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A Study on Model of Regional Logistics Requirements Prediction

*† Bo Lu, Nam-Kyu Park**

† R&D Center of Electronic Commerce and Modern Logistics, Dalian University, Dalian 116-622, China
** School of Port and Logistics, TongMyong University, Busan 608-711, Korea*

Abstract : *It is extremely important to predict the logistics requirements in a scientific and rational way. However, in recent years, the improvement effect on the prediction method is not very significant and the traditional statistical prediction method has the defects of low precision and poor interpretation of the prediction model, which cannot only guarantee the generalization ability of the prediction model theoretically, but also cannot explain the models effectively. Therefore, in combination with the theories of the spatial economics, industrial economics, and neo-classical economics, taking city of Erdos as the research object, the study identifies the leading industry that can produce a large number of cargoes, and further predicts the static logistics generation of the Erdos and hinterlands. By integrating various factors that can affect the regional logistics requirements, this study established a logistics requirements potential model from the aspect of spatial economic principles, and expanded the way of logistics requirements prediction from the single statistical principles to an new area of special and regional economics.*

Key words : *Spatial economics, Logistics requirements potential model, Regional logistics prediction, Economic distance*

1. Introduction

The regional logistics requirements prediction was firstly proposed in the 1990s (Xia, 2010). After nearly 20 years of development, it has made great progress. By sorting out comprehensive overview about existing method, most researchers deal with them as a regression problem. According to the development process and the level of intelligence, it can be roughly divided into three stages:

The prediction method based on statistics in the first stage. Main methods include regression analysis (Chu, 2010), elasticity coefficient method (Jing, 2010), freight intensity method, clustering method, gray theory model (Bao, 2005), Markov chain (He, 2011), input-output model (Guo, 2009), space-time multi-term probability model and decision support system, etc (Chen, 2006). The major features of this type of methods can process the sequencing and linear data, and explain the construct models effectively.

The prediction method based on artificial intelligence in the second stage. Later on, to enhance the prediction accuracy, the researcher (Yin, 2010) adopted the artificial intelligence method, such as the artificial neural network (ANN) and its improvement model. By introducing the artificial intelligence factors into the traditional method, such as the learning and generalization ability of neural networks, expert system inference rules, etc, then the regional logistics requirements prediction accuracy can be improved.

The prediction methods based on statistical learning theory is the third stage. To further enhance the accuracy and stability of the prediction models, in recent years, the researchers started to explore the prediction method based on the principle of structural risk minimization (Huang, 2008). Such methods are represented by the support vector machine (SVM).

Although certain achievements have been made, some urgent problems still exist in the regional logistics requirements prediction (Luo, 2010), mainly as follows: first, when the quantity of learning samples is limited, the learning process error is easy to converge to a local minimal point, and the learning accuracy is difficult to guarantee; when there are many learning sample variables, they fall into the "dimension disaster". Second, mainly rely on the empirical risk minimization principle. Therefore, the generalization capability of the prediction model cannot be guaranteed from theory, which makes the predictive models after training to have no stable prediction effect for the new logistics requirements data set. Third, since the concept of regional logistics has been introduced to China for not a long time, many logistics standards are not unified, and also lack of direct statistical data. The

† Corresponding author, Life member, lubo_documents@hotmail.com +86)135-0426-1861
* Life member, nkpark@tu.ac.kr 051)629-1861

historical data for researching prediction have to be substituted by the related cargo quantity, which affect the empirical study of the prediction methods. Especially in china, most of the literatures are only an overview of the method, and almost no actual regional logistics data are used for predictive analysis, which makes many studies lack of practical significance.

In recent years, among the relevant study in spatial economics, the theoretical breakthrough made by the economists Krugman, Fujita, Glaeser, and Baldwin, et al brought a new wave of the industrial clustering study (Zhao, 2006). But regrettably, there is still very less experiences and empirical support in the logistics industry clustering and logistics requirements prediction; therefore, this study expects to make some efforts in this area.

The paper is structured as follows: after the introductory section of Chapter 1, there will be followed by the description of the Gravity model and Reilley Principle. In so doing, the research procedure is included in Chapter 2. Moreover, the research scope and logistics requirements prediction in Chapter 3. Finally, conclusions are drawn in Chapter 4.

