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Retraction

Retracted: Measurement of Logistics Radiation Range and Improvement of Logistics Radiation Ability of City Clusters

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Q. Zhou, R. Wang, K.-H. Bae, and X. Wang, "Measurement of Logistics Radiation Range and Improvement of Logistics Radiation Ability of City Clusters," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 2937925, 10 pages, 2022.

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Research Article

Measurement of Logistics Radiation Range and Improvement of Logistics Radiation Ability of City Clusters

Qiaoping Zhou[1,2] **Rui Wang,**[2] **Ki-Hyung Bae,**[1] **and Xuejiao Wang**[1,3]

[1]*Department of Economics and Trade, Sejong University, Seoul 100744, Republic of Korea*
[2]*College of International Economics and Trade, Ningbo University of Finance & Economics, Ningbo 315175, Zhejiang, China*
[3]*College of Science & Technology, Ningbo University, Ningbo 315211, China*

Correspondence should be addressed to Qiaoping Zhou; zhouqiaoping@nbufe.edu.cn

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The current development plans for logistics of city clusters often pursue investment speed, while overlooking the economic benefits of logistics within city clusters. To prevent the waste of logistics resources, it is meaningful to study the meaning of the logistics radiation ability of city clusters and determine their logistics radiation range. Taking Ningbo Metropolitan Area as an example, this paper tries to measure logistics radiation range and improve logistics radiation ability of city clusters. The analytic hierarchy process (AHP) was adopted to quantify the logistics influencing factors. Besides, an improved breakpoint model was established based on the breakpoint theory, the logistics radiation range model, and the integrated logistics field theory. Drawing on the statistics in 2017, the improved model was applied to empirically measure the variation of integrated logistics quality of eight cities and determine the logistics radiation ranges of Ningbo Metropolitan Area relative to Shanghai Metropolitan Area and Hangzhou Metropolitan Area. Finally, several countermeasures were developed to improve the logistics radiation ability of Ningbo Metropolitan Area: the positioning of metropolitan areas, the model of logistics development, the development of industries closely associated with logistics, and the cultivation of strategic locational advantages. The research provides a good reference for the government of Ningbo to develop advantageous logistics fields around advantages and turn the city into an economic center.

1. Introduction

With the rapid development of the global economy, huge changes have taken place in the services, operations, and management of modern logistics, which are supported by information technology [1–4]. The development plans and policies on logistics between city clusters play an important role in improving the development of logistics and other industries, promoting the economic development model of city clusters, and safeguarding social stability [5–10]. However, the current development plans for logistics of city clusters often pursue investment speed, while overlooking the economic benefits of logistics within city clusters [11–15]. Since the actual situation of city clusters is not considered, the logistics radiation range is unintentionally exaggerated, causing the waste of logistics resources, i.e., suboptimal space utilization of warehouses, packaging, or transportation. The existing results on logistics radiation range mainly focus on city cluster economy and financial radiation ability. Therefore, it is meaningful to study the meaning of the logistics radiation ability of city clusters and determine their logistics radiation range.

Based on breakpoint and its field strength theory, Xu et al. [16] proposed an integrated breakpoint model, and applied the model to recognize the radiation range of a logistics park. The model fully considers the comprehensive capacity, traffic location, and service type of the logistics park. Next, SPSS was adopted to compute the breakpoint and its field strength of the logistics park and determine the radiation scope of the park. Based on the potential model of economic geography, a traditional spatial zoning model, Peng et al. [17] fully considered the importance of transport network in logistics activities, introduced accessibility to the traditional potential model, which is based on Euclidean distance, modified the distance parameter, and presented a way to assist the potential model with accessibility analysis in computing the radiation range of logistics parks. Considering the competition between multiple logistics parks and the consumer demand for a logistics park, Sun et al. [18] combined breakpoint model with Hough probability model into a multistep determination method for the service scope of logistics parks and managed to obtain the initial scope of spatial services. Matsumoto [19] empirically analyzed how to distribute commodities from the supplier to multiple consumers nearby via trucks: the total logistics cost of the supplier and consumers was established; to minimize the cost, the interval between deliveries was optimized, and the logistics cost was balanced with consumer services. Empirical results show that the supplier attempts to ensure that the consumer services are better than the level corresponding to the minimal total cost.

The above review shows that the literature on logistics radiation range mainly focuses on the economic and financial radiation ability of city clusters but rarely tackles the measurement of logistics radiation range of city clusters. There are few studies on the measurement of logistics radiation range of city clusters. To solve the problem, this paper takes Ningbo Metropolitan Area as an example to measure the logistics radiation range and improve the logistics radiation ability of city clusters. The main contents are as follows: (1) The logistics radiation range of the city cluster was modeled, including both intra- and extra-cluster radiations. (2) The traditional breakpoint model was improved, and the logistics radiation range of the city cluster was predicted by the GM (1, 1) grey model. (3) Through the example analysis of Ningbo Metropolitan Area, the radiation energy levels were analyzed, the hinterland boundary was delineated, and the comprehensive strength of urban logistics and radiation radius were computed. Finally, several countermeasures were provided based on the research results.

