=1}^n (Q_{FAPi} - \overline{Q_{FAP}})^2}$	(9)
$S_2 = \sqrt{\frac{1}{n} \sum_{i=1}^n (e(i) - \bar{e})^2}$	(10)
$C = \frac{S_2}{S_1}$	(11)

Where: $e(i)$ is the residual; \bar{e} is the mean value of residuals; S_1 is standard deviation of the true dependent variable data; S_2 is standard deviation of forecasting error; C is mean square error ratio.

RESULTS ANALYSIS

This section aims to anticipate the demand for cold chain logistics for fresh agricultural foods in Fu Jian province from 2023 to 2027. The purpose is to enhance the fulfilment of Fu Jian’s development goal in the field of cold chain logistics. *OV* stands for the original value, and *FV* stands for the forecasted value, $e(i)$ stands for residuals, C stands for mean square error ratio.

Table 2. Results of the Demand for Fresh Agricultural Foods Cold Chain Logistics in Fu Jian Province (Unit: 10,000 tons)

Year	<i>OV</i>	<i>FV</i>	$e(i)$	C
2015	2993.4	2993.4	0	0.0008
2016	3003.5	3008.9	5.4	-
2017	3129.1	3137.4	8.3	-
2018	3274.2	3271.3	2.9	-
2019	3430.7	3411.0	19.8	-
2020	3557.7	3556.6	1.1	-
2021	3711.7	3708.4	3.3	-
2022	3856.9	3866.7	9.8	-
2023	-	4031.8	-	-
2024	-	4203.9	-	-
2025	-	4383.3	-	-
2026	-	4570.5	-	-
2027	-	4765.6	-	-

Table 2 presents the cold chain logistics demand for raw fresh produce in Fu Jian province from 2015 to 2022, as well as the projected demand for the years 2023–2027. It also includes the residuals and the mean square error ratio. Upon analyzing the findings, it is found that all values of the C are below 0.35. This indicates a high level of forecasting accuracy, and the forecasting results fulfil the specified standards.

CONCLUSION

This study forecasted the future demand for cold chain logistics in the fresh produce industry over the next five years in Fujian province of China. In 2027, the demand for cold chain logistics for fresh produce in Fujian province is projected to reach 4765.6 million tons.

Amidst the surging demand for cold chain logistics within Fujian Province's fresh agricultural foods industry, there arises a pressing imperative to fortify the construction and upkeep of cold chain facilities. This imperative underscores the crucial need to not only establish, upgrade, and maintain modern refrigeration and freezing facilities at key points such as production bases, logistics nodes, and sales terminals but also across the entire expanse of the supply chain network. These facilities must not only conform to the latest standards but also adapt and evolve in tandem with the dynamic market demands, while embracing emerging cold chain technologies. To effectively meet the diverse requirements inherent in transporting various types of fresh agricultural foods, a comprehensive optimization of cold chain logistics transport networks and technologies emerges as paramount. This optimization encompasses not only the refinement of transportation route planning but also the enhancement of the insulation performance of transport vehicles and the integration of intelligent transport monitoring systems. Through the adoption of technologies such as the Internet of Things (IoT), big data analytics, and artificial intelligence (AI), the cold chain logistics sector stands poised to realize heightened efficiency, cost reduction, and the preservation of the integrity of perishable goods throughout their journey. Furthermore, the establishment of robust management and monitoring mechanisms assumes utmost importance in safeguarding the quality and safety of fresh agricultural foods during transportation. The implementation of a sophisticated temperature and humidity monitoring system capable of continuous surveillance of critical parameters becomes indispensable for the timely identification and resolution of transportation-related issues.

The cultivation and retention of a highly skilled and adaptable workforce stand as imperative pillars for fostering the sustainable development and resilience of the cold chain logistics industry. In light of this, it is paramount to channel concerted efforts towards the holistic nurturing of talent, encompassing multifaceted strategies aimed at honing expertise and fostering professional growth.

Central to this endeavor is the provision of a robust framework of educational opportunities tailored to the specific demands of the cold chain logistics domain. This entails not only the establishment of comprehensive academic courses but also the facilitation of specialized training programs meticulously designed to impart requisite knowledge and cultivate practical skills. Moreover, the creation of internship and training bases serves as pivotal platforms for aspiring professionals to gain hands-on experience and refine their capabilities under real-world operational scenarios. Concurrently, proactive initiatives targeting the attraction of outstanding talents to the cold chain logistics sector are essential for augmenting the overall caliber and competitiveness of industry professionals. By strategically positioning the industry as an appealing career destination, efforts can be directed towards enticing individuals possessing exceptional aptitude and innovative prowess. Such endeavors encompass a spectrum of endeavors, ranging from targeted recruitment drives to incentive programs designed to incentivize top-tier talent to venture into the realm of cold chain logistics. In essence, the expansion and fortification of the cold chain logistics workforce mandate a comprehensive approach integrating education, training, and talent acquisition initiatives. By nurturing a cadre of skilled professionals equipped with cutting-edge knowledge and practical acumen, the industry can fortify its foundations and propel sustainable growth amidst evolving challenges and opportunities.

Moreover, fostering collaborative endeavors among governmental bodies, private enterprises, and academic research institutions emerges as an indispensable imperative for catalyzing the advancement of cold chain logistics infrastructure. The orchestration of synergistic partnerships and the cultivation of robust collaboration mechanisms serve as foundational pillars upon which stakeholders can collectively navigate the intricacies of the industry landscape, surmounting challenges and seizing emergent opportunities with concerted vigor. Central to this collaborative ethos is the establishment of strategic alliances within and beyond the confines of the cold chain logistics sector. By fostering symbiotic relationships among diverse stakeholders, avenues for seamless resource sharing and knowledge exchange are unlocked, laying the groundwork for enhanced

operational efficiencies and amplified innovation. Moreover, the cultivation of cross-sectoral partnerships serves to broaden the spectrum of expertise and perspectives brought to bear on industry challenges, engendering a fertile environment for transformative breakthroughs. In parallel, concerted efforts to incentivize private enterprises to invest in research endeavors and the application of cutting-edge cold chain logistics technologies constitute a linchpin in propelling the industry towards sustained growth and resilience. Leveraging a multifaceted toolkit of incentives, ranging from fiscal incentives to regulatory frameworks conducive to innovation, stakeholders can galvanize corporate investment in pioneering research initiatives and the deployment of state-of-the-art technological solutions. Such proactive measures not only catalyze continuous innovation within the sector but also imbue it with the dynamism and adaptability requisite for navigating evolving market dynamics and consumer demands.

In essence, through concerted efforts, industry collaboration, and technological innovation, the fresh agricultural foods cold chain logistics industry in Fujian Province can chart a course towards robust development, ensuring the seamless transportation and preservation of perishable goods while meeting the evolving demands of consumers and markets alike.

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