# Evaluation of Urban Emergency Logistics Capacity based on Cloud Weight-TOPSIS: A Case Study of Beijing

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***Abstract*****—**Urban emergency logistics capacity is critical for managing unexpected events and ensuring urban resilience. This study constructs a comprehensive evaluation index system to assess urban emergency logistics capacity using the Cloud Weight- Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method. Beijing serves as the case study for this evaluation, covering the period from 2003 to 2022. The findings reveal a continuous annual improvement in Beijing's emergency logistics capacity, marked by five significant enhancements. By 2022, Beijing's emergency logistics capacity has reached a relatively high level, providing valuable insights for optimizing urban emergency logistics strategies. This research contributes a robust framework for evaluating and enhancing urban emergency logistics, offering practical guidance for other cities aiming to improve their emergency logistics capabilities.

***Keywords*****—***Urban Emergency Logistics; Cloud Model; TOPSIS; Emergency Logistics; Capacity Evaluation*

## I. INTRODUCTION

The increasing frequency and severity of natural disasters, public health emergencies, and other unforeseen events have underscored the critical importance of robust emergency logistics systems. Effective emergency logistics is essential not only for safeguarding human lives but also for maintaining economic stability and social order during crises. Incidents such as the 2003 SARS outbreak and the 2008 Wenchuan earthquake have prompted significant advancements in China's emergency management infrastructure, leading to the establishment of comprehensive epidemic prevention organizations and public health systems. These advancements were further tested and refined during the 2019 COVID-19 pandemic, showcasing China's progress in emergency management and response capabilities [1][2].

Emergency logistics capacity refers to a city's ability to efficiently mobilize resources, coordinate response efforts, and sustain operations during emergencies. Assessing and enhancing this capacity is crucial for urban resilience, disaster mitigation, and long-term socio-economic stability. The significance of emergency logistics was evident during the COVID-19 pandemic, where timely and effective logistics operations played a critical role in controlling the spread of the virus and ensuring the continuous supply of essential goods and services [3][4].

This study aims to construct a robust evaluation index system for urban emergency logistics capacity, leveraging the Cloud Weight-Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method. By employing Beijing as a case study, this research evaluates the growth of emergency logistics capacity from 2003 to 2022, providing valuable insights for the optimization of urban emergency logistics strategies. The research constructs an evaluation system for urban emergency logistics capacity encompassing five dimensions: Support Capacity for Circulation, Infrastructure Support Capacity, Human Resources Assurance Capacity, Information Technology Assurance Capacity, and Government Command Capacity. Sixteen secondary indicators are selected based on data availability and relevance. The Cloud Weight-TOPSIS method integrates the cloud model for weight calculation with the TOPSIS method for ranking and evaluation, ensuring objectivity and reliability in the assessment. This study contributes a scientifically robust framework for evaluating and enhancing urban emergency logistics capacity. The findings provide critical insights for policymakers and urban planners, enabling them to develop effective strategies for emergency preparedness and response. By understanding and addressing the key factors influencing emergency logistics capacity, cities can improve their resilience and readiness for future emergencies.

### *A. Research Objectives*

1. Develop a comprehensive evaluation index system for urban emergency logistics capacity.
2. Apply the Cloud Weight-TOPSIS method to objectively assess emergency logistics capacity.
3. Analyze the growth and trends in Beijing's emergency logistics capacity from 2003 to 2022.
4. Provide actionable recommendations for enhancing urban emergency logistics capabilities in Beijing and other cities.

## II. LITERATURE REVIEW

In research on constructing index systems for emergency logistics, Dong Yanan and Jin Jianhang [5]developed their framework based on the connotations and characteristics specific to emergency logistics. Cheng Binwu [6]approached the issue from the perspective of resource allocation, while Ding Pengyu[7] utilized interviews and literature statistics to create an evaluation index for emergency logistics capacity. Jiang et al.[8] employed the Delphi method to establish a reliability evaluation index system for emergency logistics.

Additionally, various scholars have applied diverse methodologies. Deng Aimin and Zhang Fan [9]utilized the fuzzy grey comprehensive evaluation method to quantify emergency logistics capacity. Liu Mingfei and Wang Chongyue [10]proposed an evaluation approach using a combined weighting cloud model to assess the cold chain emergency logistics capacity for agricultural products. Chen Heng, Qi Xianchao, and Zhang Yan [11] applied the entropy weight TOPSIS method to evaluate the emergency logistics response capacity across different provinces in China and examined its impact on economic growth.

Xiao Yigui and Li Yiqun [12] used a combined weighting method and introduced a cloud model to quantify evaluation language. Tan Xiaoyong and Huang Xueyan [13] conducted a thorough evaluation of emergency logistics support capacity using the entropy weight method and the grey comprehensive evaluation method. Xiangguo Ma [14] and colleagues developed an emergency logistics capacity analysis model for the Beijing-Tianjin-Hebei region using the fuzzy matter-element method. Yang Yaxu [15] proposed a model for emergency logistics capacity based on probabilistic linguistic term sets. GUAN et al. [16]employed the cloud hierarchical analysis and fuzzy comprehensive evaluation methods to build an index system for earthquake rescue emergency logistics capacity. LIU et al. [17] created a comprehensive evaluation index system covering the entire disaster cycle, including preparedness, response, and recovery, evaluated with the fuzzy symmetric sorting technique. ZHANG et al. [18] constructed an evaluation index system for emergency logistics capacity based on the operational mechanisms of public health emergencies and used neural networks to establish a dynamic assessment model.

