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Research Article

The Redesign of Logistics Network of Fresh Fruit in Guangxi Province of China

Liurong Pan [1,2*], Boonsub Panichakarn [3], Melvin Esmayor Garin [4]

[1] Associate Professor, College of Economics and Management, Beibu Gulf University, Qinzhou, China
[2] Ph.D candidate, Faculty of Logistics and Digital Supply Chain, Naresuan University, Phitsanulok, Thailand
[3] Doctor, Faculty of Logistics and Digital Supply Chain, Naresuan University, Phitsanulok, Thailand
[4] Lecturer, Faculty of Logistics and Digital Supply Chain, Naresuan University, Phitsanulok, Thailand
* **Corresponding Author:** panl61@nu.ac.th

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ABSTRACT

This study aims to investigate the distribution characteristics of China's agricultural industry and its logistics network design. The study is based on the theory and method of hub-and-spoke logistics network design, takes the logistics of agricultural products in China as the research area, and focuses on the fresh fruit industry. The specific case study took the fruit industry in Guangxi Province as an object and analyzed the overall spatial distribution from 2014 to 2022. By considering the factors of economic development, logistics development and fruit industry development, 11 indicators were selected to construct a comprehensive evaluation index system of logistics-level node cities within the logistics network. This index system aims to provide a holistic assessment of the logistics capabilities of these cities. The hub cities and spoke cities of the fresh fruit industry logistics network were determined by cluster analysis based on factor analysis. The cities are identified using the gravitational model and the logistics affiliation degree. As a result, a hub-and-spoke logistics network for the fresh fruit industry is centered on Nanning, Liuzhou and Guilin, which are designated as the key hub cities. Yulin, Qinzhou, Guigang and Baise are the secondary spoke nodes, while Beihai, Wuzhou, Chongzuo, Fangchenggang, Hezhou, Laibin and Hechi are the tertiary and quaternary spoke nodes. In order to better develop the fresh fruit industry in Guangxi, proposals are made to guide the layout of the fruit industry, improve the logistics infrastructure in the node cities, and ensure the quality of fruit transportation.

Keywords: Fresh Fruit, Logistics Network Redesign, Guangxi, China.

INTRODUCTION

The production and export of fresh fruits from China have increased tremendously over the past few years (Kubo, Pritchard, & Phyo, 2021), considering the high demand for fruits globally in recent times by consumers (Zhao, Gao, Wu, Wang, & Zhu, 2014).

Furthermore, following the advancement of science and technology and China's continuous attention to agricultural development, the country's agricultural economic growth model has undergone great transformation, and is gradually moving in the direction of intensification, mechanization and intelligence. China is moving towards becoming an agricultural power, and the development of agricultural logistics is inseparable from the process of promoting the optimization of the industrial structure of agricultural products (Jiani Wu & Haasis, 2018). The logistics and distribution of fresh agricultural products are particularly important in agricultural logistics, which exhibit corrosive characteristics in food transportation and require the right temperature for storage (X. Liu, 2014). In view of this, and considering the logistics network design of agricultural products, it is important to comprehensively analyze the spatial distribution characteristics of production and reasonably construct an evaluation index system to obtain the most efficient logistics distribution network of fresh fruit in Guangxi province of China. It has also been reported that in the era of rapid economic development, high-quality logistics development plays an essential role in high-quality economic development (Pulina & Timpanaro, 2012). Thus, major agricultural production provinces must enhance the construction of agricultural product logistics backbone networks alongside cold chain logistics systems. The Chinese government has also been urged to focus on creating sustainable agricultural product logistics network systems (Vilas-Boas, Rodrigues, & Alberti, 2022).

In this research, we found that Guangxi, which is located in the southwest of China, is the largest fruit production area in China, and geographically connects with Southeast Asian countries, with natural fruit logistics and distribution advantages (Guo, Xiong, Li, Fan & Shen, 2022). The fruit industry is the leading agricultural industry in Guangxi, with unique advantages and characteristics, making it crucial for the local economy to thrive (Y. Chen & Manchester, 2015). The local and central governments of China therefore consider the fresh fruit industry an essential development direction towards promoting agricultural modernization (Roi, You, Nguyen, & Kim, 2023). The quality and yield of fruits are continuously improved by introducing new varieties and improving technology, thereby expanding the agricultural industry and improving farmers' income. In 2022, the orchard's region surpassed 2 million hectares, while its fruit production reached 30.8 million tons, maintaining its position as the country's top producer for five consecutive years (Ma et al., 2017). Tangerine production, for instance, accounted for one-tenth of the global tangerine production, and the total value of fresh fruit production exceeded 170 billion yuan, thereby consolidating the fresh fruit industry base worth 100 billion yuan (China National Bureau of Statistics, 2023).

Nevertheless, since the primary fresh fruit suppliers in the region are predominantly individual farmers, and considering the unique challenges in fresh fruit logistics, significant attention must be directed toward effective preservation. Ensure fruit transportation quality, requires short transportation times, few transfers, and protection from high temperatures. However, the transportation and logistics of fresh agricultural products in Guangxi still rely on traditional transportation methods and lack professional transportation, logistics systems and modern warehousing.

