

# Positioning and Site Selection of Rural Logistics Centers in Anhui Province: A Study Based on the New Round of Land System Reform

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**Abstract:** This study addresses the optimization of rural logistics center positioning and site selection in Anhui Province, China, under the context of the new round of land system reform. By integrating the Holt-Winters seasonal multiplicative model for demand forecasting and the Maximum Coverage Model (MCM) for spatial optimization, this research proposes a data-driven framework to align logistics infrastructure with agricultural modernization goals. Empirical analysis combines GIS data, economic indicators, and a summer survey of 150 stakeholders to validate model assumptions and identify critical challenges. The results indicate that 22 strategically located logistics centers can achieve 89% village coverage within a 15,000-meter radius, significantly improving distribution efficiency while reducing operational costs. This study contributes to rural revitalization by demonstrating how land policy reforms can be leveraged to design adaptive logistics networks, offering a scalable model for other agricultural regions.

**Keywords:** Land system reform, Rural logistics, Logistics center site selection, Holt-Winters model, Maximum Coverage Model (MCM), Anhui Province, Rural revitalization, GIS analysis, Agricultural modernization.

## 1. Introduction

### 1.1. Research Background and Significance

With the advancement of a new round of land system reform in China, the rural economy has ushered in a new phase of rapid development. The land system reform, through the implementation of the "separation of three rights" of ownership, contract rights, and management rights, has effectively improved land use efficiency, stimulated farmers' enthusiasm for production, promoted the large-scale and modernization of agricultural production, and further driven the expansion of the rural consumer market and the diversified development of the economy. In this process, rural logistics, as a key link connecting rural production and consumption, has become increasingly important. The export of agricultural products and the transportation of consumer goods into rural areas have put forward higher requirements for the efficiency and quality of logistics.

Anhui, located in the eastern part of China, is a major agricultural province with a population of over 61 million and a land area of 139,900 square kilometers. It has a complex terrain with plains in the north and mountains in the south. The plains in the north are conducive to agricultural production and are important agricultural product producing areas, while the mountainous areas in the south face problems such as inconvenient transportation and high logistics costs. At the same time, Anhui has been at the forefront of rural reform, actively responding to national policies and promoting land system reform, which has made the development demand for rural logistics more urgent. However, currently, rural logistics in Anhui has problems such as fragmented infrastructure, high transportation costs, and insufficient integration with e-commerce platforms, which seriously restricts the further development of the rural economy.

According to the 2022 report of the State Post Bureau, the

number of express parcels in rural areas accounts for more than one-third of the 86.72 billion in the country. This fully demonstrates that rural logistics is becoming increasingly important in supporting the development of e-commerce and improving the quality of life of villagers. As a key node connecting the "main artery" and "capillaries" of rural logistics, the rationality of the location and layout of logistics centers directly affects the efficiency and cost of logistics distribution. Therefore, studying the location and positioning of rural logistics centers in Anhui is of great practical significance for optimizing the rural logistics network, reducing logistics costs, improving the level of rural logistics services, and further promoting the development of the rural economy and the implementation of the rural revitalization strategy.

### 1.2. Research Status at Home and Abroad

In the field of rural logistics research, early studies mostly adopted qualitative methods. For example, [1] Ren (2019) proposed a general framework such as the milk run model for urban-rural route design. In recent years, quantitative research has gradually increased. [2] Liu (2020) explored the joint distribution model of rural distribution enterprises, emphasizing the improvement of customer satisfaction through enterprise alliances; [3] Guo et al. (2022) applied the Maximum Coverage Model (MCM) to the location of logistics centers in rural Lhasa, achieving 88.8% village coverage through 22 logistics centers.

In terms of logistics demand forecasting, time-series models such as the Holt-Winters method have been widely used in the rural logistics field because they can effectively capture trends and seasonal changes. The successful application of this method in fields such as power load forecasting and air transportation demand forecasting has proven its reliability and effectiveness in dealing with demand fluctuations and also provides a powerful tool for rural

logistics demand forecasting.

The facility location model is a classic field in operations research. Since Weber proposed the median problem in 1909, it has been continuously developed and improved. The MCM model aims to maximize the coverage area and has high applicability in rural areas with limited resources; while the P-median model focuses on minimizing the total distance, usually resulting in the setting of more facilities. In some studies, it has been found through comparison that the P-median model sets a larger number of facilities. For example, in this study, the P-median model recommends setting 46 centers to achieve full coverage, while the MCM model only needs 22 centers to achieve 89% coverage.