The application of fuzzy clustering analysis to categorize and remove irrational indices is covered by Nie et al. [19]. This process identifies important components for the assessment of emergency logistics centers. Jia et al. [20] also stress the significance of index system development and network structure analysis, emphasizing the use of Analytic Network Process (ANP) to create a support capability model.

In order to facilitate logistical assistance and evacuation operations during disaster response activities, Yi and Özdamar [21] offer an integrated location-distribution model, which they illustrate with an earthquake scenario in Istanbul. In order to evaluate urban emergency rescue capabilities, Lin et al.[22] provide a thorough assessment framework that combines Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive assessment (FCE) approaches. This framework is verified by a case study conducted in a southern city. In order to facilitate the analysis of vehicle location and response district design, Larson et al.[23]provide an approximation approach based on a hypercube queuing model for estimating performance parameters of urban emergency service systems.

In order to assess emergency logistics center capabilities, Zhang and Nie[24] investigate the application of linguistic factors in conjunction with the TOPSIS approach, translating expert assessments into interval values for analysis. With an emphasis on the examination of resource stocks across departments, Tang, Li, and Gu[25]develop a model for assessing the support capacity of emergency logistics utilizing Hilbert space vector norm and AHP.

A dual-objective mixed integer nonlinear programming model for emergency logistics is established by Wang and Ma [26], with an emphasis on optimizing material satisfaction and decreasing rescue time during the COVID-19 pandemic. In order to assess emergency logistics capacities during earthquakes, Ju et al. [27] employ integrated GF-AHP models, which provide insights into system inputs and operational management. A multi-layer fuzzy comprehensive assessment model based on entropy weight is developed by Yuansheng, Ying, and Xinyao [28], who demonstrate its use in urban community emergency management during the COVID-19 pandemic.

## III. CONSTRUCTION AND MODEL SELECTION OF URBAN EMERGENCY LOGISTICS CAPABILITY EVALUATION SYSTEM

### A. *Construction of Urban Emergency Logistics Capability Evaluation System*

Based on expert consultations and literature review, an analysis of the factors influencing urban emergency logistics capabilities was conducted. Adhering to principles of comprehensiveness, scientific validity, comparability, and data availability, this paper constructs an evaluation system for urban emergency logistics capabilities from five dimensions which are Support Capacity for Circulation, Infrastructure Support Capacity, Human Resources Assurance Capacity, Information Technology Assurance Capacity, Government Command Capacity. In total, 16 secondary indicators were selected based on the availability of data for these indicators, as shown in Table 1.

Economic support capacity for circulation is a crucial factor in enhancing urban emergency logistics capabilities and serves as a fundamental guarantee for the effectiveness of other elements. Infrastructure support capacity is the foundational prerequisite for establishing an urban emergency logistics network and underpins the execution of emergency logistics activities. Human resources assurance capacity reflects the region's expertise in developing emergency response technologies and the service capabilities of emergency logistics personnel. Information technology assurance capacity plays a pivotal role in predicting, disseminating, collecting, analyzing, processing, and sharing urban emergency information. Government command capacity encompasses the ability of local governments to manage, direct, and plan rescue operations in response to emergencies, including their macro-coordination capabilities for systems, materials, personnel, information, and funds, as well as their decision-making abilities in emergency logistics activities.

table1. Urban Emergency Logistics Capability Evaluation System

| | First level indicator | Secondary indicators | investigate subject |
|---|---|---|---|
| Evaluation of Urban Emergency Logistics Capacity | Circulation economic support capabilities | GDP | Examine the final value of production activities of regional resident units within one year |
| | | The total retail sales of social consumer goods | Examining the total volume of consumer goods in each industry |
| | | Financial self-sufficiency rate | Examining the degree to which the region's finances rely on state payments |
| | | Total fixed asset investment in logistics industry | Annual fixed asset investment in transportation, warehousing and postal services in the region |
| | | Investment in information and information technology fixed assets | The annual fixed asset investment in information transmission, software and information technology services in the region |
| | Infrastructure support capabilities | Highway mileage | Investigate the scale of highway construction in the region |
| | | Truck ownership | Investigate the number of commercial freight vehicles with civilian license plates in the area operated by public safety and transportation management departments |
| | Human resources support capabilities | Information and information technology industry practitioners | Number of people engaged in information transmission, software and information technology services in the surveyed region |
| | | Logistics industry practitioners | Number of people working in the transportation, warehousing and postal industries in the surveyed area |
| | Information technology support capabilities | Information collection, analysis and feedback capabilities | Investigate the speed of information acquisition during emergency logistics activities |
| | | Disaster monitoring and early warning capabilities | Investigate the real-time monitoring of natural disasters and early warning capabilities of secondary disasters by relevant urban departments |
| | | Timeliness of emergency information release and sharing | Examine the communication and sharing capabilities of information between departments |
| | Government command capacity | Frequency of organizing emergency drills and revising plans | Examine the frequency with which cities organize emergency drills and issue revised plans |
| | | Are the emergency organization and responsibilities sound? | Examine the soundness of government emergency organizations and responsibilities |
| | | The degree of soundness of laws and regulations | Investigate the soundness of laws and regulations related to emergency |

| | | | |
|---|---|---|---|
| | | related to emergency logistics | logistics |
| | | Scale of emergency logistics expert team building | Investigate the construction of experts in the field of emergency logistics in the city |