2. Research Method

2.1 Gravity model

Gravity model is based on universal gravitation of Newtonian typical mechanics. Tinbergen (1962) and Poyhonen (1963) set forth one complete and sample economics model - gravitation model for its development and extension in economics area. The ideal of the model is that single trading amount of the two economies are in proportional to its economic scale (expressed by GDP) and it is inversely proportional to the distance. The model has been successfully verified in aspects of actual analysis from many experts. Meanwhile, gravity model is expansively included in various references due to focus from economic geographer.

An important feature of gravity model is that its basic term is not changed. Gravity model could be applied to various fields if the definition of parameters and weights are suitability changed (Guo et al, 2010). This study would estimate its parameters from the basic model. And, the definition of model form is specified as following:

$$F_{ij} = K\frac{Y_i \cdot Y_j}{D_{ij}} \tag{1}$$

where, K is a constant (it is called as gravity coefficient, but 1 in this study); Y_i and Y_j are endogenous variables, which are balanced by the specified conditions required by the model. The endogenous variables set in this study, are static cargo quantity of each city and GDP; D_{ij} is the space distance. The gravity model could be expressed as:

$$F_{ij} = \frac{(Q_i \cdot GDP_i)\times(Q_j \cdot GDP_j)}{D_{ij}^2} \tag{2}$$

It refers to the strength of spatial logistics of the two centers (city and economy points) located at different position. One or more centers in the area attract surrounding areas. It means that area is a gravity place. At different position of the area, there has different distribution of field strength. Central city is a comprehensive economic center with certain scale. The more scale of the city, the more developed economy will be and the strength of the gravity area will be greater. City strength at a distance with one city is proportional to square root of product between the scales and developing degree of the city and it is inversely proportional to square of distance d.

$$S = \frac{\sqrt{Q \cdot G}}{d^2} \tag{3}$$

where, S is field strength, Q is static cargo quantity of each city, G is the GDP, d is the space distance, the above mentioned term is the calculating formula of strength of any city with distance of d apart from center city.

2.2 Reilley Principle

The purpose of introducing gravity model by Reilley is to analyze the market boarder of one area. Two main factors of scale and distance for gravity model are introduced in Reilley principle. Scale is corresponding to quality of Newton gravity model. Reilley claimed that the generating retail trade amount in its surrounding area of one city is proportional to its population scale and it is inversely proportional to distances of cities.

The formula is $A_i = P_i/d_{ij}^2$, created trading amount in i city, are generated by i city attracting citizens of j city. The above-mentioned formula is regarded as potential interaction flow from i to j. Thereafter, Converse modified and expanded the formula and set forth Reilley - Converse intermediate point formula:

$$d_{ix} = d_{ij}/(1+\sqrt{P_j/P_i}) \tag{4}$$

where, i and j refer to two market centers, x is market intermediate point, d_{ix} is distance from i to x, d_{ij} is distance from i to j, P_i and P_j refer to population of the two market centers.

Based on Reilly – Converse formula, this study has defined limit between the service areas of the two cities. Attracting scopes of the two cities could be divided to verify breaking points of the two cities. Inspection distance is d_{12}. It is shown as figure 1.

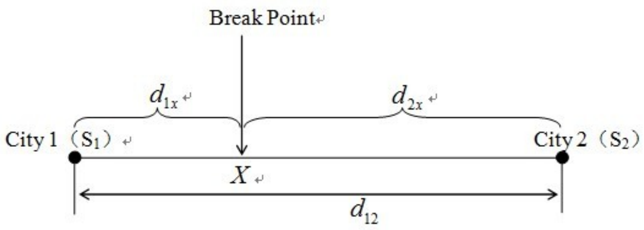

Fig. 1 Identifying break point based on Reilley Principle

It is assumed that gravity of city 1 and city 2 are S_1 and S_2. Division of the service areas of the two cities is to identify the broke points between them. d_{1x} and d_{2x} could be set as the distance of city 1 and city 2 from the break points, as

$$d_{1x} + d_{2x} = d_{12} \tag{5}$$

As conception of gravity model, it is the same for people who are locating at the break point, go to any cities. That means at the break point, gravity is the same in city 1 and city 2, as:

$$S_1/d_{1x}^2 = S_2/d_{2x}^2 \tag{6}$$

From formula (4), $d_{1x} = d_{12} - d_{2x}$ is obtained, inserting it into formula (6):

$$d_{1x} = d_{12}/(1+\sqrt{S_2/S_1}) \tag{7}$$

so: $$d_{2x} = d_{12}/(1+\sqrt{S_1/S_2}) \tag{8}$$

Formula (7) and (8) define the limit of service areas of the two cities.

