Logistics distribution mode analysis based on demand forecast

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Abstract. With rapid development of marketization in rural areas, the demand for logistics in rural areas, especially small-piece logistics for special agricultural products and daily necessities of farmers, has increased exponentially. Meanwhile, the supply of rural small-piece logistics cannot meet the demand over country. At present, postal companies and large private express delivery companies such as SF Express, YunDa Express, and ZhongTong Express are considered to be effective measures to alleviate the unbalanced situation, but their services do not satisfy markets in rural areas in three aspects: reasonable price, high efficiency and quality. In this paper, in order to establish a technically feasible and economically rational joint distribution mode, demand forecast for five counties in Hainan province is carried out based on time series model. Then two types of joint distribution mode are proposed based on the forecast using Logit model. Our results show that bus pick-up mode is suitable for initial start-up stage of rural small-piece logistics distribution projects, and logistics special-purpose vehicle distribution mode is suitable for mature stage of rural small-piece logistics projects.

1. Introduction

Logistics has grown steadily in the past 10 years, but current rural logistics system in China is still relatively weak[1]. The rapid increase in online shopping of farmers’ daily necessities has driven the simultaneous growth of small-piece logistics demand, but current distribution services are difficult to meet the needs. At the same time, two-way rural logistics is seriously uneven, but the future demand is huge and needs to be developed and guided urgently.

Many scholars have conducted research on rural logistics. Ji Guojun and Huang Weiwang attempts to integrate 4 kinds of logistics including distribution of agricultural products, distribution of daily consumer goods, agricultural means of production distribution and rural reverse logistics to a distribution center[2]. Yuyan and Sun Huimin put forward the mode suitable for the choice of logistic distribution center based on the thought of the scale economy theory and Delphi method and analytic hierarchy process[3]. Li Juntao and Liu Bingwu analyze the logistics distribution network planning problem and propose a mixed integer programming model, and heuristics solution procedure for this problem was given to simplify the model and solve the problem[4]. He Meiling, Hu Qifan and Wu Xiaohui propose a two-stage agricultural products Logistics Service Supply Chain (LSSC) was established with one agricultural products logistics service integrator and one functional logistics service provider to solve the capability coordination in logistics service based on the agricultural products industry[5].

However, most scholars fail to consider the characteristics of different villages. The demand of small rural logistics, mainly express delivery, is relatively scattered, and mainly one-way logistics, while the proportion of local agricultural and sideline products exported logistics that really contributes to the development of rural economy is low[6]. Therefore, this paper models the actual
demand of rural logistics distribution, and designs the mode of joint distribution in line with the
medium - and long-term development.

2. Analysis and forecast of rural small-piece logistics demand in Hainan province
Logistics demand is an important factor of deciding the development of logistics industry[7]. The
demand function can be obtained by taking the demand for a certain commodity as a dependent
variable and the factors affecting people's demand for that commodity as independent variables:

\[ Q = f(P, I, T, R, \ldots) \]  

(1)

Where: Q -- demand for the commodity; P -- price of the commodity; I -- resident income; T -- degree
of people's preference for the product; R -- price of a substitute for the commodity.

Field survey of five cities and counties in Hainan province shows that with popularization of e-
commerce platform in Hainan, it greatly shortens the distance between farmers' shopping market and
agricultural products market, and stimulates the growth of small logistics (including express delivery)
demand in five cities and counties, among which QiongHai and DanZhou grow the most rapidly, as shown
in figure 1 and figure 2 below.

![Figure 1. Express business revenue in 2015](image1)

![Figure 2. Express delivery volume in 2015](image2)

Due to the lack of sample data in the express industry, this report adopts time series prediction
method[8]. The advantage of this method is that data required for prediction is small and the prediction
method is simple and easy, and it has high accuracy in short-term prediction. The specific steps are as
follows.

2.1. Data preprocessing
Data preprocessing is required before multiple linear regression. Cubic exponential smoothing formula is:

\[ Y_t = a_t + b_tL + c_tL^2 \]  

(2)

Where, \( Y_t \) -- prediction target; t -- time series; L -- is future unit time period; \( A_t \)-- primary exponential
matching coefficient; \( B_t \)-- quadratic exponential smoothing coefficient; \( C_t \)-- exponential smoothing
coefficient of the third degree. The smoothing coefficient is determined as follows:

\[ a_t = 3S^{(1)}_t - 3S^{(2)}_t + S^{(3)}_t \]  

(3)

\[ b_t = a / 2(1-a)^2[(6-5a)S^{(1)}_t - 2(5-4a)S^{(2)}_t + (4-3a)S^{(3)}_t] \]  

(4)

\[ c_t = a / 2(1-a)^2[S^{(1)}_t - 2S^{(2)}_t + S^{(3)}_t] \]  

(5)

Where, \( S^{(1)}_t \), \( S^{(2)}_t \) and \( S^{(3)}_t \)-- the exponential smoothing value of the first order, the exponential
smoothing value of the second order and the exponential smoothing value of the third order respectively. A
-- a scaling factor (0< a <1) for the prediction of old and new data. When determining smooth values \( S^{(1)}_t \),
\( S^{(2)}_{t} \) and \( S^{(3)}_{t} \) of \( a_t, b_t \) and \( c_t \), the larger the alpha value is, the greater the role of new data will be, and the higher the sensitivity of the model will be and the faster it will adapt to the new level.