2. Model Construction

2.1. Intra-Cluster Model. Figure 1 illustrates the radiation mechanism of city cluster logistics information platform. It can be seen that the logistics radiation of city clusters includes intra-cluster radiation and extra-cluster radiation. The breakpoint theory is about the interaction between cities and regions. It is often adopted to break down city clusters or urban agglomerations and to examine the economic influence scope of urban agglomerations. Therefore, this paper relies on breakpoint theory to analyze the data of different cities in the same metropolitan area and measure the logistics radiation range of these cities with the reconstructed basic breakpoint model.

Focusing on the interaction between cities and regions, the breakpoint theory is widely used to delineate the spatial influence range of cities and towns and often adopted to

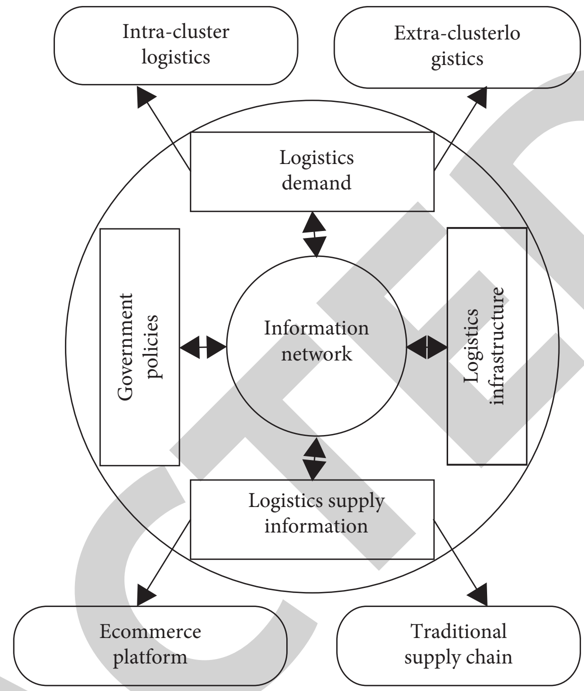

FIGURE 1: Radiation mechanism of city cluster logistics information platform.

divide the economic hinterland or economic zone of cities. The breakpoint of two influence areas can be calculated by the following equation:

$$D_{a\longrightarrow b} = \frac{d}{\left(1 + \sqrt{(P_b/P_a)}\right)}, \qquad (1)$$

where $D_{a\longrightarrow b}$ is the distance from the breakpoint to city b; d is the distance between cities a and b; P_a and P_b are the populations of cities a and b, respectively.

Concerning the influence of regional economy, the basic breakpoint model can only analyze the separation property with a point or draw the vertical line of the connection line between cities based on that point. The result cannot intuitively describe the influence range of each city in the cluster. According to the breakpoint theory, the attraction of a city to its surroundings is positively correlated with the city scale and negatively correlated with the distance from the city. Based on the formula of the basic breakpoint model, this paper models the logistics radiation range of each city in a metropolitan area:

$$\left(X - \frac{L_i * D_{ij}}{L_i - L_j}\right)^2 + y^2 = \left(\frac{\sqrt{L_i L_j D_{ij}}}{L_i - L_j}\right)^2. \qquad (2)$$

Formula (2) adopts the following coordinate system: the origin is the city with the greater integrated logistics strength in a pair of cities, the x axis is the connecting line between the two cities, and the y axis is vertical to the x axis.

Note that i and j are cities i and j in the city cluster, respectively; L is the integrated logistics quality of each city, representing the comprehensive logistics strength of the city;

L_i is the stronger integrated logistics quality between two cities; (x, y) are the coordinates of the breakpoint; and D_{ij} is the distance between cities i and j.

The result of the logistics range model is an arc with $(L_i{\cdot}D_{ij}/L_i - L_j, 0)$ being the center O_1, and $(L_iL_jD_{ij})^{1/2}/L_i - L_j$ being the radius R. Besides, the center lies on the reverse extension line of the connection line between the center points of the two cities. The intersection between the arc and x axis is the result of the basic breakpoint model (1), i.e., the basic breakpoint Z.

2.2. Extra-Cluster Model. In an economic circle, the complex logistics activities have various spatial forms, which exert different impacts inside and outside the circle. This forms a complex logistics field. Drawing on logistics field theory, this paper determines the logistics radiation range of Ningbo Metropolitan Area and analyzes the range from the strength and force of logistics field.

Logistics field strength refers to the material supply capability of the three main prefectures (cities) in Ningbo Metropolitan Area for each logistics demand point within the area and in other economic circles in unit time. This concept is important to the economic hinterland of overlapping areas. The logistics field strength can be calculated by the following equation:

$$\overline{E} = K\frac{Q_0}{R^2}\overline{n}, \tag{3}$$

where K is the logistics influencing factor; Q_0 is the logistics volume provided by a logistics economic circle to the outside; R is the distance from an external logistics demand point to the core area of the logistics economic circle; and n is the direction vector from the circle to the said point. Formula (3) shows that the logistics influencing factor K, which covers logistics distance, logistics time, transportation environment, transportation vehicles, and transportation price, results in a special phenomenon: the logistics field strength of several points, which are at the same distance from a specific logistics economic circle, may be different.

The calculation of logistics field strength obeys the principle of vector superposition. When a region is radiated by multiple metropolitan areas, the field strength of a point in the computing domain can be obtained through vector superposition:

$$E = \sum_i^n E_i = K\sum_i^n \frac{Q_i}{R^2}\overline{n}, \tag{4}$$

where Q_i is the logistics volume of the ith logistics economic circle in a specific computing domain, which involves n logistics economic circles, and R is the distance from the ith circle to a specific logistics demand point in the overlapping circles.