3. Result Analysis

3.1 Study scope

The logistics requirements of center city is depended by the surrounding city, and it also has a certain geographic range (Li, et al, 2007), therefore, The study is centering on city of Erdos, scope of I, II, III area surrounding, I area is as per radius of 100 kms, II area is as per radius of 100-300 kms, III area is as per radius of 300-500 kms.

Definition of I, II, III surrounding areas is as following: central city: Erdos; I area: Baotou(B.T.); II area: Hohhot, Shuozhou(S.Z.), Xinzhou(X.Z.), Lvliang(L.L.), Yulin(Y.L.), Wuhai(W.H.) and Bayanzhuoer(B.Y.Z.E.); III area: Beijing (B.J.), Shijiazhuang(S.J.Z.), Taiyuan(T.Y.), Yinchuan(Y.C.), Zhangjiakou(Z.J.K.), Wulanchabu(W.L.C.B.), Linfen(L.F.), Zhongwei(Z.W.), Alashanmeng(A.L.S.M.) and Shizuishan (S.Z.S.).

3.2 Prediction for static cargo quantity

In recent years, Erdos has great regional economic development and the total output value is increased to 264.3 billions RMB in 2011 from 15 billions RMB in 2000 and increasing of per capital GDP is at the leading place in the county. Economic development speed of Erdos has direct correlations with its industrial structure. The main industrial structures are: coal, chemistry, metallurgy, equipment manufacturing, textile, engineering machinery and components, cars and components, natural gas, building materials, farming and animal products, life data and rural capital. By combining with the status of economic development, the following nine industries as Coal, Chemical industry, Building materials, Metallurgy, Equipment manufacturing, Cashmere, Dairy products, Livestock products and the flow of commerce are analysed in combination of status of economic development.

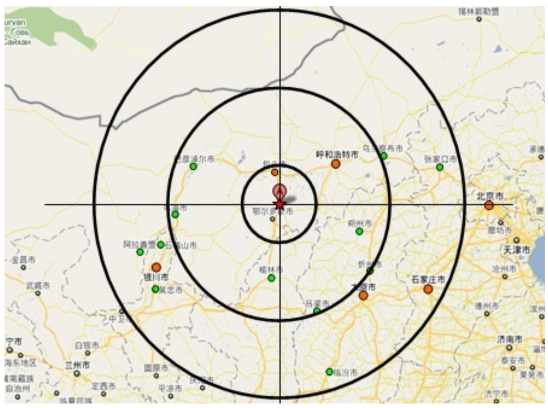

Fig. 2 Radiation area of research scope

Based on data collection of site survey, statistical yearbooks and bulletins, this study, firstly, has calculated the static cargo quantity of 9 industries of Erdos and surrounding three areas by means of data fitting, $Q_n = Q_0 \times (1+x)^{n-1}$. It is shown in table 1.

3.3 Prediction for dynamic logistics requirements

This study would predict dynamic logistic requirements within scope of 18 cities at distance of 500 kms surrounding of Erdos based on gravity model and theory of Reilley Principle.

There are different attracting degree for production and consumption due to key factors of politics and culture of each city. However, partial cities have no gravity due to similar industrial structure and mature development scale.

Therefore, six representative cities are selected as independent attracting points against attraction for static cargo quantity of another 12 cities.