2.2. Prediction model establishing
Combining urban and rural residents’ disposable income level and tertiary industry output value index to build the model as follows:

\[
D = f(R, S) + \sigma
\]

Where \( D \) -- express delivery volume, \( R \) -- disposable income level of urban and rural residents in Hainan province, \( S \) -- tertiary industry output value, \( \sigma \) -- error coefficient. It is predicted that by 2020, the express delivery volume in Hainan will reach 125.710,500 pieces, as shown in Figure 3.

2.3. Demand analysis of rural small-piece logistics in each county and city
Combining urban residents’ disposable income level, rural per capita disposable income level and urban and rural population indicators to build the model as follows:

\[
D_n = \varepsilon f(R_u, R_c, P_u, P_c)
\]

Where, \( D_n \) -- the proportion of rural small goods logistics in all urban and rural logistics, \( R_u \)-- disposable income of urban residents, \( R_c \) -- the per capita disposable income of rural residents, \( P_u \) -- the number of urban permanent residents, \( P_c \) -- the number of rural permanent residents, \( \varepsilon \) -- the correction coefficient. At the same time, considering the future policy support factors to stimulate and induce the effect of response to the impact of demand and supply, express volume data in 2014 and 2015 were combined to adjust the result. The demand of small parts logistics in rural areas of each county and city is shown in the following table:

| Country           | 2016   | 2017   | 2018   | 2019   | 2020   |
|-------------------|--------|--------|--------|--------|--------|
| QiongHai          | 37.86  | 50.59  | 67.59  | 90.30  | 120.64 |
| LingShui          | 17.07  | 22.80  | 30.46  | 40.70  | 54.38  |
| TunChang          | 72.22  | 96.49  | 128.91 | 172.23 | 230.10 |
| QiongZhon         | 9.70   | 12.96  | 17.32  | 23.14  | 30.91  |
| DanZhou           | 20.85  | 27.86  | 37.22  | 49.73  | 66.44  |

3. Technical and economic analysis of small parts distribution mode in rural areas of Hainan
According to the existing logistics requirements and technical conditions in Hainan province, the preliminary mode of rural small-piece logistics development in Hainan province is summarized as joint distribution mode, which is the distribution activity jointly organized and implemented by multiple logistics (express delivery) enterprises. Based on a logistics information platform and the market mechanism, the scattered small goods of various e-commerce and logistics enterprises are
integrated to a certain scale according to the direction of cargo flow, and then one of them is entrusted for unified distribution, or a special distribution agency is entrusted for unified distribution of their goods through a distribution and transportation network system, so as to realize the intensification of goods and distribution[9].

By using the mode of joint distribution in urban and rural logistics, distribution enterprises can make systematic planning in terms of distribution time, location, quantity and route. This kind of distribution method is conducive to save transportation resources and increase full load rate of transport vehicles, and to some extent solve the problem of scattered rural logistics nodes and insufficient material flow.

3.1. Bus pick-up mode
With the help of rural roads and urban-rural bus network, we adopt a certain cooperative operation mechanism and service mode, and use the spare space such as the trunk of rural bus to complete the delivery of small goods. On the basis of joint distribution mode, bus pick-up mode is a kind of economic, efficient and practical method, combining bus stations with the logistics distribution network, and makes use of the existing routes and frequency of the bus company throughout the countryside. In addition to meeting the requirements of rural passenger buses, bus vehicles are used to carry rich space to provide small logistics piggy-back service to villages along the route.

3.2. Logistics special-purpose vehicle distribution mode
On the basis of joint distribution mode, logistics special-purpose vehicle distribution mode pays more attention to the safety and convenience of express delivery. Through third-party logistics companies, the unified distribution of all enterprises collecting express delivery to rural areas by express delivery vehicles can ensure the timeliness and safety of express delivery. Due to the need to set up a new transport company and purchase distribution vehicles, the establishment and development of logistics special-purpose vehicle distribution mode requires greater upfront investment. In addition, logistics special-purpose vehicle distribution mode does not provide passenger transport services like bus pick-up mode, so a larger amount of material flow is needed to ensure the normal operation of this mode.

