Forecast and Solution of Urban Freight Distribution Demand in Xiamen

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Abstract. In order to face the challenge of changing market demand, it is necessary to reasonably predict the demand for urban freight distribution in Xiamen and solve the market development potential problem. Firstly, by using Pearson correlation test and multiple regression analysis method, this paper fully considers the influencing factors of demand prediction, and forecasts Xiamen’s urban distribution demand of postal services, and the urban distribution demand of grain and oil, fresh food, FMCG, etc. The forecast results show that by 2025, the total postal services will reach 28.2 billion yuan, and the urban distribution demand for grain and oil, fresh food, FMCG and other products will reach 38.5 billion yuan. Then, based on forecasting the future demand of Xiamen’s urban freight distribution, this paper analyzes the problems in the development of Xiamen’s urban freight distribution, and proposes solutions accordingly, aiming to promote the efficient and high-quality development of Xiamen’s urban distribution.

Keywords. Freight distribution demand forecast, Pearson correlation test, multiple regression analysis, postal services delivery demand, distribution demand for grain and oil, fresh food, FMCG

1. Introduction

The development of Xiamen’s modern logistics industry started in the late 1990s. Benefited from the policy advantages of Municipalities with Independent Planning Status, Economic Special Zone, and Southeast International Shipping Center, the logistics industry of Xiamen occupies a prominent position in the development pattern of the country’s modern logistics industry.

In recent years, Xiamen’s urban distribution industry has made great progress, showing the characteristics of high technology, diversification, and excellent service. However, it is also facing the challenge of changes in market demand under the new situation. It is necessary to reasonably predict the demand for urban goods distribution and solve the problem of market development potential.

2. Literature Review

Wang and Meng (2007) established a dynamic analysis model of multiple linear
regression based on historical sample data, and verified the feasibility and effectiveness of model fitting and prediction results through simulation experiments [1]. Li et al. (2011) established a cold chain logistics demand prediction model based on multiple linear regression analysis, and used Eviews software to test it, which proved the scientificity and reliability of the model [2]. Yang (2016) constructed a combined forecasting model of distribution demand in multiple regions in the logistics network, which can make full use of the advantages of different forecasting methods to obtain better forecast results [3]. Li (2017) constructed a gray linear combination model to predict the logistics demand of agricultural products in Beijing, and gave relevant suggestions to increase the logistics supply of agricultural products [4].

Li et al. (2018) proposed a two-stage combined forecasting model called GSPS-BPNN, and used this model in the forecast of logistics demand in Chengdu and Tianjin. The results show that the model is superior to the single-stage single prediction model in terms of prediction accuracy and prediction stability [5]. Wu et al. (2019) established a combined forecasting model based on three single forecasting models, and used this model to forecast Chongqing’s port logistics demand. Research shows that combined forecasting models are more stable than single forecasting models [6]. Li et al. (2021) proposed a regional logistics prediction model based on deep learning, and proved that the model has good prediction performance and strong stability through simulation experiments [7].

3. Method

In this paper, Pearson’s correlation test and multiple regression methods are utilized to quantitatively analyze the related factors of Xiamen’s urban freight transportation [8].

3.1. Pearson Correlation Test

X, Y are two variables, if the correlation coefficient is larger, the correlation is stronger. The closer the correlation coefficient is to 1 or -1, the stronger the correlation; the closer the correlation coefficient is to 0, the weaker the correlation [9].

\[ \rho_{x,y} = \frac{\text{cov}(X,Y)}{\sigma_x \sigma_y} = \frac{E((X - \mu_X)(Y - \mu_Y))}{\sigma_x \sigma_y} = \frac{E(XY) - E(X)E(Y)}{\sqrt{E(X^2) - E^2(X)}\sqrt{E(Y^2) - E^2(Y)}} \]  \hfill (1)

\[ \rho_{x,y} = \frac{-\frac{N\sum XY - \sum X \sum Y}{N\sum x^2 - (\sum x)^2}}{\sqrt{N\sum x^2 - (\sum x)^2} \sqrt{N\sum y^2 - (\sum y)^2}} \]  \hfill (2)

\[ \rho_{x,y} = \frac{\sum \frac{XY}{N} - \frac{\sum X \sum Y}{N}}{\sqrt{\left(\sum \frac{X^2}{N} - \frac{(\sum X)^2}{N}\right) \left(\sum \frac{Y^2}{N} - \frac{(\sum Y)^2}{N}\right)}} \]  \hfill (3)
3.2. Multiple Regression Analysis

Suppose there is a linear correlation between the dependent variable \( y \) and the independent variables \( x_1, x_2, x_3, \ldots, x_n \), then the multiple linear regression model can be expressed by equation (1) as:

\[
y = b_0 + b_1 \times x_1 + b_2 \times x_2 + \cdots + b_n \times x_n
\]  
(4)

Among them, \( b_0, b_1, b_2, \ldots, b_n \) are undetermined coefficients, which are determined by the least square method. \( x_1, x_2 \cdots x_n \) represents independent variables [10].