### B. . *Selection of the Urban Emergency Logistics Capability Evaluation Model*

The Cloud Weight-TOPSIS method is an objective decision analysis technique that integrates the cloud model with the TOPSIS method. The weight of indicators is a critical factor in determining whether the evaluation model is objective and reasonable. This paper adopts a combination of the Delphi method and the cloud model to calculate indicator weights, effectively reducing the subjectivity inherent in the Delphi method. The TOPSIS method quantifies and ranks the evaluation objects by comparing their relative distances from the ideal point. Therefore, this study uses the Cloud Weight-TOPSIS method to measure urban emergency logistics capability.

## IV. EMPIRICAL ANALYSIS OF BEIJING'S EMERGENCY LOGISTICS CAPABILITY

### A. *Determination of Cloud Weight for Beijing's Emergency Logistics Capability*

This study invited several experts from the fields of emergency management and logistics to express the importance of various indicators in numerical form, measuring their value relative to the target layer C. The importance of Ci (i=1,2,3) is measured relative to C, and the importance of Cij is measured relative to Ci. There are 16 evaluation indicators involved. Based on expert scores and validation through the cloud model, the weights of each indicator were calculated. Here, the determination process of the cloud weight for circulation economic support capacity C1 in Beijing is illustrated as an example. The first round of expert scoring is shown in Table 2.

Table2. Experts ' first C1 weight scoring table

| Expert | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Weights | 0. 91 | 0.90 | 0.90 | 0. 91 | 0.89 | 0.90 | 0.91 | 0.91 | 0.90 | 0.91 |

Based on the proposed improved inverse cloud algorithm with indeterminacy, the obtained data was processed using Python. The cloud weights from the scoring results were calculated as (0.9040, 0.0075, 0.0035). Then, a forward cloud generator was used to create a cloud chart, as shown in Figure 1. The cloud chart displays characteristics of thick cloud layers and high dispersion, indicating some disagreement among the experts in the initial scoring process. To eliminate this fuzziness, reduce subjectivity, and enhance the consistency of experts' recognition of the results, the experts were invited to re-evaluate the indicators. The second round of expert scoring is shown in Table 3.

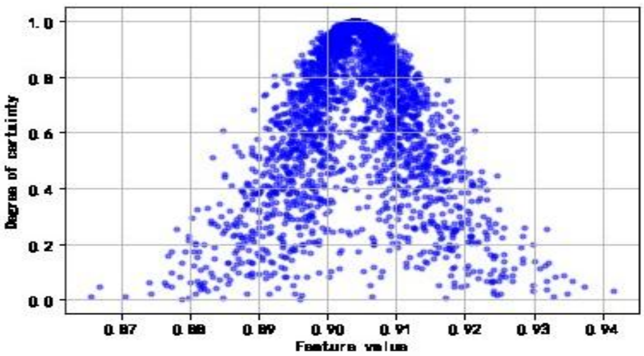


Fig. 1. Cloud Chart of the First Round of Expert Scoring

Table 3.Second Round of Expert Scoring on Weights for C1

| Expert | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Weights | 0. 91 | 0.90 | 0.90 | 0.90 | 0.89 | 0.90 | 0.92 | 0.91 | 0.90 | 0.91 |

The cloud weights from this round of scoring were (0.9040, 0.0085, 0.0029), with the cloud chart shown in Figure 2. The cloud layers remain relatively thick, with a slightly reduced dispersion compared to the first cloud chart, but still relatively high. This indicates that the results are still somewhat unreasonable and that there is still disagreement among the experts in their scoring. To further minimize the subjective randomness in the scoring process, the experts were invited to score again. After multiple rounds of adjustments, the final round of expert scoring is shown in Table 4.

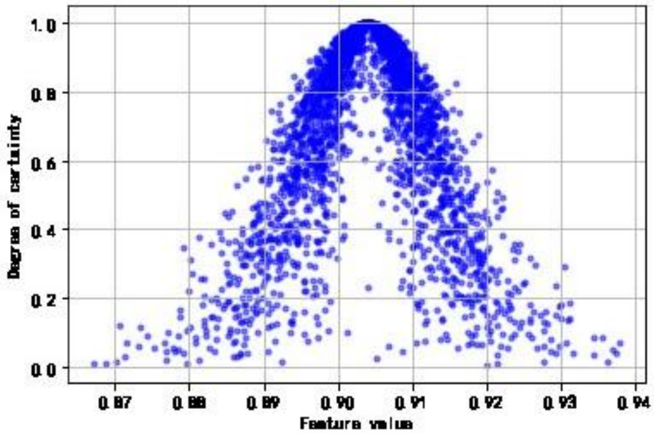


Fig. 2. Second expert scoring cloud chart

Table 4. Experts' last evaluation of C1 weights

| Expert | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Weights | 0. 91 | 0.90 | 0.90 | 0.90 | 0.89 | 0.90 | 0.90 | 0.91 | 0.90 | 0.91 |