The logistics field force is related to the strength and the logistics demand of the logistics field. Let Q_0 be the logistics volume that can be provided by the integrated logistics service capability of an economic circle; let q be the logistics demand of a specific demand point within and outside the circle. Then, the logistics field force from the economic circle acting on the logistics demand point can be calculated by the following equation:

$$\overline{F} = q\overline{E} = K\frac{qQ_0}{R^2}\overline{n}, \tag{5}$$

where Q is the logistics demand of a point within or outside the circle and E is the logistics field strength of the economic circle at point A. Since logistics field strength is a vector, the superposition of logistics field satisfies the vector superposition equation.

When multiple economic circles overlap in an area, the integrated logistics radiation range of a circle m is affected by the other circles, and the influence of different circles reaches an equilibrium at a dividing point. The integrated logistics radiation range of circle m can be calculated by the field theory:

$$\overline{R}_m = \sqrt{\frac{K_mQ_m}{E_m}} = \sqrt{\frac{K_mQ_m}{\sum_{i=1,i\neq m}^n K_i\left(Q_i/R_i^2\right)\overline{n}}}, \tag{6}$$

where R_m is the integrated logistics radiation range of circle m under the effects of multiple economic circles; K_m is the integrated logistics influence factor of circle m; and Q_m is the total logistics volume provided by circle m. The result of (6) is the inside of the circle with m as the center and R_m as the radius, which represents the radiation range of the circle m under the effects of multiple economic circles.

3. Improved Model and Range Prediction

3.1. Improved Model. Logistics radiation energy level is directly manifested as the logistics radiation radius of a metropolitan area. By this definition, the radiation range of the logistics field model is often a circle, which is inconsistent with the reality. The circular range makes it difficult to solve the combined influence of the economic circles overlapping or associated with the economic circle. To solve the problem, this paper improves the breakpoint model.

Let F_1 and F_2 be the logistics field forces of two opposite metropolitan areas O_1 and O_2 on point P, respectively. Then, the two forces can be calculated by the logistics field force formulas:

$$\begin{aligned} F_1 &= q_0E_1 = K_1\frac{Q_1q_0}{R_1^2}, \\ F_2 &= q_0E_2 = K_2\frac{Q_2q_0}{R_2^2}. \end{aligned} \tag{7}$$

The breakpoint between the two metropolitan areas, i.e., the equilibrium point between the logistics field forces generated by the two areas, can be determined when $F_1 = F_2$. In this case, we have the following:

$$\frac{F_1}{F_2} = \frac{q_0E_1}{q_0E_2} = \frac{K_1\left(Q_1q_0/R_1^2\right)}{K_2\left(Q_2q_0/R_2^2\right)} = 1, \tag{8}$$

where R_1 and R_2 are the transport distances from point P to the two metropolitan areas, respectively; d_1 and d_2 are the straight-line distances from point P to the two metropolitan areas, respectively. It is obvious that $d = d_1 + d_2$, $R_1 = \varepsilon_1 d_1$, and $R_2 = \varepsilon_2 d_2$, with ε_1 and ε_2 being the coefficients of extension line. Then, the boundaries of the radiation ranges of the two metropolitan areas, i.e., the boundary points of hinterland, can be expressed as follows:

$$\left\{\begin{array}{l} d_1 = \dfrac{\mathrm{d}}{1 + \sqrt{\left(K_2 \varepsilon_1^2 Q_2 / K_1 \varepsilon_2^2 Q_1\right)}} \\ \\ d_2 = \dfrac{\mathrm{d}}{1 + \sqrt{\left(K_1 \varepsilon_2^2 Q_1 / K_2 \varepsilon_1^2 Q_2\right)}} \end{array}\right\}, \tag{9}$$

where d_1 is the distance from metropolitan area Q_1 to the dividing point of radiation range and d_2 is the distance from metropolitan area Q_2 to the dividing point of radiation range. On the connection line between the two metropolitan areas, the point with a straight-line distance d_1 from Q_1 and the point with a straight-line distance d_2 from Q_2 are the breakpoints of the two metropolitan areas in the direction of Q_1Q_2.

Based on the above known parameters, the integrated logistics radiation range of a city cluster can be measured. During the measurement, the overall resource quantity can be characterized by the integrated factor of city cluster development, which is derived from diverse indices. Let P_{ij} be the resource attraction, i.e., the radiation strength of city i to city j; U_i be the resource strength actually supplied by city i; $\exp(-\gamma w_{ij})$ be the interaction kernel between cities; d_{ij} be the Euclidean distance between two cities; γ be the attenuation factor representing the attenuation speed of integrated radiation strength with the distance; and λ be the normalization coefficient (without considering city differences, λ was set to 1). According to Wilson's model, P_{ij} can be expressed as follows:

$$P_{ij} = \lambda U_i Q_j \exp\left(-\gamma d_{ij}\right). \tag{10}$$

The strength of P_{ij} is directly related to the attenuation factor and the distance between cities. To derive the integrated radiation radius d_j of a city, the given threshold can be obtained by dividing U_i on both sides of (10):

$$\omega = Q_j \exp\left(-\gamma d_{ij}\right). \tag{11}$$

When a city in the metropolitan area has an integrated logistics radiation capacity smaller than ω, the city must have lost the logistics radiation effect. Further transformation of (11) yields the integrated radiation radius of city j:

$$d_j = \frac{1}{\gamma} \ln \frac{Q_j}{\omega}. \tag{12}$$

γ can be calculated by the following equation:

$$\gamma = \sqrt{\frac{2W}{\phi_{\max} V}}, \tag{13}$$

where W is the number of factors transmitted in the metropolitan area; V is the regional unit of the geographical space; and $\varphi_{\max}$ is the maximum number of diffusive regional units in the city.