This deficiency tends to adversely affect the storage and preservation of fresh agricultural products during transportation. Furthermore, there are challenges such as weak logistics infrastructure construction, poor logistics informatization, and a shortage of experts in the logistics industry (H. Huang, 2023). All these issues have confined the development of the fruit industry. Moreover, the efficiency of fresh fruit logistics will directly affect the quality of residents' lives and the regular operation of cities (Xie, 2022). The current distribution of fruit in Guangxi cannot deliver a wide variety of high-yielding fruits to consumers as quickly as possible. Therefore, an efficient fruit logistics network needs to be designed to boost the effectiveness of fresh fruit logistics, enhance the professionalism of fresh fruit logistics enterprises, and lift the level of fresh fruit logistics services provided system, by simultaneously assisting fruit farmers in increasing their incomes to promote rural economic development and accelerate rural modernization (Z. Liu, 2015).

Generally, specific results have been attained in the research on constructing the agricultural product logistics network. International scholars focused on constructing the logistics network model considering different constraints and employed different algorithms for solution analysis, contributing to creating the agricultural logistics system and network planning. However, although the spatial distribution of the industry is a critical factor influencing the location of logistics network nodes, only a few scholars have combined the spatial pattern of the fruit industry with logistics network design (Jingqiong Wu, He, Su, & Deng, 2019). Therefore, it is crucial to design an efficient fruit industry logistics network based on the spatial distribution characteristics of the fruit industry. Relevant logistics network research shows that the axial-spoke network logistics model is an effective network structure that integrates logistics resources, improves the utilization rate of logistics resources, and reduces logistics costs.

Therefore, this paper combines the spatial distribution of the fruit industry in Guangxi Province to construct evaluation indicators, ranks logistics nodes in the Guangxi fruit industry logistics network using factor analysis and cluster analysis methods, and determines the radiation range and inter-node logistics channels of hub and node cities using gravity models and logistics affiliations, thus constructing a logistics network for the fresh fruit industry in Guangxi Province. In this study, the following are the research questions:

1. How can the characteristics of the current fresh fruit industry in the region be accurately analyzed?

2. How can the optimal core logistics nodes in a sustainable regional logistics network be found?

3. What determines the strength of the connection between the nodes of the logistics network?

4. How will the Hub-spoke logistics relationship between different nodes be determined?

The rest of the paper is organized as follows: Section 2 provides the background of this research work. The Principles of data acquisition, along with mathematical formulation, are given in Section 3. Section 4 presents the computational experiments, findings, and subsequent discussion, along with a delineation of managerial implications. Finally, in Section 5, we have concluded the whole work and some policy recommendations were made to stakeholders and government departments to effectively guide government planning and operations.

LITERATURE REVIEW

Regional Agricultural Product Logistics Network Models

The research on constructing the logistics network of fresh agricultural products focuses on the organizational model and network planning of the logistics network of fresh agricultural products, including network nodes, transportation, distribution, and network construction.

Regarding logistics network system construction, the research directions mainly include network model improvement and solution algorithm optimization. Among the studies performed by foreign scholars, Wang, Chen, Tang, and Liu (2017) summarized the factors influencing the perishability of agricultural products during the distribution process of agricultural products. He comprehensively examined the relationship between the degree of spoilage and distribution plans to minimize distribution costs and maximize the freshness of distributed products. Accordingly, he established a multi-objective network model. Amorim and Almada-Lobo (2014) and others studied the location of a single distribution center serving a limited number of sales outlets for perishable products. Drezner and Scott (2013) proposed a new MILP model and HOS method to identify the most cost-effective logistics network solution to meet the perishable products' quality requirements. De Keizer, Haijema, Bloemhof, and Van Der Vorst (2015) took Indonesia's packaged shipping connectivity as an example and evaluated the national logistics system using an integrated and efficient logistics network to minimize total transportation costs. Lazuardi, van Riessen, Achmadi, Hadi, and Mustakim (2017) introduced a new target function to evaluate elastic hub-and-spoke network designs with operational and interruption risks and effectively solved this complex multi-faceted problem using a mixed solution method. Zhalechian, Torabi, and Mohammadi (2018) found that optimal total cost of regional logistics and efficiency could be easily achieved when employing 4-5 hub nodes, which significantly contribute to the network's utility. Matsubayashi, Umezawa, Masuda, and Nishino (2018) verified vehicle allocation issues in hybrid hub-and-spoke networks with uncertain demand and found that the transportation route, quantity, and type of vehicles are vital factors in diminishing total transportation costs in hybrid hub-and-spoke networks. The Dantzig allocation method was also utilized to perform calculation case design. Choi, Lee, and Park (2018) hypothesized and combined the nodes of hub-and-spoke networks and conducted a comparative analysis of the corresponding resultant cost differences, expanding new ideas for network node selection research.