The equations of the least square method are:

\[
Q(b_0, b_1) = \sum_{i}^{n} (y_i - \hat{b}_0 - \hat{b}_1 \times x_i)^2 = \min_{b_0, b_1} \sum_{i}^{n} (y_i - b_0 - b_1 \times x_i)^2
\]  
(5)

\[
\hat{b}_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})}
\]  
(6)

\[
\hat{b}_0 = \bar{y} - \hat{b}_1 \bar{x}
\]  
(7)

The goodness of fit test is generally realized with coefficient of determination \( R^2 \).

\[
R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST}
\]  
(8)

Coefficient of determination \( R^2 \) measures how well the regression line fits the observed data. Usually, the observations are partially on the regression line, which is \( 0 < R^2 < 1 \). The closer \( R^2 \) is to 1, the better the fit of the regression line; The closer \( R^2 \) is to 0, the worse the fit of the regression line [11].

4. Elements of Demand Forecasting and Data Sources

4.1. Economic Level and Scale

The most fundamental reason that determines the demand for urban distribution is the overall development level and scale of the economy. Table 1 shows the sales volume of main grain, oil and food products in Xiamen city. If a region has a high level of economic development and a large economic aggregate, the greater its demand for urban distribution services such as cargo transportation and distribution, and the stronger the growth in demand for urban distribution [12]. From 2007 to 2018, Xiamen’s GDP increased from 141.81 billion yuan to 479.14 billion yuan, with an average annual growth rate of 11.8%, shown in Figure 1.
Figure 1. The relationship among Xiamen’s gross regional product, total postal business, and total sales of grain, oil and food.

Table 1. Sales volume of main grain, oil and food products in Xiamen city (Unit: 10,000 tons).

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>15.86</td>
<td>24.31</td>
<td>23.73</td>
<td>28.13</td>
<td>24.44</td>
<td>11.58</td>
<td>24.81</td>
<td>24.81</td>
</tr>
<tr>
<td>Miscellaneous grains</td>
<td>112.37</td>
<td>151.47</td>
<td>145.50</td>
<td>159.61</td>
<td>121.00</td>
<td>248.31</td>
<td>442.80</td>
<td>442.80</td>
</tr>
<tr>
<td>Edible vegetable oil</td>
<td>63.78</td>
<td>55.84</td>
<td>76.41</td>
<td>87.53</td>
<td>104.54</td>
<td>40.58</td>
<td>44.77</td>
<td>44.77</td>
</tr>
<tr>
<td>Pork</td>
<td>3.96</td>
<td>8.51</td>
<td>7.67</td>
<td>9.71</td>
<td>10.64</td>
<td>6.68</td>
<td>8.46</td>
<td>8.46</td>
</tr>
<tr>
<td>Beef</td>
<td>0.02</td>
<td>0.10</td>
<td>1.46</td>
<td>1.04</td>
<td>1.52</td>
<td>2.83</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>Lamb</td>
<td>0.00</td>
<td>0.03</td>
<td>0.04</td>
<td>0.04</td>
<td>0.08</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Poultry meat</td>
<td>0.32</td>
<td>5.00</td>
<td>5.46</td>
<td>6.59</td>
<td>7.27</td>
<td>4.05</td>
<td>2.14</td>
<td>2.14</td>
</tr>
<tr>
<td>Fresh egg</td>
<td>0.61</td>
<td>1.12</td>
<td>0.75</td>
<td>1.03</td>
<td>0.89</td>
<td>0.76</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Total</td>
<td>209.21</td>
<td>277.92</td>
<td>290.16</td>
<td>309.03</td>
<td>300.38</td>
<td>323.99</td>
<td>552.71</td>
<td>552.71</td>
</tr>
</tbody>
</table>

During the same period, the average annual growth rate of postal business was as high as 41%. At the same time, grain, oil, food, etc., as the main urban distribution objects, their sales account for more than 70% of the transaction volume of commodities with more than 100 million yuan. From 2011 to 2018, the sales of grain, oil and food rose from 9.11 billion yuan to 19.93 billion yuan, and the demand rose from 209.2 tons to 552.7 tons, indicating that the demand for urban distribution has also increased. It shows that high-speed economic growth has greatly promoted the demand for urban distribution. Economic growth has an increasing demand for logistics, and its dependence on logistics has become stronger and stronger.