After processing the data, the cloud weights from this round of scoring were determined to be (0.9020, 0.0060, 0.0004), with the cloud chart shown in Figure 3. After multiple rounds of adjustments, the cloud layer thickness has significantly decreased, and the dispersion has relatively weakened. This indicates that the results are more consistent, effectively reducing the subjective randomness of expert scoring. Ultimately, the cloud weights for C1, the emergency logistics fundamental capability relative to the urban natural disaster emergency logistics capability, were determined to be (0.9020, 0.0060, 0.0004).

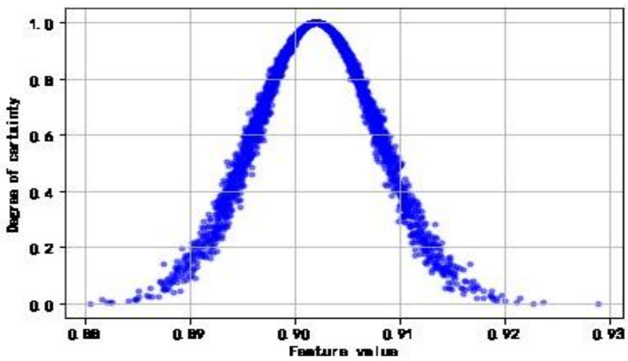


Fig. 3. The last expert scoring cloud chart

Other indicators followed the same process, determining and continuously adjusting the cloud weights for each layer's indicators to achieve more reasonable cloud weights. Finally, the data was normalized to obtain the weight of each indicator. The final weights are shown in Table 5.

Table 5. Cloud Weights for Evaluation Indicators of Beijing's Emergency Logistics Capability

| | First level indicator | | Secondary indicators | |
|---|---|---|---|---|
| | Index | Cloud Weight | Index | Cloud Weight |
| Evaluation of Urban Emergency Logistics Capacity | Circulation economic support capacity ($C_1$) | (0.9020, 0.0060, 0.0004) | Gross Regional Product ($C_{11}$) | (0.8089, 0.0074, 0.0009) |
| | | | Total retail sales of consumer goods ($C_{12}$) | (0.7900, 0.0075, 0.0018) |
| | | | Financial self-sufficiency rate ($C_{13}$) | (0.9109, 0.0092, 0.0017) |
| | | | Total fixed asset investment in logistics industry ($C_{14}$) | (0.7620, 0.0085, 0.0018) |
| | | | Investment in information and information technology fixed assets ($C_{15}$) | (0.7920, 0.0060, 0.0004) |
| | Infrastructure support capabilities ($C_2$) | (0.8869, 0.0127, 0.0015) | Highway mileage ($C_{21}$) | (0.6880, 0.0060, 0.0004) |
| | | | Number of trucks in use ($C_{22}$) | (0.8400, 0.0075, 0.0018) |
| | Human resources support capability ($C_3$) | (0.7790, 0.0092, 0.0017) | Information and information technology industry practitioners ($C_{31}$) | (0.5879, 0.0060, 0.0004) |
| | | | Logistics industry practitioners ($C_{32}$) | (0.7380, 0.0060, 0.0004) |
| | Information technology support capability ($C_4$) | (0.8709, 0.0092, 0.0017) | Information collection, analysis and feedback capabilities ($C_{41}$) | (0.7920, 0.0060, 0.0004) |
| | | | Disaster monitoring and early warning capabilities ($C_{42}$) | (0.8869, 0.0102, 0.0021) |
| | | | Timeliness of emergency information release and sharing ($C_{43}$) | (0.7319, 0.0060, 0.0004) |
| | Government Command Capability ($C_5$) | (0.9259, 0.0090, 0.0016) | Frequency of organizing emergency drills and revising plans($C_{51}$) | (0.8920, 0.0060, 0.0004) |
| | | | Are the emergency organization and responsibilities sound?($C_{52}$) | (0.8799, 0.0100, 0.0007) |
| | | | The degree of soundness of laws and regulations related to emergency logistics($C_{53}$) | (0.7900, 0.0100, 0.0007) |
| | | | Scale of emergency logistics expert team building($C_{54}$) | (0.8900, 0.0075, 0.0018) |

After normalizing the cloud weights, Table 6 is obtained, as shown below.