In China, some scholars have also attained some achievements in this area. Horner and O'Kelly (2019) explained the concept of international cold chain logistics for fresh agricultural products by summarizing the current state of international research in this area and verifying the composition of the operation process. Yu (2015) examined the paths for developing cross-border e-commerce of agricultural products and smart logistics and came up with some suggestions on the existing problems. M. Huang (2023) selected the node cities for agricultural product logistics centers in Shaanxi Province using a clustering analysis method, primarily analyzing the network operation model of agricultural product logistics in central node cities.

Related Theories of Hub and Spoke Logistics Networks

Regarding the research theory and method of the regional logistics network, the popular research is the hub-and-spoke logistics networks with a hub station as the core. The hub-and-spoke network structure is a network model similar to a "bicycle wheel", which is a spatial structure composed of a "hub" and "spokes". All supplies from each node should be transported to the hub first and then to the sites in demand through main-line transportation, creating a clustering effect. As a result, trunk line traffic has increased dramatically, and the advantages of scale economies can be realized, thereby alleviating network transportation costs, improving transportation efficiency, maximizing logistics resources utilization, and minimizing network operation costs. In the 1980s, researchers first introduced the concept of hub-and-spoke networks and designed and improved site selection and the P-Hub median model. O'Kelly (1987) pioneered the practical application of hub-and-spoke networks by designing them for truck and railway transport companies: Less Truck Loading (LTL) in Brazil, respectively. Cunha and Silva (2007) have established various hub location/node allocation models to minimize the total cost of network services. Campbell (1996) also established a hub-and-spoke network design model with unlimited and limited hub capacity using linear programming and mixed integer programming. Mayer and Wagner (2002) introduced a hybrid hub-and-spoke network design model with node interconnection. In the logistics industry, hub-and-spoke network structures were first successfully applied in United Parcel Service (UPS), establishing a hub-and-spoke delivery network. Moreover, logistics hub-and-spoke networks are employed in other industries, such as passenger transportation, air transportation, and shipping. Early algorithms were also widely utilized in this area.

The Fruit Industry from Logistics Perspective

Some Chinese scholars have studied the fruit industry from a logistics perspective. For example, Sung and Jin (2001) analyzed customer satisfaction based on fruit characteristics, with fruit freshness and delivery timeliness as the standard. Accordingly, they established a site selection-route optimization model based on graded customer satisfaction and designed a corresponding solution algorithm. Relying on the Internet, C. Chen, Tan, and Deng (2019) made suggestions to develop a rural fresh fruit logistics cold chain in line with the actual situation of rural production and transportation. P. Li (2018) utilized the Floyd algorithm. They considered the multimodal transport scheme under dynamic programming to optimize the transportation route by establishing a topological structure model of the logistics network of the origin. Kang et al. (2017) considered the economics of network transportation and performed detailed planning of the fruit logistics network. Gong and Qi (2012) performed a static analysis of the fruit development status of village market towns based on the four factors of production, industry formation, market operation, and external influence and constituted the evaluation index system of the development status of the fruit industry in the village by dividing the elements into 13 indicators and using AHP hierarchical comparison method for analysis and evaluation. Based on the experience of establishing multi-level logistics node layout models in different industries. Y. Li (2019) applied the optimization of multi-level logistics node layout to the logistics node layout of fresh fruits and vegetables. A mathematical model was established and the optimization problem of multi-level logistics node layout was solved by genetic algorithm. An empirical study was performed based on the production of fresh fruits and vegetables in X County and compared with the actual layout of Y company to verify the model optimization's efficiency. He (2023) established the logistics capability evaluation index system, employed the principal component analysis method to evaluate the districts and counties in southern Jiangxi, and selected several cities as the node cities of navel orange logistics. Then, he measured the spoke range of the logistics nodes to the surrounding navel orange production areas through the break-point model. He measured and compared the logistics cost of navel oranges in southern Jiangxi and verified the optimization effect of the logistics space layout after optimizing with the actual data.

METHODOLOGY

Data Collection

It is difficult to directly obtain detailed data such as categories, flows and flow directions of intercity logistics transportation in the region. Therefore, this study starts from the collection of basic logistics data at all levels, and processes the collected relevant data according to the research needs to obtain the kind of data suitable for the study.

Selection of logistics hubs and location. The logistics nodes are selected from 14 municipal-level administrative regions under the jurisdiction of Guangxi Province as logistics nodes, and according to the geographical information reality, each logistics node is located in the center of gravity of the region.

Node economic, logistics and fruit industry indicator data. According to the relevant data from "China Statistical Yearbook (2022)" and "Guangxi Statistical Yearbook (2022)", 11 important evaluation index data of 14 logistics network nodes in Guangxi Province in 2021 were collected and obtained.

The shortest road transport mileage uses the spherical distance between any two logistics nodes to represent the transportation distance between them. Road freight rate is measured by multiplying fuel consumption per kilometer by transportation distance plus highway fees between nodes. The shortest road transit time is measured by dividing the distance traveled by the maximum speed limit of the truck.