4.2. Industrial Structure

In recent years, Xiamen’s industrial structure has been continuously adjusted, the proportion of the primary and secondary industries has continued to decline, and the proportion of the tertiary industry has continued to increase, from 45.2% in 2000 to 58.2% in 2018. Because the tertiary industry includes many industries, wide distribution of outlets, high added value, and numerous lines, the requirements and demands for urban
distribution are increasing, shown in Figure 2.

![Figure 2. Industrial structure of Xiamen city.](image)

### 4.3. Social Development Level

Urbanization. In 2010, the urbanization rate of Xiamen City had reached 88.3%, and by 2018, the urbanization rate had reached 89.1%. The demand for urban distribution is even more prominent.

Population development. Population development includes total population and size, population composition, etc. Its development status not only restricts the process of modernization and the speed of economic development, but also has an important impact on the consumption structure of residents. The relationship between total postal business volume and per capita consumption expenditure and permanent population is shown in Figure 3.

The income level of urban residents. With the development of urban economy and the improvement of urbanization, the per capita disposable income of urban residents has also increased, and the purchasing power of urban residents has also increased accordingly. Diversified and personalized life needs are gradually emerging, and the urban distribution volume is also "increasing" as the consumption level of urban residents increases [13].

Internet penetration rate. 70% of online shopping requires express delivery business, and the volume of goods produced has accounted for more than half of the express delivery business. According to data, in 2017, the penetration rate of Internet users in Xiamen reached 168%, and the penetration rate of fixed broadband households reached 92%. The penetration rate of 3G/4G users has reached 120%, the number of Internet users has exceeded 6 million, and the number of 4G mobile phone users has exceeded 4 million. The huge group of netizens and mobile phone users has promoted the demand for urban distribution in Xiamen.

### 4.4. Degree of Marketization (Wholesale and Retail Industry)

The wholesale and retail industry has a wide variety of goods, and the circulation speed in the market is relatively fast, and the sales range is relatively wide. From 2007 to 2018, the average annual growth rate of total retail sales of consumer goods in Xiamen was 13%. The high-speed total retail sales of consumer goods have driven the growth of urban distribution demand. The relationship between total social consumer retail sales and total postal business, grain, oil and food sales is shown in Figure 4.
Figure 3. The relationship between total postal business volume and per capita consumption expenditure and permanent population.

Figure 4. The relationship between total social consumer retail sales and total postal business, grain, oil and food sales.

The openness of the market is also a factor that affects the delivery volume. With the construction of the economic zone on the west side of the Straits and the implementation of the One Belt One Road strategy, Xiamen City is accelerating its integration with surrounding areas. Many large foreign logistics companies have poured into Xiamen’s logistics market, which has brought a huge impact to the traditional transportation market structure [14].

4.5. Other Factors

Transport infrastructure factors. The development of highways, urban roads and other infrastructure is an important factor that affects urban distribution. For example, the number of stops, area, and accessibility of urban roads has a certain impact on the scale of urban distribution demand. At the same time, the rationality and smoothness of urban traffic is one of the important indicators to measure the level of urban distribution services [15].

Macro policy factors. The government’s equation of relevant laws and regulations to regulate market economic behavior is conducive to improving the fairness and transparency of the market, and it is also conducive to the development of the logistics industry, which can promote the development of Xiamen’s logistics and distribution
needs. At the same time, changes in macroeconomic policies and management systems will stimulate or inhibit logistics demand.

5. Demand Forecast

5.1. Prediction of Urban Delivery Demand for Postal Services

This report uses Pearson’s correlation test to focus on economic and social indicators such as total postal business and regional GDP, population, total retail sales of consumer goods, per capita disposable income, and per capita consumption expenditure [16]. It is found that the total volume of postal business is highly correlated with economic and social factors, and the correlation is as high as 95%, indicating that the total economic volume and population are the key factors determining postal business, as shown in Table 2.