Table 6. Normalized Cloud Weights for Evaluation Indicators of Beijing's Emergency Logistics Capability

| | First level indicator | | Secondary indicators | |
|---|---|---|---|---|
| | Index | Cloud Weight | Index | Cloud Weight |
| Evaluation of Urban Emergency Logistics Capacity | Circulation economic support capacity ($C_1$) | (0.2067, 0.1302, 0.0580) | Gross Regional Product ($C_{11}$) | (0.1990,0.1917,0.1364) |
| | | | Total retail sales of consumer goods ($C_{12}$) | (0.1944,0.1943,0.2727) |
| | | | Financial self-sufficiency rate ($C_{13}$) | (0.2242,0.2383,0.2576) |
| | | | Total fixed asset investment in logistics industry ($C_{14}$) | (0.1875,0.2202,0.2727) |
| | | | Investment in information and information technology fixed assets ($C_{15}$) | (0.1949,0.1554,0.0606) |
| | Infrastructure support capabilities ($C_2$) | (0.2032, 0.2755, 0.2174) | Highway mileage ($C_{21}$) | (0.4503,0.1818,0.1818) |
| | | | Number of trucks in use ($C_{22}$) | (0.5497,0.8182,0.8182) |
| | Human resources support capability ($C_3$) | (0.1785, 0.1996, 0.2464) | Information and information technology industry practitioners ($C_{31}$) | (0.4434,0.5000,0.5000) |
| | | | Logistics industry practitioners ($C_{32}$) | (0.5566,0.5000,0.5000) |
| | Information technology support capability ($C_4$) | (0.1995,0.1996,0.2464) | Information collection, analysis and feedback capabilities ($C_{41}$) | (0.3285,0.2703,0.1379) |
| | | | Disaster monitoring and early warning capabilities ($C_{42}$) | (0.3679,0.4595,0.7241) |
| | | | Timeliness of emergency information release and sharing ($C_{43}$) | (0.3036,0.2703,0.1379) |
| | Government Command Capability ($C_5$) | (0.2121, 0.1952, 0.2319) | Frequency of organizing emergency drills and revising plans($C_{51}$) | (0.2584,0.1791,0.1111) |
| | | | Are the emergency organization and responsibilities sound?($C_{52}$) | (0.2549,0.2985,0.1944) |
| | | | The degree of soundness of laws and regulations related to emergency logistics($C_{53}$) | (0.2289,0.2985,0.1944) |
| | | | Scale of emergency logistics expert team building($C_{54}$) | (0.2578,0.2239,0.5000) |

Based on previous literature research, the expected value in the cloud weights was selected as the indicator's weight. Consequently, the weights of each secondary indicator relative to the target layer were obtained, as shown in Table 7.

Table 7. Comprehensive Weights of Secondary Evaluation Indicators for Beijing's Emergency Logistics Capability

| First level indicator | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | Secondary index comprehensive weight |
|---|---|---|---|---|---|---|
| Secondary indicators | 0.2067 | 0. 2032 | 0. 1785 | 0. 1995 | 0. 2121 | |
| $C_{11}$ | 0. 1990 | 0 | 0 | 0 | 0 | 0. 0411 |
| $C_{12}$ | 0. 1994 | 0 | 0 | 0 | 0 | 0. 0412 |
| $C_{13}$ | 0. 2242 | 0 | 0 | 0 | 0 | 0. 0463 |
| $C_{14}$ | 0. 1875 | 0 | 0 | 0 | 0 | 0. 0388 |
| $C_{15}$ | 0.1949 | 0 | 0 | 0 | 0 | 0.0403 |
| $C_{21}$ | 0 | 0.4503 | 0 | 0 | 0 | 0.0915 |
| $C_{22}$ | 0 | 0.5497 | 0 | 0 | 0 | 0.1117 |
| $C_{31}$ | 0 | 0 | 0.4434 | 0 | 0 | 0.0791 |
| $C_{32}$ | 0 | 0 | 0.5566 | 0 | 0 | 0.0993 |
| $C_{41}$ | 0 | 0 | 0 | 0.3285 | 0 | 0.0655 |
| $C_{42}$ | 0 | 0 | 0 | 0.3679 | 0 | 0.0734 |
| $C_{43}$ | 0 | 0 | 0 | 0.3036 | 0 | 0.0606 |
| $C_{51}$ | 0 | 0 | 0 | 0 | 0.2584 | 0.0548 |
| $C_{52}$ | 0 | 0 | 0 | 0 | 0.2549 | 0.0540 |
| $C_{53}$ | 0 | 0 | 0 | 0 | 0.2289 | 0. 0485 |
| $C_{54}$ | 0 | 0 | 0 | 0 | 0. 2578 | 0. 0547 |

### *B. TOPSIS Evaluation of Beijing's Emergency Logistics Capability*

Based on the indicator weights derived from the cloud model, the TOPSIS comprehensive evaluation method was used to assess Beijing's emergency logistics capability from 2003 to 2022. The results indicate that the selected indicators and methods effectively evaluate Beijing's emergency logistics capability, clearly demonstrating the development of Beijing's emergency logistics from 2003 to 2022.

## a. *Data Sources*

Quantitative data were obtained from platforms such as the China Statistical Yearbook, Beijing Statistical Yearbook, and Beijing Emergency Management Bureau, covering the original data of Beijing from 2003 to 2022. These quantitative data were specially quantified, as shown in Tables 8 and 9. Qualitative indicators, such as the frequency of organizing emergency drills and revising plans, were derived from surveys since such data were not available. The survey targeted individuals with a background or experience in emergency logistics, leveraging the experts' knowledge and experience. The scoring method was based on the number of plans, policies, and plans released in key years in Beijing, with values assigned as follows: "Very Poor" (0-1.0), "Poor" (1.1-2.0), "Average" (2.1-3.0), "Good" (3.1-4.0), and "Very Good" (4.1-5.0). This provided an accurate evaluation of qualitative indicators. The survey was distributed via email, and 10 experts were selected for evaluation. Through several rounds of data feedback, a relatively focused evaluation result was obtained, as shown in Table 10.