Factors including economy, society, and transportation should be considered when selecting logistics network nodes. Thus, the completeness of the index selection, the clarity of the meaning of the index, and the availability of data are utilized to balance the specificity and comprehensiveness of the urban capacity assessment. Based on the selection of the prior indicators, the evaluation index system of node importance of the fruit logistics network in Guangxi (**Table 1**) was established from three aspects: fruit industry status, urban economic level, and logistics level.

Table 1. Evaluation Index of Key Node of Logistics Network

Primary indicators	References	Secondary indicators	Third level indicators	Unit
Urban economic level	Cao, Yin, & Wang (2015); Yang (2022)	GDP	GDP (X1)	Billion
			GDP per capita (X2)	Yuan
		Consumption	Total retail sales of social consumer goods(X3)	Billion
		Investment in the fixed assets	Growth rate of total social fixed assets investment in the region(X4)	%
Logistics level	Ghaffari-Nasab, Ghazanfari, & Teimoury (2016)	Transportation convenience	Traffic mileage(X5)	KM
		Transportation development	Civilian automobile ownership(X6)	10,000 vehicles
			Number of people employed in transportation, transportation, storage, and postal services(X7)	10,000 people
		The size of the logistics market	Total postal business(X8)	Billion
			Express delivery business volume(X9)	10,000 pieces
Fruit industry status	Gong & Qi (2012); Orjuela Castro, Orejuela-Cabrera, & Adarme-Jaimes (2021)	The scale of the fruit industry	Orchard acreage(X10)	10,000 acres
			Fruit production(X11)	10,000 tons

Factor Analysis

Factor analysis is a multivariate statistical method employing a linear function of a few common factors and the sum of specific factors to represent each originally observed variable. Some complex variables are summarized into comprehensive factors by studying the dependencies within the correlation matrix. The basic idea is to employ a descending model to transform multiple indicators into a few comprehensive indicators. This paper employs the principal component analysis method to extract the mentioned factors, and the public factors can be expressed using a linear combination of the original variables. Second, the maximum orthogonal rotation of the variance is applied to the initial factor load matrix to achieve the definition of a common factor, the observed values of the variables are utilized to estimate the overall score of each factor, and further analysis and evaluation are performed to arrive at the corresponding conclusion:

The factor analysis method has three main characteristics: first, the limited number of factors that effectively reduced the workload of statistical analysis. Next, new factors reconstructed from the original variables can reflect most of the original information. Lastly, there is no linear correlation between factor variables. However, there is a high degree of linear correlation between the indicators that make up the factors, and each composite factor is highly representative. Therefore, it is scientifically reasonable to employ the factor analysis method to construct an index system for evaluating the fresh fruit flow development level in Guangxi.

Gravitational Model and Logistics Affiliation

The gravitational model is derived from the universal gravitational model of physics, which can measure the gravitational strength between cities. The basic formula is

$$I_{ij} = \frac{GMiMj}{d_{ij}^{r}} \tag{1}$$

where I_{ij} is the strength of attraction between study subjects; M_i and M_j are the "mass" of the study subjects; d_{ij} is the distance between study subjects; r is the gravitational attenuation coefficient, typically 2; G is the gravitational coefficient, which cannot affect the results, typically 1.

The overall score of each node obtained according to the factor analysis method is "logistics quality", which reflects the city's water and fruit flow development level. Considering that the main way of fruit logistics in the Guangxi region is road transportation, this paper quantifies the economic distance d_{ij} from the space, time, and cost of road transport with the following formula

$$d_{ij} = (D_{ij} C_{ij} T_{ij})^{\frac{1}{3}} \tag{2}$$

Where d_{ij} is the economic distance between nodes. D_{ij}, C_{ij}, and T_{ij} are the shortest road transport mileage, road freight rate, and the shortest road transit time, respectively. Substituting the above indicators into the basic formula of the gravitational model gives the gravitational model for cold chain logistics of regional agricultural products as follows

$$I_{ij} = \frac{M_i M_j}{\left[\left(D_{ij} C_{ij} T_{ij} \right)^{\frac{1}{3}} \right]^2} \tag{3}$$

Logistics affiliation (indicating the degree of affiliation of one city node with respect to the other) can reflect a city's influence range. The calculation formula is as follows

$$P_{ij} = \frac{I_{ij}}{\sum_{j=1}^{n} I_{ij}} \tag{4}$$

Where P_{ij} and I_{ij} are logistics affiliation and gravitational strength between nodes, respectively, calculated by substituting the calculation results of formula (3).

RESULTS AND DISCUSSION

The Characteristics of Fruit Industry in Guangxi

Guangxi has a substantial fruit production capacity. From 2014 to 2022, Guangxi's fruit output has consistently increased (**Figure 1**). Among them, the production surged from 14,578,800 tons in 2014 to 34,024,600 tons in 2022, an increase of 133.38%. The fruit industry is the leading agricultural industry in Guangxi. Since 2018, Guangxi's total fruit production has ranked first in the country for six consecutive years, surpassing provinces such as Shandong, Henan, Hebei and Guangdong. The production of citrus, mango, dragon fruit, persimmon, and passion fruit ranked first in the country, while the output of lychee, longan, and banana also reached second position in the country. The fruit industry, such as peaches, plums, pears, and grapes, has developed on a large scale (Krykavskyy, Shandrivska, & Pawłyszyn, 2023).