In the improved breakpoint model, the most important parameters include the logistics volume, logistics influencing factor, maximum transportation distance, and field strength of the city cluster. Due to the low availability of complete data on each city in the metropolitan area, this paper computes these coefficients based on the available and collectable logistics volumes. Multiple factors were selected as logistics influencing factors, and the K value of the composite influence factor was determined through AHP. Firstly, logistics influencing factors were decomposed into 26 factors (Figure 2). The factors were weighed by entropy weight method.

3.2. Range Prediction. Figure 3 shows the principle of measuring the integrated logistics radiation range of city clusters. Based on the improved breakpoint model, this paper adopts the GM (1, 1) model to predict the logistics radiation range. The main steps are as follows:

Step 1. Establishing the prediction model

Compute the adjacent mean series $C^{(1)}$ of the 1-AGO series $B^{(1)}$ generated from the original influencing factor data series $B^{(0)}$ (Table 1). Estimate the parameter $r* = (r, e)^T$ by the least squares method. The GM (1, 1) prediction model can be expressed as follows:

$$\frac{\mathrm{d}b^{(1)}}{\mathrm{d}p} + rb^{(1)} = e. \tag{14}$$

The time corresponding to the model can be expressed as the following series:

$$b^{*(0)}(p+1) = \left(b^{(0)}(1) - \frac{e}{r}\right) f^{-rp} + \frac{e}{r}. \tag{15}$$

The inverse accumulating generation operator (AGO) can be expressed as follows:

$$\begin{aligned} b^{*(0)}(p+1) &= b^{*(1)}(p+1) - b^{*(1)}(p) \\ &= \left(1 - f^{r}\right)\left(b^{(0)}(1) - \frac{e}{r}\right) f^{-rp}. \end{aligned} \tag{16}$$

Step 2. Residual test

The improvement of the breakpoint model aims to predict the logistics radiation range. Residual test is needed to ensure the numerical precision of the improved model. The residual between $B^{(0)}$ and the corresponding simulated series $a*^{(1)}$ can be calculated by the following equation:

$$\sigma^{(0)} = b^{(0)}(p) - b^{*(0)}(p). \tag{17}$$

Step 3. Model prediction

The prediction of logistics radiation range is to generate the predicted value of series $B^{(1)}$ with the AGO. The

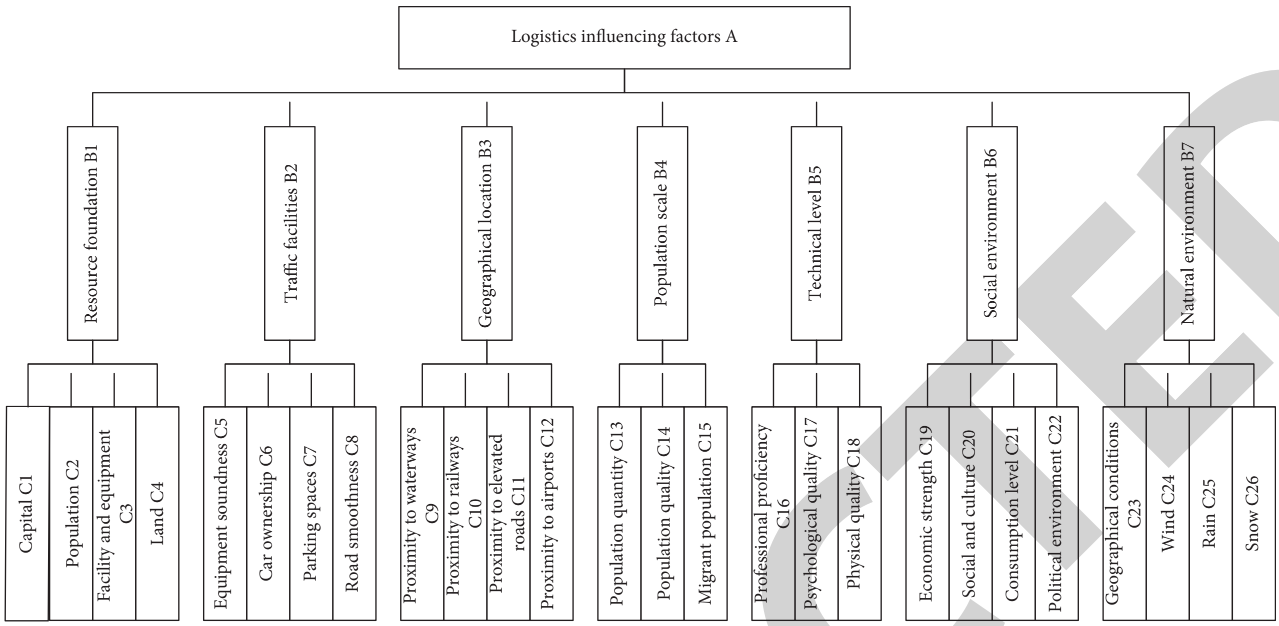

FIGURE 2: Hierarchical evaluation model for logistics influencing factors.