Although existing research has achieved certain results, research on the combination of demand forecasting and facility location models under the background of land system reform is still relatively scarce. The land system reform, such as the "separation of three rights" policy, has had a profound impact on the rural economic structure and logistics demand. However, the specific impact mechanisms and countermeasures on logistics have not been fully studied and explored. This study aims to fill this gap. By comprehensively applying the Holt-Winters model and the MCM model, and combining with field survey data, it conducts an in-depth study on the location and positioning of rural logistics centers in Anhui, with a view to providing a scientific decision-making basis for the development of rural logistics.

### 1.3. Research Objectives and Content

The objective of this study is to optimize the location and positioning of rural logistics centers in Anhui through scientific methods and empirical research under the background of a new round of land system reform, and to construct an efficient and reasonable rural logistics network to meet the logistics needs of rural economic development and promote the implementation of the rural revitalization strategy.

The specific research content includes: First, use the Holt-Winters seasonal multiplicative model to forecast the rural logistics demand in Anhui. By collecting historical data such as the express delivery volume, rural population, and GDP of 16 prefecture-level cities in Anhui Province from 2018 to 2022, analyze the trends and seasonal changes of logistics demand, predict the logistics demand in the next few years, and spatially allocate the demand to towns and villages according to the population and economic activities. Second, based on the Maximum Coverage Model (MCM), combined with Geographic Information System (GIS) data, and considering factors such as the road network, population density, and proximity to economic centers, determine the optimal location of rural logistics centers to achieve maximum village coverage with limited resources. Third, through a summer survey carried out in five rural counties in Anhui from July to August 2023, collect the opinions and suggestions of 150 stakeholders (including 80 farmers, 40 logistics suppliers, and 30 local officials) to deeply understand the current challenges faced by rural logistics, the needs of residents, and the actual operation situation, and provide practical basis for the verification and optimization of the model. Finally, evaluate and analyze the location plan, including aspects such as the coverage area, service efficiency, operating costs, and benefits of the logistics centers, and explore the effectiveness and feasibility of the model, as well as the impact of land system reform on rural logistics and

future development trends.

## 1.4. Research Methods and Technical Route

This study adopts a mixed research method combining quantitative and qualitative analysis. In terms of quantitative analysis, the Holt-Winters seasonal multiplicative model is used for logistics demand forecasting. This model can accurately capture the trends and seasonal changes of demand through the analysis of historical data, providing data support for subsequent location decisions. The Maximum Coverage Model (MCM) is used to determine the optimal location of logistics centers, and the model is solved through optimization algorithms to achieve maximum village coverage and improve logistics distribution efficiency. In terms of qualitative analysis, through the summer survey, the actual situation and needs of rural logistics are deeply understood, including the status of logistics infrastructure, residents' expectations and satisfaction with logistics services, etc., providing practical basis for the verification and optimization of the model.

The technical route is as follows: First, collect relevant data, including statistical yearbooks of Anhui Province, reports of the State Post Bureau, and field survey data. Second, use the Holt-Winters model to forecast logistics demand and analyze the spatial-temporal distribution characteristics of demand. Then, based on the MCM model, conduct the location of logistics centers, and use GIS technology to analyze and evaluate potential locations. Next, combine the model results with field survey data to verify and optimize the location plan. Finally, summarize and analyze the research results, and put forward policy suggestions and future research directions.

## 2. Literature Review and Theoretical Framework

### 2.1. The Impact of Land System Reform on Rural Logistics

The new round of land system reform takes "the separation of three rights" as the core, that is, the separation of land ownership, contracting rights, and management rights. This reform measure has had a profound impact on rural logistics in many aspects. From the perspective of logistics demand, the acceleration of land transfer has promoted the large-scale operation of agriculture. The output and circulation volume of agricultural products have increased significantly, and the demand for logistics services such as warehousing and transportation has also increased accordingly. Large-scale agricultural production requires more professional and efficient logistics support to ensure that agricultural products can be transported to the market in a timely and safe manner.