Guangxi has a large expanse of cultivation area for fruits. Fertile land, ideal climate, and abundant water sources have made Guangxi the largest single fruit-producing region in China. According to data from the National Bureau of Statistics, Guangxi's fruit planting area makes it the province with the largest fruit planting area in the country. Among them, the planting area of citrus ranks first in China, and litchi, longan and mango ranked second in China.

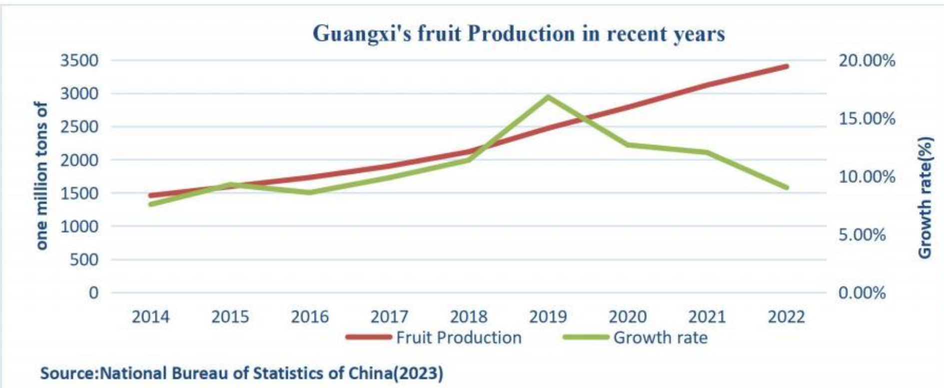
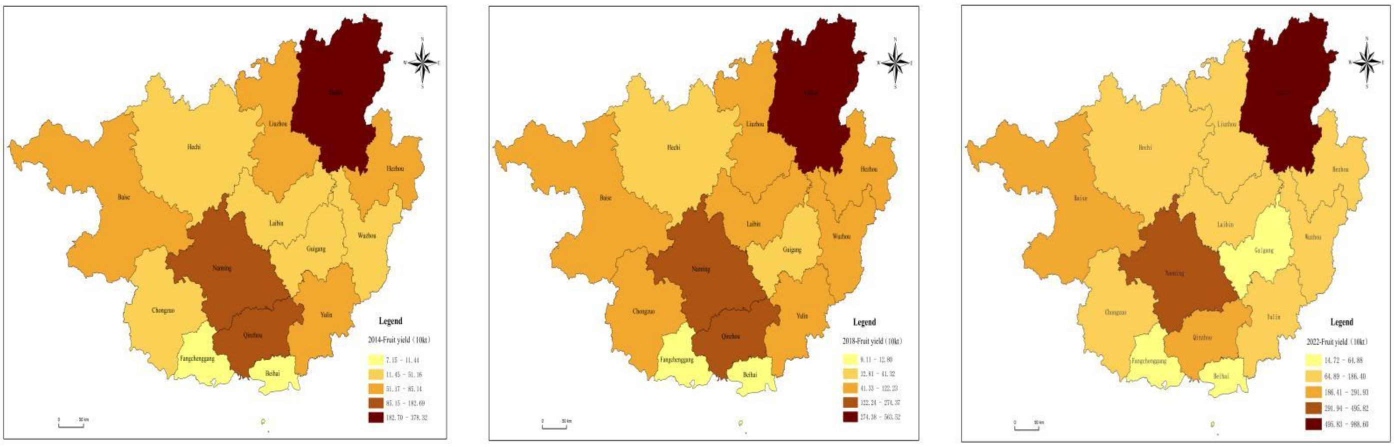


Figure 1. Trend in Fresh Fruits Production in Guangxi from 2014 to 2022 [Source: Guangxi Statistical Yearbook (2023)]

With the 14 cities in Guangxi as a spatial analysis scale, fruit production data from 2014, 2018, and 2022 were selected and divided into five levels using ArcGIS software, as shown in **Figure 2**. It illustrates that Guilin was the primary fruit production area in Guangxi in both 2014 and 2018 followed by dominant production areas Nanning and Qinzhou, showing an overall pattern of "one primary (Guilin) and two secondary (Nanning, Qinzhou) areas". In 2022, it progressed from the original to "one primary (Guilin) and one secondary (Nanning) area". The main fruit production area in Guangxi was still Guilin, and the dominant production area was Nanning. Overall, the regions with high fruit production in Guangxi were mainly Guilin, Nanning and Qinzhou. The areas with low fruit production were mainly Fangchenggang and Beihai in the southern, exhibiting a spatial distribution pattern of "Nanning as the center, with higher and lower production in the northern and southern areas. This is mainly due to the limited fruit production and cultivation areas in Fangchenggang and Beihai.



a.2014 b.2018 c.2022

Figure 2. Spatial Distribution of Fruit Production by City in Guangxi in 2014, 2018, and 2022 [Source: Guangxi Statistical Yearbook (2014, 2018, 2022)]

Selection of the Central Node Cities of the Distribution Network

Evaluation of Logistics Network Node

The KMO statistical tests and Bartlett sphericity test results (**Table 2**) were obtained by obtaining data on 11 importance evaluation indicators from 14 logistics network nodes in Guangxi and performing standardized processing and adaptability tests using SPSS software. The index data were acquired from the "Guangxi Statistical Yearbook 2022" and the Guangxi Bureau of Statistics.