Table 8. Raw Data for Quantitative Indicators

| years | Regional GDP (100 million yuan) | Total retail sales of consumer goods (100 million yuan) | Financial self-sufficiency rate (%) | Total fixed asset investment in logistics industry (100 million yuan) | Investment in information and information technology fixed assets (100 million yuan) | Highway mileage (km) | Number of trucks in use (10,000 units) | Number of people employed in the information and information technology industry (10,000 people) | Number of people employed in the logistics industry (10,000 people) |
|---|---|---|---|---|---|---|---|---|---|
| 2003 | 5267.2 | 2492.6 | 80.37 | 139 | 68 | 14453 | 17.7 | 16 | 28.9 |
| 2004 | 6252.5 | 2883.6 | 86.31 | 154.06 | 72.74 | 14630 | 17.7 | 16.3 | 31.4 |
| 2005 | 7149.8 | 3221.4 | 87.47 | 226.20 | 80.29 | 14696 | 17.7 | 17.5 | 33 |
| 2006 | 8387 | 3673.3 | 86.44 | 436.76 | 75.83 | 20503 | 17.7 | 22.3 | 38.4 |
| 2007 | 10425.5 | 4307.4 | 90.63 | 570.85 | 97.90 | 20754 | 17.6 | 27.1 | 40.5 |
| 2008 | 11813.1 | 5257.5 | 93.93 | 636.04 | 103.02 | 20340 | 18.1 | 48.8 | 54.8 |
| 2009 | 12900.9 | 6140 | 88.06 | 727.68 | 140.01 | 20755 | 18.3 | 50.6 | 55.8 |
| 2010 | 14964 | 7273 | 86.67 | 733.70 | 143.31 | 21114 | 19.4 | 58.4 | 56.5 |
| 2011 | 17188.8 | 8334.8 | 92.6 | 698.88 | 112.93 | 21347 | 21.5 | 66.7 | 63.3 |
| 2012 | 19024.7 | 9440.2 | 89.95 | 734.74 | 165.40 | 21492 | 23.7 | 73.2 | 64.4 |
| 2013 | 21134.6 | 10382.5 | 87.79 | 681.44 | 209.74 | 21673 | 25.7 | 79.4 | 65.5 |
| 2014 | 22926 | 11354 | 89.29 | 775.80 | 183.44 | 21849 | 28.9 | 84.4 | 66.6 |
| 2015 | 24779.1 | 12271.9 | 82.13 | 849.55 | 242.75 | 21885 | 30.6 | 92.2 | 66.8 |
| 2016 | 27041.2 | 13134.9 | 79.31 | 995.40 | 198.85 | 22026 | 33 | 92.9 | 64.1 |
| 2017 | 29883 | 13933.7 | 79.58 | 1349.58 | 283.87 | 22226 | 36.7 | 101.6 | 63.6 |
| 2018 | 33106 | 14422.3 | 77.44 | 1376.57 | 372.44 | 22256 | 40 | 111.5 | 66.3 |
| 2019 | 35445.1 | 15063.7 | 78.52 | 1164.58 | 323.00 | 22366 | 47.6 | 112.9 | 67.9 |
| 2020 | 35943.3 | 13716.4 | 77.06 | 1055.11 | 323.65 | 22264 | 51.6 | 130.5 | 61.9 |
| 2021 | 40269.6 | 14867.7 | 82.33 | 1018.18 | 388.38 | 22320 | 53.7 | 138.9 | 60.4 |
| 2022 | 41610.9 | 13794.2 | 76.51 | 940.8 | 528.19 | 22363 | 54.7 | 137.2 | 58.1 |