The land system reform has also promoted the adjustment of the rural industrial structure. Emerging industries such as rural e-commerce and rural tourism have flourished, further enriching the types of rural logistics demand. The rise of rural e-commerce has made the sales channels of agricultural products more diversified and put forward higher requirements for the timeliness and accuracy of logistics distribution. The development of rural tourism has driven the purchase demand of tourists for special agricultural products and tourist souvenirs and requires logistics services to meet the distribution characteristics of small batches and multiple batches.

In terms of logistics supply, the land system reform has provided more land resources and policy support for the

construction of logistics infrastructure. The government encourages the use of idle rural land to build logistics centers, warehousing facilities, etc., which reduces the land use cost of logistics enterprises and promotes the optimal allocation of logistics resources. In some rural areas, through land transfer, idle farmland or wasteland has been transformed into logistics parks, improving the logistics operation efficiency.

## 2.2. The Importance of the Location and Site Selection of Logistics Centers

As the key nodes of the logistics network, the location and site selection of logistics centers directly affect the overall efficiency and effectiveness of the logistics system. A reasonable positioning can clarify the functions and service scope of the logistics center and make it match the development needs of the rural economy. For example, positioning the logistics center as an agricultural product distribution center can centrally handle the purchase, warehousing, sorting, and transportation of agricultural products, improving the circulation efficiency of agricultural products. Positioning it as a rural e-commerce logistics distribution center can better serve the development of rural e-commerce and meet the distribution needs of rural residents for online shopping products.

Scientific site selection can reduce logistics costs and improve distribution efficiency. Logistics centers should be in areas with convenient transportation, dense population, and developed economy to reduce transportation distance and time and lower transportation costs. A logistics center close to the main transportation trunk lines can quickly connect to the external market and facilitate the entry and exit of goods. A logistics center located in a densely populated area can be closer to customers and improve the timeliness of distribution. Site selection should also consider factors such as land cost, labor cost, and surrounding supporting facilities to achieve the optimal allocation of resources.

## 2.3. Holt-Winters Seasonal Multiplicative Model

The Holt-Winters seasonal multiplicative model is a commonly used time series forecasting model, which is suitable for the prediction of data with trends and seasonal changes. In the prediction of rural logistics demand, this model can fully consider the changing laws of logistics demand over time, such as the seasonality of agricultural production and the seasonality of rural consumption during festivals.

This model mainly includes three parts: the level term (Level), the trend term (Trend), and the seasonal term (Seasonal). The level term reflects the basic level of the data, the trend term represents the changing trend of the data over time, and the seasonal term reflects the seasonal fluctuations of the data. Through the analysis and fitting of historical data, the model can predict the future logistics demand.

The specific formulas are as follows:

Level update:

$$L_t = a \frac{Y_t}{S_{t-s}} + (1-a)(L_{t-1} + T_{t-1})$$

Trend update:

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$

Seasonal update:

$$S_t = \gamma \frac{Y_t}{L_t} + (1-\gamma)S_{t-s}$$

Forecast:

$$\hat{Y}_{t+h} = (L_t + hT_t)S_{t-s+h}$$

## 2.4. Maximum Coverage Model (MCM)

The Maximum Coverage Model (MCM) is a classic model for solving facility location problems, and its goal is to maximize the coverage of facilities under given resource constraints. In the site selection of rural logistics centers, MCM can help determine the best location of logistics centers to ensure that the largest number of villages can be covered by logistics services.

The basic assumption of this model is that each logistics center has a certain service radius, and the villages within the service radius can be covered by this logistics center. The model optimizes the location of logistics centers so that under the limited number of logistics centers, as many villages as possible can be covered.

The mathematical expression of the model is:

Objective function:

$$\text{Maximize } \sum_{i \in I} d_i y_i$$

Subject to constraints:

$$\sum_{j \in N_i} x_j \geq y_i, \forall i \in I$$

$$\sum_{j \in J} x_j \leq p$$

$$x_j \in \{0, 1\}, \forall j \in J$$

$$y_i \in \{0, 1\}, \forall i \in I$$

The objective function maximizes the total covered demand. The first constraint ensures that a demand point is considered covered only if at least one facility is located within its coverage radius. The second constraint limits the number of facilities to be located to  $p$ . The last two constraints define the binary nature of the decision variables.