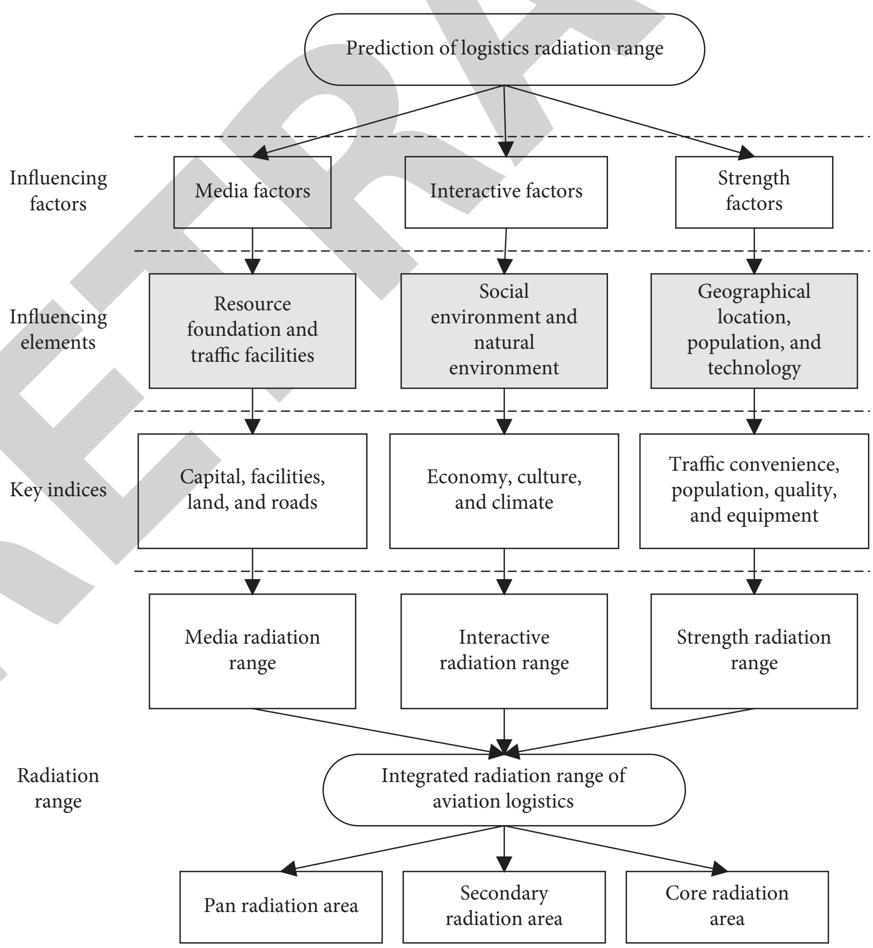

FIGURE 3: Principle of measuring the integrated logistics radiation range of city clusters.

Table 1: AHP model for logistics influencing factors.

Primary indices	Secondary indices
Comprehensive urban development B1	Regional GDP (C1), per-capita regional GDP (C2), added value of industries above designated size (C3), total retail sales of consumer goods (C4), total import and export (C5)
Logistics market supply and demand B2	Regional cargo capacity (C6), cargo turnover (C7), main port cargo throughput (C8)
Logistics infrastructure level B3	Transport infrastructure investment (C9), interior expressway mileage (C10), interior highway mileage (C11)

Note. GDP is short for gross domestic product.

predicted value of the original series $B^{(0)}$ can be obtained with the inverse AGO:

$$\begin{cases} \hat{a}^{(1)}(p+1) = \left(a^{(0)}(1) - \dfrac{e}{r}\right) f^{-rp} + \dfrac{e}{r}, \\ \hat{a}^{(0)}(p+1) = \hat{a}^{(1)}(p+1) - \hat{a}^{(1)}(p). \end{cases} \tag{18}$$

4. Case Analysis

Ningbo Metropolitan Area is an important part of the Yangtze River Delta Economic Circle. Its economic hinterland overlaps with that of core cities in the delta, such as Shanghai and Hangzhou. Therefore, it is practical to explore the integrated logistics radiation capacity of this metropolitan area. In this paper, Ningbo Metropolitan Area is defined as specified in the Development Planning for Yangtze River Delta City Cluster. Three cities are covered in the area: Ningbo, Zhoushan, and Taizhou. The data on intra-cluster economy and integrated logistics radiation levels were extracted from the three cities.

4.1. Radiation Level Analysis. Considering data availability, key policy support, and analysis value, this paper studies the relevant data on eight cities, namely, Ningbo, Zhoushan, Taizhou, Shanghai, Hangzhou, Jiaxing, Huzhou, and Shaoxing. Based on model operability and data availability, the logistics radiation state was measured by the improved breakpoint model, in the light of multiple indices (Table 1).

Each of the relevant metropolitan areas contains multiple big cities. The 11 indices between the big cities influence each other. For simplicity, index C6 was chosen to represent the intra-cluster logistics volume (Table 2).

For the lack of space, the data of specific indices are not listed. Through AHP, indices C1–11 were selected to analyze the influence of the eight cities. The integrated logistics influence factor of each city was thereby obtained (Table 3).