3.3. Logistics distribution mode selection based on Logit model
Suppose that a rural small-piece logistics line is set up in a county with n villages and towns along the route. \( d_i \) -- distance from village i to previous site on the route. \( q_i \) -- estimated delivery demand of village i. \( c \) -- express delivery price for a parcel. \( \bar{c} \) -- delivery price of a parcel. It is assumed that the express price of each village is the same and does not change when transportation distance are changing, according to the survey results, the ratio of express volume to delivery volume is 1:4. \( \bar{\lambda} \) is supposed to be unit distance cost on transportation of an ordinary 29 passenger vehicle. Annual subsidy cost for site service personnel is \( w_f \).

Thus, it can be concluded that the income of rural small-piece logistics business of this line is:

\[
I_{bus} = \sum_{i=1}^{n} cq_i + \frac{1}{4} \sum_{i=1}^{n} \bar{c} q_i \tag{8}
\]

In the equation, the first item on the right is the income of express, and the second item is the income of delivery. For bus pick-up mode, there is no vehicle purchase cost, and the station service personnel need to be placed in each village, so the cost of the whole transport line is:

\[
C_{bus} = w_f \times n + \sum_{i=1}^{n} d_i \times \bar{\lambda} \tag{9}
\]
In the equation, the first item on the right is the salary of service personnel at the distribution site, and the second item is the running cost of vehicles. As for special-purpose vehicle distribution mode, since there is a vehicle purchase cost and no need to place service personnel in each village, the service can be provided by special vehicle personnel, so the cost of the whole transportation line is:

$$C_v = f + \sum_{i=1}^{n} d_i \times \lambda$$  \hspace{1cm} (10)

At the same time, compared with bus pick-up mode, special-purpose vehicle distribution mode has fewer intermediate links and higher express safety features. Taking these factors into consideration as the scale factor of express delivery price, the revenue formula of special-purpose vehicle distribution mode can be rewritten as follows:

$$I_v = \sum_{i=1}^{n} \delta \cdot c d_i + \frac{1}{4} \sum_{i=1}^{n} \delta c d_i$$  \hspace{1cm} (11)

$\delta$ -- the scale factor, $\delta \geq 1$

Through the formula above, we can calculate the estimated subsidy amount $R$ of the two distribution modes according to the following formula:

$$\frac{R + I - C}{C} = \eta \rightarrow R = \eta C + C - I$$  \hspace{1cm} (12)

$\eta$ -- the benchmark rate of return of industry.

By calculating the subsidy amount of two different modes for the same location, Logit model can be used to obtain the probability of choosing the operation mode of rural small logistics in this region$^{[10]}$:

$$P_a = \frac{\exp(-R_a/\sum_a R_a)}{\sum_a \exp(-R_a/\sum_a R_a)}$$  \hspace{1cm} (13)

In the equation above, $a \in \{1, 2\}$ when $a = 1$ represents bus pick-up mode, when $a = 2$ represents logistics special-purpose vehicle distribution mode. Taking Lingshui County as an example, it is assumed that a rural logistics route will be opened in Lingshui, which includes four villages: Wenluo, Longguang, Yingzhou and Sancai. Basic situation of the four villages is shown in the following table:

|                  | Wenluo | Longguang | Yingzhou | Sancai |
|------------------|--------|-----------|----------|--------|
| Population       | 1.7    | 2.1       | 0.73     | 1.24   |
| Demand for logistics | 3.5    | 4.7       | 1.7      | 2.37   |

Suppose: $c = 0$, $\lambda = 5$, $\lambda = 0.3$, $wf = 0.8$. For special-purpose vehicle distribution mode, van of 0.5 ton load. $f = 10$, $\delta = 1.2$.

According to the calculation, at the beginning of the operation of this line, the probability of being selected for bus pick-up mode and special-purpose vehicle distribution mode are 64% and 36% respectively. Subsidy needed is 13,900 yuan for bus pick-up mode and 19,808 for the other mode.

In the long run, assuming that the annual growth rate of express business along the route is 20% and the project term is 5 years, the probability of being selected for bus pick-up mode and special-purpose vehicle distribution mode are 47% and 53% respectively. Subsidy needed is 43,766 yuan for bus pick-up mode and 42,900 for the other mode.
4. Mode comparison and conclusion

Through analysis and comparison of economic costs of the two modes of transportation under mode of joint distribution, bus pick-up mode has small initial input and low operating risk, which is suitable for the initial stage of small rural logistics distribution project, in order to solve the problem of rural logistics and stimulate the growth of material flow.

As for special-purpose vehicle distribution mode, large basic material flow and financial subsidies are needed to ensure the normal operation of third-party logistics companies. Therefore, this model is more suitable for the mature stage of rural small logistics projects, or to serve target groups in towns with large population and economic aggregate or in concentrated contiguous administrative villages.

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