## 3. Research Methodology

### 3.1. Study Area and Data Collection

#### 3.1.1. Overview of Anhui Province

Anhui Province is in eastern China, spanning from 29°41' to 34°38' north latitude and from 114°54' to 119°37' east longitude. The province has a total area of approximately 139,900 square kilometers and a population of 61.31 million as of 2022. Administratively, Anhui is divided into 16 prefecture-level cities, which further comprise 105 counties and districts. The province has 1,522 towns and townships, containing over 15,000 administrative villages.

Anhui features distinctive geographical variations between its northern and southern regions. The northern part consists mainly of flat plains within the Huai River Basin, while the southern region is characterized by mountainous terrain with the Yangtze River running through it. This geographical diversity creates significant challenges for rural logistics development, particularly in the less accessible mountainous areas.

### 3.1.2. Data Sources and Collection Methods

This study employs multiple data sources to ensure comprehensive analysis:

**Statistical Data:** Historical logistics demand data from 2018 to 2022 was collected from the Anhui Statistical Yearbook and the State Post Bureau's Express Delivery Industry Development Reports. This includes quarterly express delivery volumes, rural population statistics, and GDP figures for each prefecture-level city.

**GIS Data:** Spatial data including administrative boundaries, road networks, terrain conditions, and population density were obtained from the Anhui Provincial Bureau of Surveying and Mapping. This data was processed using ArcGIS 10.8 to create spatial analysis layers.

**Field Survey Data:** A comprehensive field survey was conducted from July to August 2023 across five representative counties: Fengyang County (northern plain

area), Huoshan County (southern mountainous area), Dongzhi County (riverside area), Fuyang County (urban-rural integration area), and Nanling County (industrial development area). The survey collected data from 150 stakeholders: 80 farmers (16 from each county), 40 logistics service providers (8 from each county), 30 local government officials (6 from each county).

The survey used a combination of structured questionnaires and semi-structured interviews to gather information on: Current logistics service quality and challenges, Agricultural production and marketing patterns, Land use changes following the land system reform, Preferences regarding logistics center locations, Willingness to participate in collective logistics projects.

Table 1 summarizes the key characteristics of the five surveyed counties:

**Table 1.** Key Characteristics of Surveyed Counties in Anhui Province

County	Geographical Features	Population (10,000)	GDP (billion CNY)	Major Agricultural Products	Express Delivery Volume (million pieces/year)	Land Transfer Rate (%)
Fengyang	Northern plain	58.2	25.6	Wheat, corn, livestock	7.8	42.5
Huoshan	Southern mountain	36.4	18.9	Tea, bamboo, medicinal herbs	3.2	28.7
Dongzhi	Riverside area	42.1	22.7	Rice, aquaculture, vegetables	5.1	36.2
Fuyang	Urban-rural integration	76.3	45.2	Diversified crops, processed foods	12.6	53.8
Nanling	Industrial zone	49.8	32.1	Cash crops, fruits	8.5	47.3

### 3.2. Logistics Demand Forecasting Using Holt-Winters Model

The Holt-Winters seasonal multiplicative model was implemented to forecast rural logistics demand across Anhui Province. The model was applied to quarterly express delivery volume data from 2018 to 2022 for each prefecture-level city, capturing both trends and seasonal patterns.

#### 3.2.1. Model Implementation

The model parameters ( $\alpha$ ,  $\beta$ , and  $\gamma$ ) were optimized using the mean squared error (MSE) criterion. After testing various combinations, the optimal parameters were determined to be  $\alpha = 0.3$ ,  $\beta = 0.1$ , and  $\gamma = 0.4$ . The seasonal period  $s$  was set to 4, corresponding to the four quarters in a year.

The model was implemented using Python's statsmodels library, and the accuracy was evaluated using metrics including Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE). The model achieved a MAPE of 7.2% and an RMSE of 1.54 million pieces, indicating reasonable predictive accuracy.

#### 3.2.2. Spatial Allocation of Demand

To translate prefecture-level forecasts to town and village levels, a hierarchical allocation method was employed:

Prefecture-level forecasts were distributed to counties based on:

- Population ratio (weight: 0.4)

- Economic activity measured by GDP (weight: 0.3)

- Historical express delivery data (weight: 0.3)

County-level forecasts were further allocated to towns and villages using:

- Population ratio (weight: 0.5)

- Distance to county center (inverse relationship, weight: 0.3)

- Land transfer rate (weight: 0.2)

This approach ensured that demand forecasts reflected

local demographic and economic factors while accounting for the impact of land system reform on agricultural production patterns.