Under normal conditions, the extension line coefficient falls in 1.05–1.2 for plains, 1.2–1.3 for hills, and 1.3–1.5 for mountains. The extension line coefficients were determined for the eight cities (Table 4), after considering the fact that the main highways (especially expressways) in these cities mostly go through areas with a very small mean altitude difference, as well as realistic problems like terrain, altitude difference, and highway transport limitations.

The straight-line distances between the eight cities were measured on Baidu Map. The distance from city i to city j is denoted as d_{ij}. For simplicity, the city centers were taken as the start and end points of measurement. In this way, the distance between each pair of cities was obtained (Table 5).

4.2. Hinterland Boundaries. This subsection attempts to determine the logistics radiation boundaries of Ningbo Metropolitan Area relative to core cities like Shanghai and Hangzhou. For the reliability of calculation, the hinterland of the metropolitan areas was determined in two steps: determine the breakpoint of each city; identify the breakpoint of each metropolitan area. After determining the breakpoint of each city, the distance X_{ij} from each breakpoint to each city was calculated (Table 6).

During the determination of breakpoints of cities, some cities do not have any competitor in a certain logistics service. In this case, no breakpoint can be identified in this respect. Since the administrative boundaries are easy to define and the relevant data are openly available, the administrative boundaries were taken as the radiation boundaries, and the area within the boundaries was entirely treated as the inside of the integrated logistics radiation range of the city. In this way, the authors obtained the logistics radiation range of each city (Figure 4).

During the determination of breakpoints of metropolitan areas, there is no competition in logistics infrastructure and integrated logistics capacity within the economic circle. In this case, no breakpoint can be identified in this respect. To solve the problem, the administrative boundaries were taken as the radiation boundaries, and the area within the boundaries was entirely treated as the inside of the integrated logistics radiation range of the metropolitan area. In this way, the authors obtained the logistics radiation range of each metropolitan area (Figure 5).

4.3. Integrated Logistics Strength and Radiation Radius. Based on the selected logistics influencing factors, the authors surveyed the different types of logistics parks in the eight cities and obtained the statistics on investment amount, business contents, floor area, location advantage, and cargo turnover. To unify the statistical caliber, the data were nondimensionalized (Table 7). Based on Table 7, the integrated strength and radiation radius of each logistics park were calculated by the proposed logistics radiation range prediction algorithm (Table 8).

4.4. Suggestions. The breakpoint model analysis of the integrated logistics capability data on Ningbo, Shanghai, and

Table 2: Intra-cluster logistics volume of each city.

Serial number	Name of city	Logistics potential	Total freight (100 million tons)
1	Ningbo	New first tier city	4.63
2	Zhoushan	Third tier city	2.8
3	Taizhou	Second tier city	1.9
4	Shanghai	First tier city	8.87
5	Hangzhou	New first tier city	3.02
6	Jiaxing	Second tier city	1.13
7	Huzhou	Third tier city	1.45
8	Shaoxing	Second tier city	1.67

Table 3: Integrated logistics influence factor of each city in the three metropolitan areas.

City	Ningbo	Zhoushan	Taizhou	Shanghai	Hangzhou	Jiaxing	Huzhou	Shaoxing
K_i	0.9466	0.9193	0.8602	0.9569	0.9462	0.9233	0.8435	0.8760

Table 4: Mean altitudes of main roads in the eight cities (unit: m).

City	Ningbo	Zhoushan	Taizhou	Shanghai	Hangzhou	Jiaxing	Huzhou	Shaoxing
Serial number i	1	2	3	4	5	6	7	8
Mean altitude of the area of most highway facilities	33.25	33.5	33.8	6.3	10	6.4	29.4	14.3
Extension line coefficient	1.2	1.2	1.2	1.05	1.12	1.05	1.18	1.15

Table 5: Straight-line distance d_{ij} between cities (unit: km).

d_{ij}	1	2	3	4	5	6	7	8
1	0	64.2	136.0	150.7	143.1	123.2	181.2	96
2	64.2	0	166.6	154.9	200.3	163.5	227.4	163.5
3	136.0	166.6	0	288.6	217.9	241.9	280.6	174.2
4	150.7	154.9	288.6	0	164.2	85.8	136.6	159.7
5	143.1	200.3	217.9	164.2	0	76.3	68.5	48.4
6	123.2	163.5	241.9	85.8	76.3	0	65.7	81.0
7	181.2	227.4	280.6	136.6	68.5	65.7	0	105.9
8	96.0	163.5	174.2	159.7	48.4	81.0	105.9	0

Hangzhou Metropolitan Areas in 2017 shows that, from the angle of logistics infrastructure and urban development, Ningbo has greater logistics radiation strength and greater competitiveness of logistics expansion than the other tier 1 and tier 2 cities and exhibits an outward logistics radiation over every city, except Shanghai, in its metropolitan area. Ningbo should continue to play the core role in logistics of the metropolitan area, and drive the logistics development of other cities, by making full use of the rising logistics demand, growing logistics input, and complete logistics system.

To promote the coordinated development and enhance the structural reliability of logistics in Ningbo Metropolitan Area, several suggestions were provided in terms of creating a favorable institutional environment for modern logistics development, consolidating the industrial foundation, cultivating high-quality talent teams, and optimizing service spatial layout.