Table 9. Special Quantitative Processing of Raw Data for Quantitative Indicators

| years | GDP | The total retail sales of social consumer goods | Financial self-sufficiency rate | Total fixed asset investment in logistics industry | Investment in information and information technology fixed assets | Highway mileage | Truck ownership | Information and information technology industry practitioners | Logistics industry practitioners |
|---|---|---|---|---|---|---|---|---|---|
| 2003 | 0. 62 | 0.67 | 2.37 | 0.46 | 0.63 | 1.76 | 1.50 | 0.54 | 1.30 |
| 2004 | 0.73 | 0.78 | 2.55 | 0.50 | 0.67 | 1.78 | 1.50 | 0.55 | 1.42 |
| 2005 | 0.84 | 0.87 | 2.58 | 0.74 | 0.74 | 1.79 | 1.50 | 0.59 | 1.49 |
| 2006 | 0.99 | 0.99 | 2.55 | 1.43 | 0.70 | 2.49 | 1.50 | 0.75 | 1.73 |
| 2007 | 1.23 | 1.16 | 2.68 | 1.87 | 0.90 | 2.52 | 1.49 | 0.92 | 1.83 |
| 2008 | 1.39 | 1.41 | 2.78 | 2.08 | 0.95 | 2.47 | 1.53 | 1.65 | 2.47 |
| 2009 | 1.52 | 1.65 | 2.60 | 2.38 | 1.29 | 2.52 | 1.55 | 1.71 | 2.52 |
| 2010 | 1.76 | 1.96 | 2.56 | 2.40 | 1.32 | 2.57 | 1.64 | 1.98 | 2.55 |
| 2011 | 2.02 | 2.24 | 2.74 | 2.29 | 1.04 | 2.59 | 1.82 | 2.26 | 2.86 |
| 2012 | 2.24 | 2.54 | 2.66 | 2.41 | 1.53 | 2.61 | 2.00 | 2.48 | 2.91 |
| 2013 | 2.48 | 2.79 | 2.59 | 2.23 | 1.94 | 2.63 | 2.17 | 2.69 | 2.96 |
| 2014 | 2.69 | 3.05 | 2.64 | 2.54 | 1.69 | 2.66 | 2.44 | 2.85 | 3.00 |
| 2015 | 2.91 | 3.30 | 2.43 | 2.78 | 2.24 | 2.66 | 2.58 | 3.12 | 3.01 |
| 2016 | 3.18 | 3.53 | 2.34 | 3.26 | 1.84 | 2.68 | 2.79 | 3.14 | 2.89 |
| 2017 | 3.51 | 3.75 | 2.35 | 4.42 | 2.62 | 2.70 | 3.10 | 3.44 | 2.87 |
| 2018 | 3.89 | 3.88 | 2.29 | 4.51 | 3.44 | 2.71 | 3.38 | 3.77 | 2.99 |
| 2019 | 4.16 | 4.05 | 2.32 | 3.81 | 2.98 | 2.72 | 4.02 | 3.82 | 3.06 |
| 2020 | 4.22 | 3.69 | 2.28 | 3.46 | 2.99 | 2.71 | 4.36 | 4.41 | 2.79 |
| 2021 | 4.73 | 4.00 | 2.43 | 3.34 | 3.59 | 2.71 | 4.54 | 4.70 | 2.73 |
| 2022 | 4.89 | 3.71 | 2.26 | 3.08 | 4.88 | 2.72 | 4.62 | 4.64 | 2.62 |

Table 10. Results of Qualitative Indicators

| Year | Information collection, analysis and feedback capabilities | Disaster monitoring and early warning capabilities | Timeliness of emergency information release and sharing | Frequency of organizing emergency drills and revising plans | Are the emergency organization and responsibilities sound? | The degree of soundness of laws and regulations related to emergency logistics | Scale of emergency logistics expert team building |
|---|---|---|---|---|---|---|---|
| 2003 | 1.5 | 1.1 | 2.5 | 0.5 | 2.5 | 0.5 | 0.5 |
| 2004 | 1.5 | 2.8 | 2.5 | 0.5 | 2.8 | 0.5 | 0.5 |
| 2005 | 1.5 | 2.8 | 2.5 | 0.5 | 2.8 | 0.5 | 0.5 |
| 2006 | 1.5 | 2.8 | 2.5 | 0.5 | 2.8 | 0.5 | 0.5 |
| 2007 | 2.5 | 3 | 2.8 | 1 | 3 | 2.5 | 1 |
| 2008 | 2.5 | 3 | 2.8 | 1 | 3 | 2.5 | 1 |
| 2009 | 2.5 | 3 | 2.8 | 1 | 3 | 2.5 | 1 |
| 2010 | 2.5 | 3 | 2.8 | 1 | 3 | 2.5 | 1 |
| 2011 | 2.5 | 3 | 2.8 | 1 | 3 | 2.5 | 1 |
| 2012 | 3 | 3.5 | 3.5 | 1.5 | 3.6 | 3.2 | 2.5 |
| 2013 | 3 | 3.5 | 3.5 | 1.5 | 3.6 | 3.2 | 2.5 |
| 2014 | 3 | 3.5 | 3.5 | 1.5 | 3.6 | 3.2 | 2.5 |
| 2015 | 3 | 3.5 | 3.5 | 1.5 | 3.6 | 3.2 | 2.5 |
| 2016 | 3 | 3.5 | 3.5 | 1.5 | 3.6 | 3.2 | 2.5 |
| 2017 | 3.2 | 3.8 | 3.8 | 3 | 3.8 | 3.5 | 3.2 |
| 2018 | 3.2 | 3.8 | 3.8 | 3 | 3.8 | 3.5 | 3.2 |
| 2019 | 3.2 | 3.8 | 3.8 | 3 | 3.8 | 3.5 | 3.2 |
| 2020 | 3.2 | 3.8 | 3.8 | 3 | 3.8 | 3.5 | 3.2 |
| 2021 | 3.6 | 4.2 | 4.2 | 4 | 4 | 3.8 | 4 |
| 2022 | 3.6 | 4.2 | 4.2 | 4 | 4 | 3.8 | 4 |

## b. *Data Processing Procedure*

All indicators are benefit-type indicators and do not require normalization. Using the weights obtained from the cloud model, a weighted decision matrix is constructed, and the positive and negative ideal solutions of the decision matrix are calculated, as shown in Table 11.