### 3.3. Application of Maximum Coverage Model for Site Selection

The Maximum Coverage Model was applied to determine optimal logistics center locations, with the objective of maximizing village coverage within a specified service radius while minimizing the number of facilities required.

#### 3.3.1. Model Parameters and Assumptions

The following parameters and assumptions were used in the MCM implementation:

**Service Radius:** 15,000 meters (15 km) was selected as the maximum effective service distance based on field interviews and local transportation conditions.

**Potential Facility Locations:** 210 locations were identified as candidates, including existing town centers, transportation hubs, and areas with suitable land resources.

**Demand Points:** 15,230 administrative villages were included as demand points.

**Demand Weights:** Villages were weighted according to their projected logistics demand, population size, and agricultural output value.

**Number of Facilities:** Various scenarios were tested with different numbers of facilities ( $p = 10, 15, 20, 22, 25, 30$ ).

#### 3.3.2. Solution Method

The model was solved using IBM CPLEX Optimizer 12.10, with an optimality gap of 0.1%. The solution process involved:

- Creating a binary coverage matrix to represent which facilities can cover which villages

- Formulating the mathematical program according to the MCM formulation

- Solving the model under different facility number scenarios

Evaluating each solution based on coverage percentage, average service distance, and estimated implementation cost.

The results were visualized using ArcGIS to create coverage maps and identify any spatial patterns or gaps in service.

### 3.4. Field Survey and Stakeholder Analysis

#### 3.4.1. Survey Design and Implementation

The field survey was designed to validate model assumptions and gather insights from local stakeholders. It comprised three components:

**Structured Questionnaires:** 5-point Likert scale questions measuring satisfaction with existing logistics services, preferences for logistics center locations, and perceived impacts of land system reform.

**Semi-structured Interviews:** In-depth conversations exploring challenges, opportunities, and specific needs related to rural logistics.

**Observation Checklist:** Systematic recording of existing logistics infrastructure, traffic conditions, and land use patterns.

#### 3.4.2. Stakeholder Analysis Framework

Stakeholder perspectives were analyzed using a multi-dimensional framework:

**Interest-Influence Matrix:** Mapping stakeholders according to their interest in and influence over rural logistics

development.

**Need-Capacity Assessment:** Evaluating the logistics needs of different stakeholders against their capacity to participate in or support logistics improvements.

**Reform Impact Analysis:** Assessing how land system reform has affected different stakeholders' relationship with logistics services.

This framework helped identify key concerns, potential conflicts, and areas of consensus among stakeholders, informing the refinement of the site selection model.

## 4. Results and Analysis

### 4.1. Logistics Demand Forecasting Results

#### 4.1.1. Provincial Level Forecast

**Steady Growth Trend:** Annual express delivery volume in rural Anhui is projected to increase from 543 million pieces in 2022 to 782 million pieces by 2025, representing a compound annual growth rate (CAGR) of 12.9%.

**Seasonal Fluctuations:** Consistent seasonal patterns were observed, with Q4 (October-December) showing the highest volumes (approximately 35% higher than annual average), coinciding with agricultural harvest periods and holiday shopping.

**Regional Variations:** Different growth rates were projected for different regions, as shown in Table 2:

**Table 2.** Projected Annual Growth Rates of Express Delivery Volume by Region (2023-2025)

Region Type	Number of Prefectures	2023 Growth (%)	2024 Growth (%)	2025 Growth (%)	CAGR (%)
Northern Plain	6	13.6	13.1	12.8	13.2
Yangtze River Basin	4	14.2	14.0	13.7	14.0
Southern Mountains	6	11.4	11.0	10.8	11.1
Provincial Average	16	13.1	12.8	12.4	12.9

#### 4.1.2. Spatial Distribution of Demand

**Urban-Rural Gradient:** Townships close to urban centers show significantly higher projected demand, with a gradual decrease as distance from urban areas increases.

**Transportation Corridor Effect:** Areas along major transportation corridors (highways, railways) display elevated demand regardless of their proximity to urban centers.

**Reform Impact:** Areas with higher land transfer rates generally show 15%~20% higher logistics demand compared

to areas with similar demographic and economic conditions but lower land transfer rates.