Table 1 Predicting cargo quantity of each city in 2020

Industries \ Cities	B.T.	Hohhot	S.Z.
Coal	2174.14	– –	75676.9
Chemical industry	377.37	373.41	74.66
Building materials	5033.65	1086.85	176.48
Metallurgy	10094.1	70.51	176.48
Equipment manufacturing	5.18	6.57	– –
Cashmere	0.27	0.17	– –
Dairy products	5.46	4.30	2.97
Livestock products	4.39	1.67	0.32
The flow of commerce	2266.72	3051.44	925.90

Industries \ Cities	X.Z.	L.L.	Y.L.	W.H.	B.Y.Z.E.
Coal	22707.74	39733.04	95391.81	3724.00	1768.03
Chemical industry	327.19	71.21	695.56	319.21	1007.94
Building materials	32.59	1593.81	97.70	429.04	721.87
Metallurgy	212.21	4971.72	– –	673.95	– –
Equipment manufacturing	1.13	3.89	2.26	1.09	1.19
Cashmere	– –	– –	– –	– –	3.41
Dairy products	6.32	6.71	6.14	0.88	3.10
Livestock products	0.66	1.14	4.35	0.16	4.39
The flow of commerce	1432.30	1543.19	495.93	312.32	169.04

Industries \ Cities	B.J.	S.J.Z.	T.Y.	Y.C.	Z.J.K.
Coal	75.47	853.92	11415.34	10814.77	3582.22
Chemical industry	437.47	764.66	226.39	837.01	72.93
Building materials	1136.94	10647.79	531.17	1696.48	650.4
Metallurgy	– –	2335.62	1034.88	46.66	4683.59
Equipment manufacturing	41.87	10.45	4.51	2.91	2.21
Cashmere	– –	– –	– –	– –	– –
Dairy products	32.24	17.80	7.32	4.30	8.15
Livestock products	2.16	7.22	0.45	0.80	4.47
The flow of commerce	29570.31	6181.80	4174.02	779.31	1331.48

Industries \ Cities	W.L.C.B.	L.F.	W.Z.	A.L.S.M.	S.Z.S.
Coal	– –	12757.58	– –	5025.96	2942.74
Chemical industry	76.41	37.37	96.63	943.06	503.32
Building materials	1613.52	692.36	– –	59.79	586.26
Metallurgy	272.93	5155.9	– –	374.99	1700.6
Equipment manufacturing	– –	– –	0.36	4.51	0.99
Cashmere	– –	– –	– –	0.29	– –
Dairy products	3.71	8.75	2.65	0.38	1.35
Livestock products	0.18	3.84	0.72	0.25	0.84
The flow of commerce	658.99	1184.78	187.58	91.23	235.19

Source: First-hand data computing results obtained by authors

The reasons can be summarized as following: Erdos, Baotou and Hohehot are called as Golden Triangle of Inner Mongolia. The industrial types and economic growth have competitive trends among the three cities. Beijing, which is within scope of 500 kms, is the national politics, financing and cultural center and has larger gravity. Shijiazhuang and Yinchuan are the capitals of Hebei and Ningxia Provinces, respectively, have certain gravity for economy of surrounding cities. Taiyuan, which is the largest coal production base of Shanxi province, has certain gravity for coal and related industries. Therefore, Erdos, Baotou, Hohehot, Beijing, Shijiazhuang, Taiyuan and Yinchuan are regarded as independent attracting points.

Table 2 Predicting GDP results of each city in 2020

GDP \ Cities	Erdos	B.T.	Hohhot	S.Z.
	2643.23	2460.81	1865.71	670.12
X.Z.	**L.L.**	**Y.L.**	**W.H.**	**B.Y.Z.E.**
554.52	845.51	1756.67	391.12	603.33
B.J.	**S.J.Z.**	**T.Y.**	**Y.C.**	**Z.J.K.**
13777.94	3401.02	1778.05	763.26	966.12
W.L.C.B.	**L.F.**	**W.Z.**	**A.L.S.M.**	**S.Z.S.**
567.60	892.1	189.54	235.2	392.63

The attractive force of the six cities that serve as independent attractive points to other 12 cities is determined by the locations of break points between each other. Meanwhile, as the force effect is mutual, the 12 cities also have attractive force to the six independent attractive points. Therefore, the dynamic logistics amount attracted to Erdos is to be determined by the static cargo quantity of each area and the gravity to each city generated by Erdos.