According to **Table 2**, the KMO value is 0.596, greater than 0.5; the approximate chi-square value is 232.485; the P-value is 0.0001, less than 0.05, indicating that the selected index data is suitable for factor analysis.

Table 2. Results of KMO and Bartlett

KMO value		0.596
Bartlett sphericity test	Approximate chi-square	232.485
	df	55
	P	0.0001***

Note: ***, **, * represent the significance levels of 1%, 5%, and 10% respectively

According to **Table 1**, the collected data was standardized, and SPSS was utilized for principal component analysis. Factors with a cumulative variance contribution rate greater than 85% were selected as the main factors. If the cumulative variance is greater than 85%, the selected common factors retain most of the information in the original data and can be analyzed to represent the original data. Three main factors were selected based on the calculation results, and the main factor load matrix (**Table 3**) was obtained simultaneously.

Table 3. Factor Loading Matrix after Rotation

Factors	Element		
	Ingredient 1	**Ingredient 2**	**Ingredient 3**
GDP (X1)	0.152	0.011	0.04
Per capita GDP(X2)	-0.009	-0.084	0.448
Total retail sales of social consumer goods (X3)	0.148	0.02	0.038
Growth rate of total investment in fixed assets in the whole region (X4)	0.103	-0.228	-0.551
Traffic mileage (X5)	0.045	0.182	-0.308
Civilian automobile ownership (X6)	0.168	-0.001	-0.042
Number of people employed in transportation, transportation, storage, and postal services (in urban units) (X7)	0.21	-0.1	-0.071
Total postal services (X8)	0.221	-0.117	-0.087
Express delivery business volume (X9)	0.222	-0.13	-0.06
Orchard acreage (X10)	-0.099	0.428	0.006
Fruit production (X11)	-0.14	0.471	0.213

The contribution rate of each evaluation index to the main factor (**Table 4**) could also be obtained using the maximum variance method to perform orthogonal rotation of the load matrix. The total overall score of each logistics node city was calculated using the variance contribution rate after rotation as the weighting factor of each principal factor (**Table 5**)

Table 4. Variance Contribution Rate after Main Factor Rotation

Factor weighting results			
Name	Variance explained after rotation (%)	Accumulated variance explanation rate after rotation (%)	Weights(%)
Ingredient 1	0.521	52.074	56.989
Ingredient 2	0.235	75.55	25.692
Ingredient 3	0.158	91.375	17.319

As shown in **Table 3**, the first class of common factors, X1, X3, X4, X5, X6, X7, X8, X9, and X11, demonstrate substantial load. Among them, X1, X3, and X4 reflect the urban economic level, and X5, X6, X7, X8, and X9 reflect the logistics level. Therefore, the first class of common factors constitutes a collective factor reflecting the level of urban economy and logistics. The second class of common factors carries a large load on X10 and X11, reflecting the scale or status of the fruit industry. Since the third class of common factors carry relatively large loads on X1, X2, X3, X10, and X11, they can reflect the urban economy level and the fruit industry's status.

Table 5. Factor Scores and Rankings of Logistics Network Nodes in Guangxi

Node name	**Score**	**Ranking**
Nanning（NN）	1.899	1
Guilin(GL)	0.636	2
Liuzhou(LZ)	0.591	3
Yulin(YL)	-0.01	4
Qinzhou(QZ)	-0.106	5
Guigang(GG)	-0.186	6
Baise(BS)	-0.186	7
Beihai(BH)	-0.245	8
Wuzhou(WZ)	-0.334	9
Chongzuo(CZ)	-0.362	10
Fangchenggang(FCG)	-0.381	11
Hezhou(HZ)	-0.389	12
Laibin(LB)	-0.45	13
Hechi(HC)	-0.477	14

Identifying Hub and Spoke Node Cities

Using the principal component scores, comprehensive scores, and comprehensive rankings obtained by the factor analysis method as sample matrices, a cluster analysis was performed on 14 logistics network nodes and divided into four levels (**Table 6**).

Table 6. Cluster Analysis of Logistics Network Nodes

Hub nodes	Firstly spoke nodes	Secondary spoke nodes	Tertiary spoke nodes
NN, GL, LZ	YL, QZ, GG, BS	BH, WZ, CZ, FCG	HZ, LB, HC

Hub node cities (Level 1) include Nanning (overall score: 1.899), Guilin (overall score: 0.636), and Liuzhou (overall score: 0.591). Nanning is the capital of Guangxi, which is the center of the region’s politics, economy, culture, education, technology, and finance. It is also a window and frontier of open cooperation between China and ASEAN, with a relatively complete integrated transportation system and advanced logistics infrastructure equipment. Guilin is an important comprehensive transportation hub in the southwest region and an essential component of Guangxi's modern logistics industry system, the main production area for the fruit industry in Guangxi. Its production and planting areas rank first in the region. Moreover, it also offers convenient waterways and air transportation, providing a strong integrated transportation advantage. Liuzhou is the industrial center and the logistics, a transportation hub in southwest China and a distribution center for commodities, playing the role of a logistics transit point.