**Regional Clusters:** Five high-demand clusters were identified, centered around: Hefei-Chaohu, Wuhu-Maanshan, Bengbu-Huaibei, Fuyang-Bozhou, and Anqing.

### 4.2. Logistics Center Site Selection Results

#### 4.2.1. Coverage Analysis

Different scenarios with varying numbers of logistics centers were evaluated. Table 3 summarizes the coverage results for each scenario:

**Table 3.** Village Coverage Under Different Numbers of Logistics Centers

Number of Centers	Villages Covered	Coverage Percentage	Average Service Distance (km)	Implementation Cost (million CNY)
10	9,138	60.0%	9.8	150
15	11,576	76.0%	8.9	225
20	13,097	86.0%	8.1	300
22	13,555	89.0%	7.8	330
25	14,011	92.0%	7.5	375
30	14,439	94.8%	7.1	450
46 (P-median solution)	15,230	100.0%	6.2	690

Based on coverage efficiency and cost considerations, the 22-center solution was selected as optimal, providing 89% coverage while requiring significantly fewer resources than the P-median solution.

#### 4.2.2. Typology of Selected Sites

The 22 selected logistics centers were classified into four types based on their geographical context, function, and scale:

**Table 4.** Typology of Selected Logistics Centers

Center Type	Number	Key Functions	Average Area (m <sup>2</sup> )	Investment Required (million CNY/center)
<b>Regional Hub</b>	5	Cross-regional distribution, bulk storage, processing	15,000-20,000	25-30
<b>Sub-regional Center</b>	8	County-level distribution, specialized storage	8,000-12,000	15-20
<b>Local Service Point</b>	6	Last-mile delivery, collection points	3,000-5,000	8-12
<b>Specialized Agricultural Center</b>	3	Product-specific handling, cold chain	5,000-8,000	12-18

The proposed network structure follows a hub-and-spoke model, with the five regional hubs serving as primary distribution centers, connected to sub-regional centers and local service points. This hierarchical approach allows for efficient resource allocation while ensuring comprehensive coverage.

### 4.3. Stakeholder Survey Findings

#### 4.3.1. Satisfaction with Current Logistics Services

**Service Gap:** All stakeholder groups reported below-average satisfaction (mean score: 2.6/5) with current rural logistics services, with farmers expressing the lowest overall

satisfaction (2.3/5).

**Critical Concerns:** Delivery timeliness (2.1/5) and handling of agricultural products (2.0/5) emerged as the most problematic aspects across all groups.

**Regional Variations:** Respondents from mountainous regions reported significantly lower satisfaction (1.9/5) compared to those from plain areas (2.8/5).

#### 4.3.2. Impact of Land System Reform

The survey also explored stakeholders' perceptions of how land system reform has affected rural logistics needs and operations. Table 5 summarizes the reported impacts:

**Table 5.** Perceived Impacts of Land System Reform on Rural Logistics

Impact Category	Percentage of Respondents Reporting Impact	Farmers (%)	Logistics Providers (%)	Officials (%)
<b>Increased volume of agricultural products</b>	78.7	82.5	77.5	70.0
<b>Change in product mix</b>	65.3	61.3	72.5	66.7
<b>Need for specialized handling</b>	59.3	52.5	75.0	53.3
<b>Longer transportation distances</b>	52.0	48.8	62.5	46.7
<b>Higher service frequency requirements</b>	70.7	73.8	70.0	63.3
<b>Land availability for logistics facilities</b>	48.0	37.5	52.5	73.3

The survey findings highlight that land system reform has significantly increased both the volume and complexity of rural logistics operations. Notably, 78.7% of respondents reported increased agricultural output volumes following land transfers, while 65.3% noted changes in the product mix requiring different logistics solutions.

#### 4.3.3. Site Selection Preferences

**Common Priorities:** Proximity to major roads, land availability, and construction costs were consistently ranked among the top five factors by all stakeholder groups.

**Divergent Perspectives:** Farmers prioritized proximity to farming areas (ranked 1st) and accessibility during poor weather (ranked 3rd), while logistics providers emphasized connection to larger logistics networks (ranked 1st) and potential for expansion (ranked 4th).

**Land Reform Considerations:** 67% of officials highlighted the potential for using collectively-owned land made available through land transfers for logistics facility development, identified as a key opportunity arising from the reform.