3.3.1 Break points of two cities

Regarded Erdos, Baotou, Hohehot, Beijing, Shijiazhuang, Taiyuan and Yinchuan as independent attracting points, this study would calculate the break points of Coal, Chemical industry, Building materials, Metallurgy, Equipment manufacturing, Cashmere, Dairy products, Livestock products, The flow of commerce, respectively.

The following calculating method and data quotes will take Erdos attracting the coal quantity of other 12 cities as example.

The calculating formula of break point is :

$d_{ix} = d_{iErdos}/(1+\sqrt{S_{Erdos}/S_i})$, i = (Suozhou, Qizhou, Lvliang, Yulin, Wuhai, Bayanzhuoer, Zhangjiakou, Wulanchabu, Linfen, Wuzhong, Alashanmeng and Shizuishan).

Where, d_{ix} -- break point between one city and Erdos;

d_{iErdos} -- distance between one city and Erdos;

$S_{Erdos} = GDP_{Erdos} \cdot Q_{Erdos-j}$, j=(coal, chemistry, building material, metallurgy, equipment manufacturing, cool, milk product, farming and animal product and circulation of commerce and trading)--product of regional total output value of Erdos and one kind of goods;

$S_i = GDP_i \cdot Q_{ij}$ -- product of regional total output value of one area and certain goods.

3.3.2 Gravity coefficient

Gravity coefficient of one city against Erdos is that, $a_1 = d_{ix}/d_{i-Erdos}$. Hence, gravity coefficient of Erdos against one city is that, $a_0 = 1 - a_1 = 1 - d_{ix}/d_{i-Erdos}$.

Because of calculating the six independent attracting points respectively, the obtained gravity coefficient should be normalization processing to obtain the relative gravity coefficients.

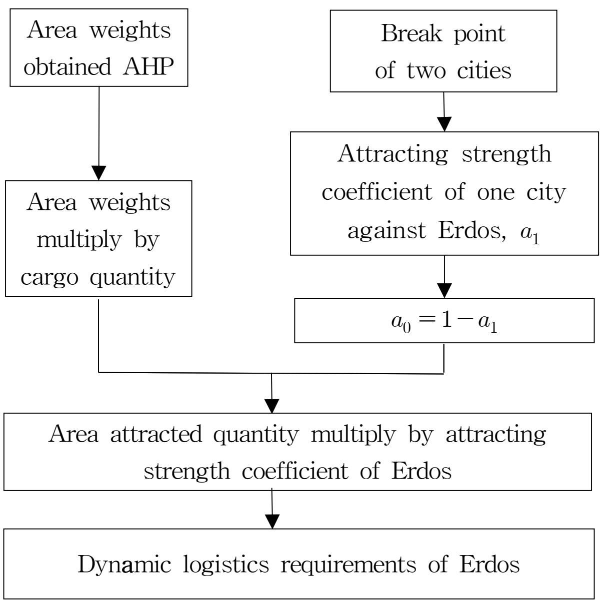

Fig 3. Research procedure of Erdos dynamic logistics requirements

3.3.3 Area attracted cargo quantity

Area attracted cargo quantity could be obtained by cargo quantity of one city multiplies by area weight. As mentioned that, the study is centering on city of Erdos, scope of I, II, III area surrounding, and logistics attractive force of each scope is different. With the purpose of increasing model fidelity, therefore, this study need identify the scope area weights. Total cargo amounts of each city could be predicted to obtain, moreover, the weight of III area is distributed by means of analytic hierarchy process (AHP). Specific procedures of weight distribution by AHP could be summarized as following:

a) Establishing the evaluation index system of hierarchical structure;
b) Structuring judgement matrix;
c) Calculating each coefficient of index weight;
d) Testing for consistence of judgement matrix.

The index consistence of judgement matrix could be obtained by $CI = \frac{\lambda_{\max} - n}{n-1}$, when $\lambda_{\max} = n$, $CI = 0$, it means complete consistence; CI value is larger, CI value is larger, the consistence of judgement matrix is worse. Generally, if $CI \le 0.1$, it means that the consistence of judgement matrix is acceptable, otherwise it must be re-judged by paired comparison. Moreover, the more coefficient of matrix, the worse of consistence, therefore, this paper has introduced correction RI (as shown 5.4), and applied more suitable CR value as the index of judging consistence of matrix.