4.4.1. Continuously Improve the Logistics in Ningbo Metropolitan Area. Improve the logistics channels in the three cities of the area, improve the construction of the trunk and branch channels, fully utilize the clustering and diffusion functions of the logistics nodes, realize the transfer and diffusion of elements in the area, and achieve linkage development.

4.4.2. Optimize the Logistics Development Model in Ningbo Metropolitan Area. Based on the existing and potential development advantages of Ningbo, further expand the spatial advantages of the city by upgrading both capacity clustering and logistics radiation level.

4.4.3. Develop Logistics between Cities within the Area. Position the logistics development of the three cities differently, and integrate policies with the market.

4.4.4. Improve the Industries Closely Associated with Logistics in the Area. Improve the logistics capacity of industries in the area by making optimal use of the scattered logistics infrastructure in the port area; provide nearby manufacturers and traders with integrated logistics services, promote the transformation to intelligent economy, and improve the logistics service level.

Table 6: Straight-line distance from each breakpoint to each city (unit: km).

X_{ij}	1	2	3	4	5	6	7	8
1	0	36.35	84.44	58.18	104.53	98.27	148.83	76.77
2	27.85	0	92.72	50.37	94.09	94.64	133.69	77.04
3	51.56	73.88	0	80.07	90.16	126.44	149.28	87.66
4	92.52	104.53	208.53	0	106.35	63.53	102.11	115.80
5	38.57	106.21	127.74	57.85	0	46.40	42.26	28.52
6	24.93	68.86	115.46	22.27	29.9	0	33.46	38.92
7	32.37	93.71	131.32	34.49	26.24	32.24	0	49.90
8	19.23	86.46	86.54	43.9	19.88	42.08	56	0

Figure 4: Logistics radiation range of each city.

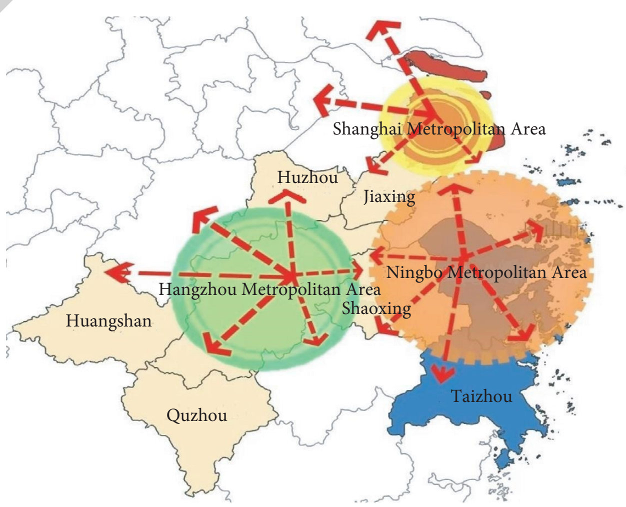

Figure 5: Logistics radiation range of each metropolitan area.

Table 7: Scores of different types of logistics parks in the eight cities.

City number	1	2	3	4	5	6	7	8
Investment amount	467	36	137	48	415	485	2336	41
Business contents	Warehousing, container operation, parking, distribution, and logistics information processing	Logistics information processing, international logistics distribution, logistics center export tax rebate, and bonded warehousing	Textile and clothing, and leather goods	Comprehensive wholesale market	Coal, refined oil, cold chain, and warehousing	Import and export trade, and exchange trade	Chemical plastics, hardware tools, and electromechanical accessories	Car and spare parts trading, and auto parts supermarket
Floor area	935	394	328	967	2775	5768	10004	762
Location advantage	14	13	15	12	8	6	9	5
Cargo turnover	234	67	78	135	434	819	1728	104

Table 8: Integrated strength and radiation radius of each logistics park.

Logistics park	1	2	3	4
Integrated strength	1563.52	485.14	526.14	1187.26
Radiation radius	33.16	17.25	15.36	32.64
Logistics park	5	6	7	8
Integrated strength	3526.45	6824.16	13556.12	875.26
Radiation radius	63.18	97.46	138.85	27.42

4.4.5. Further Optimize Industries and Collaboratively Improve Logistics Service Level. Highlight the advantages of the synergistic development between the industrial logistics service and the manufacturing demand in Ningbo, and further improve the status of Ningbo in the global value chain.

4.4.6. Further Exploit the Strategic Location Advantage. Give full play to the manufacturing advantage of Ningbo, construct a global manufacturing innovation center around key advantage industries, make good use of pilot resources, try to realize breakthrough in smart industrial logistics, strive to build a world-leading industrial logistics system, and radiate the adjacent metropolitan areas and the global industry chain.

4.4.7. Optimize Urban Space Planning and Enhance Attractiveness. Enhance the diffusion effect of urban spatial structure, and cultivate and develop the hinterland of development; strengthen the power of Ningbo Metropolitan Area, and increase the attractiveness of Ningbo to the other cities in the area.

5. Conclusions

Taking Ningbo Metropolitan Area as an example, this paper tries to measure the logistics radiation range and improve the radiation capacity of city clusters. Firstly, the intra- and extra-cluster logistics radiations were modeled for city clusters. Next, the traditional breakpoint model was improved, and the logistics radiation range of city clusters was predicted based on the GM (1, 1) grey model. After that, an example analysis was carried out on Ningbo Metropolitan Area. The radiation energy levels were obtained, the hinterland boundaries were determined, and the integrated logistics strengths and radiation radii were computed for the relevant cities. Based on the current situation of logistics service radiation, several countermeasures were presented for Ningbo Metropolitan Area in terms of the positioning and development of the metropolitan area, the development model of logistics, the improvement of the industries closely associated with logistics, and the mining of strategic location advantages. These countermeasures provide the government with a reference to make the relevant policies, develop advantageous logistics fields around advantages, and turn the city into an economic center.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] X. Tang and G. Wang, "Design and analysis of e-commerce and modern logistics for regional economic integration in wireless networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2020, no. 1, 15 pages, Article ID 2082020, 2020.