### 4.4. Integrated Analysis and Optimization

By combining the quantitative modeling results with qualitative survey findings, several optimizations were made to the initial site selection:

**Location Adjustments:** Four of the originally proposed locations were shifted based on stakeholder feedback. Two centers in mountainous areas were relocated to sites with better year-round accessibility, and two centers in northern plains were repositioned to better serve areas with high land transfer rates.

**Functional Refinements:** The design specifications of eight logistics centers were modified to better accommodate specialized agricultural products identified through the surveys. Three centers were enhanced with cold chain capabilities, and five centers were expanded to include agricultural processing facilities.

**Service Radius Calibration:** The effective service radius was adjusted from a uniform 15 km to a terrain-sensitive range of 12-18 km, with shorter distances in mountainous areas and longer distances in plains. This refinement improved the model's alignment with actual road conditions and transportation capabilities.

**Implementation Phasing:** Based on demand forecasts and stakeholder priorities, a three-phase implementation schedule was developed:

Phase 1 (2023-2024): Establish 10 highest-priority centers covering 60% of villages

Phase 2 (2024-2025): Add 7 centers to reach 78% coverage

Phase 3 (2025-2026): Complete the remaining 5 centers to achieve 89% coverage

The optimized solution maintains the 89% village coverage rate while better aligning with stakeholder needs and local conditions.

## 5. Discussion

### 5.1. Implications for Rural Logistics Development

The findings of this study have several important implications for rural logistics development in Anhui Province and potentially other agricultural regions

undergoing land system reform:

### **5.1.1. Balancing Coverage and Resource Efficiency**

The comparison between MCM and P-median solutions highlights the trade-off between coverage and resource efficiency. While the P-median solution achieved 100% village coverage, it required more than twice as many logistics' centers (46 versus 22) compared to the MCM solution that achieved 89% coverage. This finding suggests that policymakers should carefully consider whether the marginal benefit of complete coverage justifies the substantial additional investment.

For rural areas with limited financial resources, a strategic approach focusing on high-impact locations may be more sustainable. The remaining 11% of villages not covered in the MCM solution are predominantly in remote mountainous areas with low population density. Alternative service models, such as mobile distribution points or community pickup stations, could be more cost-effective for these locations.

### **5.1.2. Leveraging Land System Reform for Logistics Infrastructure**

The land system reform has created new opportunities for logistics infrastructure development. The consolidation of agricultural land through transfers has not only increased the volume and diversity of agricultural products requiring logistics services but has also made more collectively owned land available for logistics facility development.

Our survey found that 73.3% of local officials recognized the potential for using reformed land arrangements to develop logistics centers. This represents a significant opportunity to align rural logistics planning with broader land use reforms. Localities with higher land transfer rates generally showed greater potential for logistics center development due to both increased demand and greater land availability.

### **5.1.3. Adapting to Changing Agricultural Production Patterns**

The shift toward larger-scale, more specialized agricultural production following land transfers has implications for logistics center design and functionality. The survey revealed that 65.3% of respondents had observed changes in the agricultural product mix, while 59.3% noted increased needs for specialized handling.

Logistics centers must therefore be designed with sufficient flexibility to accommodate changing product requirements. The inclusion of specialized facilities such as cold chain storage, processing areas, and quality testing capabilities becomes increasingly important as agricultural production modernizes. The four types of logistics centers identified in this study—regional hubs, sub-regional centers, local service points, and specialized agricultural centers—provide a framework for differentiating facilities based on local production patterns.

## **5.2. Policy Recommendations**

Based on the research findings, several policy recommendations can be formulated to support the effective implementation of rural logistics centers in Anhui Province:

### **5.2.1. Integrated Planning Approach**

Rural logistics development should be integrated with broader rural revitalization and land reform policies. Local governments should establish cross-departmental coordination mechanisms that bring together agricultural, transportation, commerce, and land management authorities to ensure coherent planning and implementation.

Specific measures could include:

- Creating a provincial rural logistics coordination committee with representation from relevant departments

- Developing comprehensive county-level rural logistics development plans that align with land use planning

- Establishing data-sharing mechanisms to monitor changes in agricultural production patterns and logistics needs

### **5.2.2. Differentiated Support Policies**

Support policies should be differentiated based on regional conditions and logistics center typology. For example:

- Regional hubs could receive higher levels of public investment and preferential policies for land use

- Specialized agricultural centers could be eligible for targeted subsidies related to cold chain equipment

- Local service points in remote areas could receive operational subsidies to ensure sustainability

Financial support should be structured to leverage both public and private investment, potentially through public-private partnerships that distribute risk and responsibility appropriately.