The calculating formula of CR is as following:

$$CR = \frac{CI}{RI} \tag{9}$$

The Calculation result of I, II, III area weights have been summarized as table 4, and the $lmax$ = 3.0649; CI = 0.0324; RI = 0.58; CR = 0.0559.

Table 3 Average random consistence index of n-dimension

n-dimension	1	2	3	4
RI	0.00	0.00	0.58	0.96
5	6	7	8	9
1.12	1.24	1.32	1.41	1.45

Table 4 Area weights

Scope of area	I area	II area	III area
Single-layer weight	0.6491	0.2790	0.0719

Table 5 Predicting total logistics requirements of Erdos

Industries	S.C.Q.	D.L.R.	T.L.R.
Coal	94246.37	26359.00	120605.37
Chemical	1468.93	202.31	1671.23
Building	4652.84	303.62	4956.46
Metallurgy	593.49	925.80	1519.29
Equipment	15.22	0.74	15.96
Cashmere	1.10	0.45	1.55
Dairy	3.18	1.92	5.09
Livestock	5.66	1.05	6.70
Commerce	1420.57	227.59	1648.16
Total	102407.36	28022.48	130429.81
S.C.Q.: Static cargo quantity.			
D.L.R.: Dynamic logistics requirements.			
T.L.R.: Total logistics requirements.			

In summary, the static cargo quantity, dynamic logistics requirements and total logistics requirements (summary of static and dynamic logistic requirements) of Erdos have be summarized in table 5.

3.3.4 Results analysis and implication

Erdos is located at Inner Mongolia Autonomous Region, since the implementation of West Development Strategy; the state has intensified support for ecological construction and infrastructure construction in Autonomous Regions so that such tangible infrastructures as communication, road traffic and urban infrastructures have an obvious improvement. Especially the improvement of transportation conditions is a powerful precondition for the development of the logistics industry. Erdos which is abundant in coal resources need accelerate the construction of logistics infrastructures continuously.

Accord to the results, this research has proved the logistics dominant demand of Erdos is still coal in the future. And this is consistent with the actual conditions of Erdos. Because, municipal government of Erdos need consider that how much should invest to the logistics infrastructure, they should predict the logistics requirements of coal, exactly.

However, the researches in the present stage are mainly restricted by the non-unified logistics standard. Under the condition of lack of direct statistical data, to continue the logistics requirements prediction from the perspective of regression statistics cannot guarantee the prediction accuracy, nor explain the models effectively.

By applying with gravity model, this study has predicted the logistics requirements of Erdos, which will support the municipal government of Erdos on theory.

4. Conclusions

The logistics requirements prediction is to predict the changes of the logistics requirements and its development trend by virtue of judgment, technical method and model according to the past and current requirements of the logistics markets and the relationship among the factors that affect the changes in the logistics market requirements.

Moreover, regional logistics requirements is a derived requirements determined by the level of regional economic development, therefore, the indicators that affect the regional logistics requirements prediction such as economic factors (mainly including: the overall level and scale of the regional economy, industrial structure and product structure of the regional economy and the spatial layout of the regional economy, etc), logistics industry factors (mainly including: logistics facilities and services, changes in logistics costs, etc.), environmental factors (mainly including: technological progress, economic policies and institution, etc), as well as other factors (mainly including: regional geographic location, emergency factors, etc.), will directly or indirectly affect the growth or reduction of the regional logistics requirements.

However, the researches in the present stage are mainly restricted by the non-unified logistics standard. Under the condition of lack of direct statistical data, to continue the logistics requirements prediction from the perspective of regression statistics cannot guarantee the prediction accuracy, nor explain the models effectively.

Therefore, by integrating various factors that affect the regional logistics requirements, this study explores the logical relationship between the regional logistics requirements and many other relevant factors based on the spatial economics and new economic geography, etc, and from the perspective of market potential in the space economic principles, then this study established the logistics requirements gravity model and expanded the logistics requirements prediction way from the single statistical principles to the new area of space economics and regional economics, to enrich the research method of the regional logistics requirements.

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