<table>
<thead>
<tr>
<th>Total postal business (100 million yuan)</th>
<th>Gross regional product (100 million yuan)</th>
<th>Permanent population (ten thousand people)</th>
<th>Total retail sales of consumer goods (100 million yuan)</th>
<th>Per capita disposable income (ten thousand yuan)</th>
<th>Per capita consumption expenditure (ten thousand yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>0.968</td>
<td>0.960</td>
<td>0.965</td>
<td>0.959</td>
<td>0.961</td>
</tr>
<tr>
<td>0.968</td>
<td>1.000</td>
<td>0.923</td>
<td>0.998</td>
<td>0.996</td>
<td>0.996</td>
</tr>
<tr>
<td>0.960</td>
<td>0.923</td>
<td>1.000</td>
<td>0.923</td>
<td>0.920</td>
<td>0.911</td>
</tr>
<tr>
<td>0.965</td>
<td>0.998</td>
<td>0.923</td>
<td>1.000</td>
<td>0.994</td>
<td>0.992</td>
</tr>
<tr>
<td>0.959</td>
<td>0.996</td>
<td>0.920</td>
<td>0.994</td>
<td>1.000</td>
<td>0.995</td>
</tr>
<tr>
<td>0.961</td>
<td>0.996</td>
<td>0.911</td>
<td>0.992</td>
<td>0.995</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Regional GDP, total retail sales of consumer goods, per capita disposable income, and per capita consumption expenditure are all indicators in the economic field, and they are highly correlated, with a correlation of up to 99%. Therefore, in order to avoid the influence of the correlation between the indicators, we built a population + economy model for forecast integration. Four models of permanent population + regional GDP, permanent population + total retail sales of consumer goods, permanent population + per capita disposable income, and permanent population + per capita consumption expenditure were constructed for prediction [17], as shown in Table 3.
Table 3. Forecast model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Population + regional GDP model (1)</th>
<th>Population + total retail sales model of social consumer goods (2)</th>
<th>Population + per capita disposable income model (3)</th>
<th>Population + per capita consumption expenditure model (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-19.659</td>
<td>-17.759</td>
<td>-12.872</td>
<td>-12.306</td>
</tr>
<tr>
<td>Population GDP</td>
<td>2.105***</td>
<td>2.197**</td>
<td>2.380 **</td>
<td>2.341 ***</td>
</tr>
<tr>
<td>The total retail sales of social consumer goods</td>
<td>1.308***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disposable income per capita</td>
<td>1.170***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per capita consumption expenditure</td>
<td></td>
<td></td>
<td></td>
<td>1.841 ***</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.967</td>
<td>0.963</td>
<td>0.958</td>
<td>0.965</td>
</tr>
</tbody>
</table>

Note: *, ** and *** represent the significance level of 0.1, 0.05 and 0.01 respectively.

The prediction of parameters mainly includes two types [18].

The first is the parameters predicted based on planning documents, including three parameters including population, regional gross product, and per capita disposable income.

- **Population parameters**: According to the “Xiamen Population Development Plan (2016-2030)”, Xiamen’s permanent population will be controlled within 4.5 million in 2020, and will reach 5.5 million in 2030.

- **GDP**: Since the outline of the 14th Five-Year Plan for National Economic and Social Development of Xiamen City has not yet been released, the data forecast for 2020 involved is temporarily based on the outline of the 13th Five-Year Plan for National Economic and Social Development of Xiamen City. According to the outline of the 13th Five-Year Plan for National Economic and Social Development of Xiamen City, the average annual growth of regional GDP is about 8.5%.

- **Disposable income per capita**: According to the outline of the 13th Five-Year Plan for the National Economic and Social Development of Xiamen City, the average annual growth rate of per capita disposable income is about 8.5%.

The second is the parameters predicted based on historical trends, including the total retail sales of consumer goods and per capita consumer expenditure.

- **The total retail sales of consumer goods**: From 2007 to 2018, the average annual growth rate of total retail sales of consumer goods was about 12.8%. At the same time, combined with the high correlation with the regional GDP, it is predicted that the average annual growth rate of the total retail sales of consumer goods will be about 10.8% by 2025.

- **Per capita consumption expenditure**: From 2007 to 2018, the average annual growth rate of per capita consumption expenditure was about 7.17%. At the same time, combined with the high correlation of per capita disposable income, it is predicted that the average annual growth rate of consumer spending will be about 8.12% by 2025.

According to the above-built model and the prediction of parameters, the total postal business volume in 2025 is predicted, as shown in Figure 5.
5.2. Forecast Analysis of Urban Distribution Demand for Grain and Oil, Fresh Food, Fast-Moving Consumer Goods, etc.

With the continuous improvement of people’s requirements for quality of life and the level of economic development, the demand for urban distribution such as grain and oil, fresh food, and fast-moving consumer goods is also increasing [19]. Table 4 shows the transaction status of delivery objects in major cities, which to a certain extent reflects the scale of urban delivery demand.