[2] P. Beinschob, M. Meyer, C. Reinke, V. Digani, C. Secchi, and L. Sabattini, "Semi-automated map creation for fast deployment of AGV fleets in modern logistics," *Robotics and Autonomous Systems*, vol. 87, pp. 281–295, 2017.

[3] T. X. Wang, Y. Wu, J. Lamothe, F. Benaben, R. Wang, and W. Liu, "A data-driven and knowledge-driven method towards the IRP of modern logistics," *Wireless Communications and Mobile Computing*, vol. 20217 pages, Article ID 6625758, 2021.

[4] J. J. Guo, H. Y. Zhang, and G. Sun, "Transportation path optimization of modern logistics distribution considering hybrid tabu search algorithm," *Advances in Multimedia*, vol. 2021, Article ID 8375780, 7 pages, 2021.

[5] Y. Tang, "Sarsa(Λ)-Based logistics planning approximated by value function with policy iteration," *Journal of Algorithms & Computational Technology*, vol. 9, no. 4, pp. 449–466, 2015.

[6] R. Juvvala and S. P. Sarmah, "Evaluation of policy options supporting electric vehicles in city logistics: a case study," *Sustainable Cities and Society*, vol. 74, Article ID 103209, 2021.

[7] Y. Li, M. K. Lim, J. Y. Hu, and M. L. Tseng, "Investigating the effect of carbon tax and carbon quota policy to achieve low carbon logistics operations," *Resources, Conservation and Recycling*, vol. 154, Article ID 104535, 2020.

[8] R. Batarfi, M. Y. Jaber, and S. M. Aljazzar, "A profit maximization for a reverse logistics dual-channel supply chain with a return policy," *Computers & Industrial Engineering*, vol. 106, pp. 58–82, 2017.

[9] Y. Wu, "Research on new urban logistics policy and optimized path of social organization development," *Boletin Tecnico/Technical Bulletin*, vol. 55, no. 10, pp. 667–674, 2017.

[10] J. K. Buor, "The impact of policy change on maritime logistics level of disaster preparedness and resilience," in *Proceedings of the Operational Research Society Simulation Workshop 2016*, pp. 81–91, SW 2016, Eddington Chase, UK, April 2016.

[11] I. V. Bychkov, A. L. Kazakov, A. A. Lempert, D. S. Bukharov, and A. B. Stolbov, "An intelligent management system for the development of a regional transport logistics infrastructure," *Automation and Remote Control*, vol. 77, no. 2, pp. 332–343, 2016.

[12] Y. Y. Huang and C. Jin, "Invulnerability analysis of logistics infrastructure network based on cascading failure," *Kongzhi yu Juece/Control and Decision*, vol. 29, no. 9, pp. 1711–1714, 2014.

[13] Y. Y. Huang, C. Jin, and C. Wang, "Cascading failure model on an interdependent service-infrastructure network based on logistics network," *ICIC Express Letters*, vol. 10, no. 8, pp. 1887–1894, 2016.

[14] H. Chen, T. Sarton du Jonchay, L. Y. Hou, and K. Ho, "Multifidelity space mission planning and infrastructure design framework for space resource logistics," *Journal of Spacecraft and Rockets*, vol. 58, no. 2, pp. 538–551, 2021.

[15] D. Z. Zhang, Q. W. Zhan, Y. C. Chen, and S. Y. Li, "Joint optimization of logistics infrastructure investments and subsidies in a regional logistics network with CO2 emission reduction targets," *Transportation Research Part D: Transport and Environment*, vol. 60, pp. 174–190, 2018.

[16] J. Y. Xu, J. S. Yang, C. Gao, L. Zhang, and T. Ma, "Study on logistics park's radiation scope based on breaking point model, " CICTP 2017: transportation Reform and Change - equity, Inclusiveness, Sharing, and Innovation -,"vol. 2018, pp. 1440–1446, in *Proceedings of the 17th COTA International Conference of Transportation Professionals*, vol. 2018, pp. 1440–1446, ASCE, Shanghai, China, July 2018.

[17] J. P. Peng, Y. B. Zhang, and X. Sun, "Definition of the radiation scope of the logistics park based on applying the road accessibility analysis to a potential model," in *Proceedings of the 5th International Conference on Transportation Engineering*, pp. 875–882, ASCE, Dailan, China, September 2015.

[18] B. F. Sun, Q. Y. Luo, P. Xu, and Y. Zheng, "Determining method of service scope for logistics park," *Jiaotong Yunshu Gongcheng Xuebao/Journal of Traffic and Transportation Engineering*, vol. 11, no. 6, pp. 82–88, 2011.

[19] S. J. Matsumoto, "Trade-off between logistic cost and customer service for goods distribution in an urban area," *Doboku Gakkai Ronbunshu*, vol. 1990, no. 413, 38 pages, 1990.