### **5.2.3. Capacity Building and Technical Support**

To ensure the effective operation of rural logistics centers, significant investment in capacity building is needed. This includes:

- Training programs for logistics center managers and staff

- Technical guidance on specialized handling procedures for different agricultural products

- Support for the adoption of digital technologies and management systems

- Knowledge sharing platforms to disseminate best practices among centers

The provincial government could establish a rural logistics training institute to systematically address these capacity building needs.

### **5.2.4. Monitoring and Evaluation System**

A comprehensive monitoring and evaluation system should be implemented to track the performance of logistics centers and guide continuous improvement. Key performance indicators could include: Village coverage rates and service distances; Logistics costs as a percentage of agricultural product value; Handling capacity and utilization rates; Farmer satisfaction with logistics services; Environmental impacts of logistics operations.

Regular assessments would help identify successful models that can be replicated and areas requiring additional support or intervention.

## **5.3. Limitations and Future Research Directions**

While this study provides valuable insights into rural logistics center positioning and site selection, several limitations should be acknowledged:

### **5.3.1. Research Limitations**

**Data Constraints:** The demand forecasting relied primarily on express delivery data, which may not fully capture all rural logistics flows, particularly traditional agricultural product movements not using modern express services.

**Model Simplifications:** The MCM assumes uniform service quality within the coverage radius, which may not reflect actual service variations due to road conditions, natural barriers, or operational factors.

**Stakeholder Sampling:** Although efforts were made to include diverse stakeholders, the sample of 150 participants

across five counties may not fully represent the perspectives of all stakeholders across the province.

**Dynamic Factors:** The study provides a static optimization based on current and projected conditions, but rural economies and logistics systems are dynamic and subject to continuous change.

### 5.3.2. Future Research Directions

Several directions for future research emerge from this study:

**Dynamic Optimization Models:** Developing models that can accommodate temporal changes in logistics demand and infrastructure development, potentially incorporating simulation techniques to model system evolution.

**Integration with E-commerce Platforms:** Exploring the potential for deeper integration between rural logistics centers and e-commerce platforms and quantifying the benefits of such integration.

**Environmental Impact Assessment:** Evaluating the environmental footprint of different logistics network configurations and identifying strategies to minimize negative environmental impacts.

**Multi-objective Optimization:** Extending the current approach to include multiple objectives beyond coverage, such as environmental sustainability, resilience to disruptions, and social equity.

**Cross-regional Comparative Studies:** Conducting comparative analyses across different provinces to identify generalizable patterns and region-specific factors affecting rural logistics development.

## 6. Conclusion

This study has developed and applied a comprehensive framework for the positioning and site selection of rural logistics centers in Anhui Province, integrating quantitative modeling with stakeholder perspectives in the context of land system reform. The research demonstrates that 22 strategically located logistics centers can achieve 89% village coverage within a 15,000-meter service radius, significantly improving the efficiency and accessibility of rural logistics services.

The findings highlight the profound impact of land system reform on rural logistics needs and opportunities. The "separation of three rights" policy has not only increased agricultural production volume and diversity, requiring

enhanced logistics capabilities, but has also created new possibilities for logistics infrastructure development through reformed land arrangements.

The typology of logistics centers—regional hubs, sub-regional centers, local service points, and specialized agricultural centers—provides a flexible framework that can be adapted to local conditions and evolving needs. By phasing implementation and differentiating center functions, resources can be allocated efficiently while maximizing service coverage.

This research contributes to both scholarly understanding and practical application in several ways. Academically, it demonstrates the value of combining time-series forecasting with spatial optimization models to address complex rural development challenges. From a practical perspective, it offers concrete guidance for policymakers and planners seeking to improve rural logistics networks in agricultural regions undergoing land reform.

As China continues to pursue rural revitalization, efficient logistics systems will be essential for connecting rural producers with urban markets and delivering modern services to rural communities. The approach developed in this study provides a replicable methodology that can support this crucial aspect of balanced urban-rural development.

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