Table 4. 2015-2018 grain and oil, fresh food, fast-moving consumer goods and other transactions (Unit: 100 million yuan).

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain, oil, food</td>
<td>140.92</td>
<td>156.71</td>
<td>144.17</td>
<td>199.34</td>
</tr>
<tr>
<td>Cereals and oils</td>
<td>1.24</td>
<td>4.07</td>
<td>4.18</td>
<td>3.59</td>
</tr>
<tr>
<td>Meat, Poultry and Eggs</td>
<td>25.37</td>
<td>25.05</td>
<td>22.93</td>
<td>11.42</td>
</tr>
<tr>
<td>Aquatic products</td>
<td>48.92</td>
<td>53.35</td>
<td>50.72</td>
<td>117.10</td>
</tr>
<tr>
<td>Vegetables</td>
<td>54.59</td>
<td>65.30</td>
<td>54.95</td>
<td>55.81</td>
</tr>
<tr>
<td>Dried and fresh fruit category</td>
<td>8.45</td>
<td>8.94</td>
<td>9.65</td>
<td>8.68</td>
</tr>
<tr>
<td>Drinks</td>
<td>1.58</td>
<td>0.61</td>
<td>0.65</td>
<td>0.50</td>
</tr>
<tr>
<td>Tobacco and alcohol</td>
<td>0.99</td>
<td>1.11</td>
<td>1.07</td>
<td>1.19</td>
</tr>
<tr>
<td>Clothing, shoes and hats, knitted textiles</td>
<td>0.55</td>
<td>0.49</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>Clothing</td>
<td>0.31</td>
<td>0.27</td>
<td>0.21</td>
<td>0.22</td>
</tr>
<tr>
<td>Shoes and hats</td>
<td>0.21</td>
<td>0.20</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>Knitted textiles</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Daily necessities</td>
<td>2.12</td>
<td>1.03</td>
<td>0.64</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Considering that the distribution needs of grain, oil, fresh food, fast-moving consumer goods, etc. are highly correlated with the gross production value and the total retail sales of consumer goods, so the development trend of regional gross product and total retail sales of consumer goods is used to forecast the urban distribution needs of grain and oil, fresh food, and fast-moving consumer goods [20].

According to the above model, combined with economic development level, industrial structure, social level, degree of marketization and other factors, the demand for grain and oil, fresh food, fast-moving consumer goods, etc. is predicted, and the results are shown in Figure 6.
6. Conclusions

6.1. Conclusion of Postal Business Demand Forecast

This report combines the prediction results of the four types of models and predicts that by 2025, the total postal business will reach 28.2 billion yuan, which is 2.76 times the total postal business in 2019.

The total volume of postal services is the embodiment of the volume of postal services under the condition of unchanged prices. According to the forecast of the total postal business volume, by 2025, Xiamen’s express delivery service companies will have completed a total of 1176.2 million pieces of business, exceeding 1 billion pieces.

6.2. Forecast Conclusions of Urban Distribution Demand for Grain, Oil, Fresh Food, Fast-Moving Consumer Goods, etc.

By 2025, the urban distribution demand for grain, oil and food will reach 38 billion yuan, the distribution demand for beverages will reach 96 million yuan, the distribution demand for tobacco and alcohol will reach 228 million yuan, and the distribution demand for clothing, shoes, hats, and knitted textiles will reach 83 million yuan, the daily necessities distribution demand will reach 106 million yuan, and the distribution demand in major cities will reach 38.5 billion yuan, which is nearly double the 2018.

7. Recommendation

After predicting and analyzing the demand for urban freight distribution in Xiamen, combined with the problems faced by Xiamen’s urban distribution work, it is planned to carry out the following work to solve the problem of reducing cost and increasing efficiency of urban distribution in Xiamen.

First, in terms of the urban distribution network system, further promote the delineation and use of Xiamen’s urban dedicated truck lanes, and provide more precise and precise parking guidance policies and rules.

Second, in terms of information system management, strengthen the standardization of logistics platforms to promote information sharing between government and
enterprises, and use government information platforms to rationally plan freight routes.

Third, in terms of improving operation methods, promote the application of science and technology in urban freight logistics and distribution, and rely on the Internet of Things technology to strengthen the coordination of logistics resources.

Fourth, in terms of market development guarantees, it is necessary to establish a unified public information platform for urban distribution and coordinated supervision of the urban distribution credit system, and at the same time encourage data mining and analysis of government services, and encourage and support enterprises to explore the optimization and exploration of distribution electronic map guidance routes.

References