The First spoke node cities (Level 2) of Guangxi Province include Yulin, Qinzhou, Guigang, and Baise. These regions have a reasonable fruit industry in Guangxi and play a significant role in Guangxi's fruit and vegetable distribution network. Due to their unique economic, geographical, and transportation advantages with the basic conditions, they have become the central city of Guangxi's cold chain logistics network.

The Secondary spoke node cities (Level 3), including Beihai, Wuzhou, Chongzuo, Fangchenggang, Given their comparatively inferior economic status, logistics infrastructure, and relatively constrained transportation accessibility compared to Level 1 and Level 2 cities, these cities are expected to further development efforts.

The Tertiary node cities (Level 4), including Hezhou, Laibin, and Hechi, have a lower level of economic and logistics development. These areas need to further improve the fresh fruit logistics infrastructure.

Coverage Level and Logistics Channel Construction in Hub Cities

The overall node score obtained by the factor analysis method was linearly shifted by one unit, so the quality of the logistics was positive. Next, the shortest road transport mileage D_{ij}, the shortest road transit time T_{ij}, and the road transport cost rate C_{ij} between 14 logistics network nodes in Guangxi were substituted into the formula (3) to obtain the logistics gravitational strength between each node, and the logistics affiliation was calculated, shown in **Table 7**. The fresh fruit logistics affiliation between nodes is shown in **Table 8**.

Table 7. Result of Logistics Gravity Strength

	Logistics gravitational strength I_{ij}						
City	NN	LZ	GL	QZ	GG	YL	BS
WZ	0.032	0.023	0.020	0.014	0.024	0.024	0.008
BH	0.061	0.019	0.014	0.031	0.015	0.013	0.007
FCG	0.070	0.014	0.011	0.042	0.009	0.007	0.006
QZ	0.155	0.034	0.024	0.000	0.021	0.017	0.013
GG	0.109	0.050	0.029	0.021	0.000	0.033	0.010
YL	0.075	0.030	0.023	0.017	0.033	0.000	0.007
BS	0.063	0.019	0.017	0.013	0.010	0.007	0.000
HZ	0.024	0.020	0.025	0.006	0.008	0.007	0.004
HC	0.033	0.048	0.023	0.007	0.009	0.006	0.007
LB	0.048	0.049	0.019	0.009	0.013	0.007	0.005
CZ	0.056	0.010	0.008	0.012	0.006	0.005	0.006

Table 8. Result if Logistics Affiliation

	Logistics affiliation P_{ij}							
City	NN	LZ	GL	QZ	GG	YL	BS	Affiliated city
WZ	0.032	0.023	0.020	0.014	0.024	0.024	0.008	NN
BH	0.061	0.019	0.014	0.031	0.015	0.013	0.007	NN
FCG	0.070	0.014	0.011	0.042	0.009	0.007	0.006	NN
QZ	0.155	0.034	0.024	0.000	0.021	0.017	0.013	NN
GG	0.109	0.050	0.029	0.021	0.000	0.033	0.010	NN
YL	0.075	0.030	0.023	0.017	0.033	0.000	0.007	NN
BS	0.063	0.019	0.017	0.013	0.010	0.007	0.000	NN
HZ	0.024	0.020	0.025	0.006	0.008	0.007	0.004	GL
HC	0.033	0.048	0.023	0.007	0.009	0.006	0.007	LZ
LB	0.048	0.049	0.019	0.009	0.013	0.007	0.005	LZ
CZ	0.056	0.010	0.008	0.012	0.006	0.005	0.006	NN

According to the results of **Tables 7** and **8**, the node cities are classified as within the coverage area of the corresponding hub city with the logistics affiliation. Accordingly, it is feasible to draw the three major hub-and-spoke circles for fresh fruit logistics in Guangxi. The result showed that the hub city of Nanning, covering Beihai, Baise, Qinzhou, Guigang, Yulin, Chongzuo and Fangchenggang, Wuzhou, the hub city of Liuzhou, covering Hechi and Laibin, and the hub city of Guilin, covering Hezhou. Based on the results of each city (node) and the scope of affiliation, trunk lines connect Hub nodes and firstly nodes, and branch lines connect secondary and tertiary nodes shown in **Figure 3**.

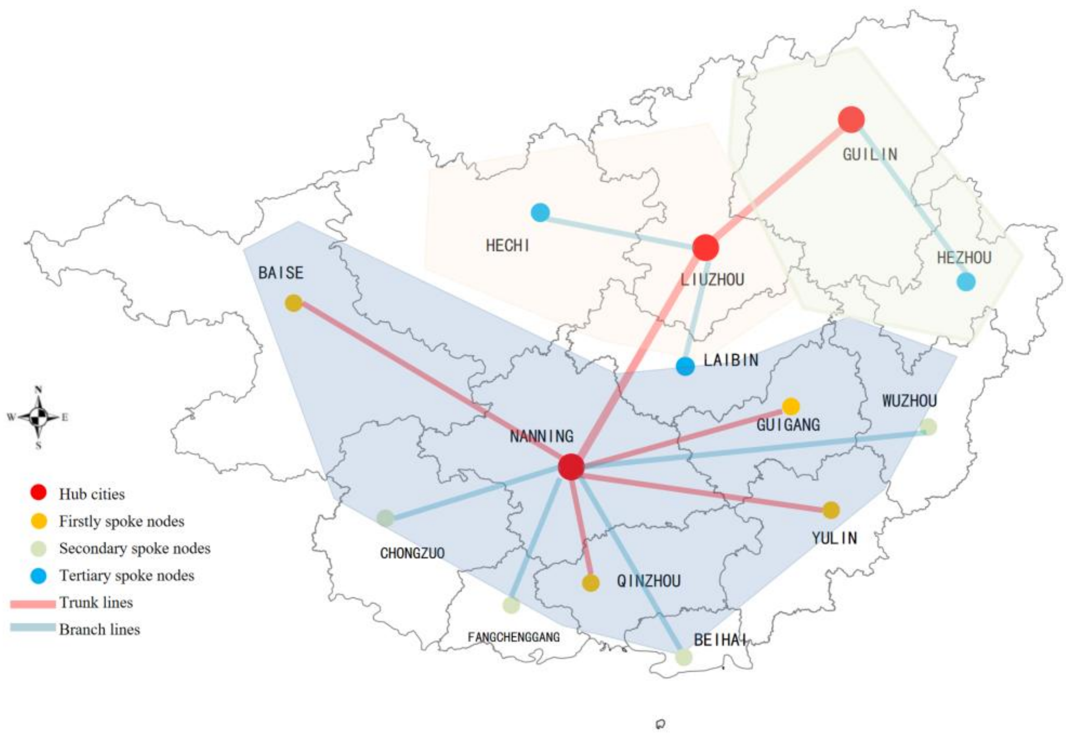


Figure 3. Hub-and-spoke Logistics Network for the Fruit Industry in Guangxi, China

The trunk line, connects the three hub cities of Nanning, Liuzhou, Guilin, Qinzhou, Baise, Guigang and Yulin, which are the core routes of the entire logistics network. The main line transportation gathers traffic on branch lines with many logistics, capital, and information within the region in the fruit industry's hub-and-spoke network. The branch line, connects the cities of Chongzuo, Fangchenggang, Beihai, Wuzhou, Laibin, Hechi, and Hezhou. It should ensure a smooth and rapid logistics flow between hub and spoke node cities at different levels. Therefore, branch lines should be designed for expansive coverage, typically relying on road transportation for connectivity (Vincek, Gregurec, & Kovšca, 2023)

CONCLUSION

Based on the data related to the development of the fresh fruit industry and logistics , the radiation range and logistics channels between nodes of each hub cities, node cities, main logistics routes and secondary logistics routes of Guangxi fresh fruit logistics are identified through the data analysis. As a result, a comprehensive logistics network for Guangxi's fresh fruit industry has been established. The specific conclusions and suggestions are as follows:

1. From 2014 to 2022, the regions with higher production volumes were mainly Guilin in northern Guangxi and Nanning and Qinzhou in southern Guangxi, while the regions with lower production volumes were Beihai and Fangchenggang in southern Guangxi. This reflects a spatial distribution pattern of "Nanning as the center, high production in the north and low in the south".

2. Nanning, Guilin, and Liuzhou were identified as the hub cities for fresh fruit logistics, and Yulin, Qinzhou, Guigang, and Baise as the firstly spoke nodes. This study also distinguishes between the three and four levels of logistics network nodes. In addition, the results of the affiliation between the cities were obtained and the trunk and branch fresh fruit logistics lines were designed. The results of this study can effectively guide plans for the construction of transportation infrastructure serving fresh fruit logistics as well as product distribution.

3. Drawing from the insights gained from the analysis of Guangxi's fresh fruit logistics network, a need arises to strategically guide the layout of the fresh fruit industry within the region. This should be harmonized with the spatial distribution of the fresh fruit industry in Guangxi to promote the comprehensive and well-rounded development of the fresh fruit industry in the region. It is imperative to improve the logistics infrastructure of hub cities to ensure optimal fruit transportation quality and minimize transshipment time, so as to promote fruit circulation in Guangxi and realize the further upgrading of the fruit industry.

This study takes the fresh fruit industry in Guangxi as the case study object, which has certain theoretical and applied research contributions to the distribution characteristics and logistics network design of China's agricultural industry. The results of the study are of guiding significance for the planning of the fresh fruit logistics network in Guangxi.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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