Table 11. Positive Ideal Solution and Negative Ideal Solution of Each Indicator

| Index | Positive ideal solution A+ | Negative ideal solution A- |
|---|---|---|
| Regional GDP (100 million yuan) | 4.890 | 0.620 |
| Total retail sales of consumer goods (100 million yuan) | 4.050 | 0.670 |
| Financial self-sufficiency rate (%) | 2.780 | 2.260 |
| Total fixed asset investment in logistics industry (100 million yuan) | 4.510 | 0.460 |
| Investment in information and information technology fixed assets (100 million yuan) | 4.880 | 0.630 |
| Highway mileage (km) | 2.720 | 1.760 |
| Number of trucks in use (10,000 units) | 4.620 | 1.490 |
| Information and information technology industry practitioners | 4.700 | 0.540 |
| Logistics industry practitioners | 3.060 | 1.300 |
| Information collection, analysis and feedback capabilities | 3.600 | 1.500 |
| Disaster monitoring and early warning capabilities | 4.200 | 1.100 |
| Timeliness of emergency information release and sharing | 4.200 | 2.500 |
| Frequency of organizing emergency drills and revising plans | 4.000 | 0.500 |
| Are the emergency organization and responsibilities sound? | 4.000 | 2.500 |
| The degree of soundness of laws and regulations related to emergency logistics | 3.800 | 0.500 |

### c. *Results and Analysis*

According to the formula, the distance of each year from the positive and negative ideal solutions and their comprehensive evaluation indices were calculated. The results were then ranked, as shown in Table 12. The comprehensive scores of the evaluation indicators for Beijing's emergency logistics capability from 2003 to 2022 show a year-on-year increase, indicating that Beijing's emergency logistics capability has been strengthening each year. By 2022, Beijing's emergency logistics capability has reached a relatively high level.

Over the past twenty years, Beijing's emergency logistics capability has seen five significant improvements, as shown in Figure 4. The first enhancement was in 2004, the outbreak of SARS led China to place greater emphasis on emergency logistics research and establish a national emergency system, significantly enhancing Beijing's emergency logistics capability. The second enhancement was in 2007, following the end of the Tenth Five-Year Plan, the improvement in Beijing's emergency logistics capability was smaller compared to the post-SARS enhancement in 2004.

The third enhancement was in 2012. During the Eleventh Five-Year Plan, Beijing implemented the "Law of the People's Republic of China on Emergency Response," improved emergency organization structures and responsibilities, and perfected laws and regulations related to emergency logistics. At the same time, the fixed asset investment in information and information technology grew by 46% in 2012, boosting information technology assurance capacity and significantly enhancing Beijing's emergency logistics capability.

The fourth enhancement was in 2017. During the Twelfth Five-Year Plan, Beijing established an early warning information release system and an early warning center for emergencies. The increase in fixed asset investment in the logistics and information sectors supported the enhancement of emergency logistics capability.

The fifth enhancement was in 2021. During the Thirteenth Five-Year Plan, Beijing refined its emergency plan system, revising the "General Emergency Plan for Public Emergencies in Beijing" and other documents, further promoting the improvement of emergency logistics capability. From 2020 to 2023, influenced by the COVID-19 pandemic, Beijing's emergency management agencies were reorganized, and the city's emergency bureau established an emergency decision-making mechanism aligned with the capital's functional positioning.

Table 12. Evaluation Results of Beijing's Emergency Logistics Capability (2003-2022)

| years | Positive ideal solution distance | Negative ideal solution distance | Relative proximity Ei * | Sorting results |
|---|---|---|---|---|
| 2003 | 2.932 | 0.024 | 0.008 | 20 |
| 2004 | 2.800 | 0.473 | 0.144 | 19 |
| 2005 | 2.762 | 0.482 | 0.149 | 18 |
| 2006 | 2.672 | 0.581 | 0.179 | 17 |
| 2007 | 2.367 | 0.881 | 0.271 | 16 |
| 2008 | 2.215 | 1.008 | 0.313 | 15 |
| 2009 | 2.148 | 1.057 | 0.330 | 14 |
| 2010 | 2.072 | 1.115 | 0.350 | 13 |
| 2011 | 2.008 | 1.204 | 0.375 | 12 |
| 2012 | 1.657 | 1.553 | 0.484 | 11 |
| 2013 | 1.558 | 1.614 | 0.509 | 10 |
| 2014 | 1.478 | 1.684 | 0.533 | 9 |
| 2015 | 1.353 | 1.778 | 0.568 | 8 |
| 2016 | 1.312 | 1.828 | 0.582 | 7 |
| 2017 | 0.901 | 2.208 | 0.710 | 6 |
| 2018 | 0.711 | 2.345 | 0.767 | 5 |
| 2019 | 0.652 | 2.386 | 0.785 | 4 |
| 2020 | 0.610 | 2.446 | 0.800 | 3 |
| 2021 | 0.372 | 2.770 | 0.882 | 2 |
| 2022 | 0.341 | 2.821 | 0.892 | 1 |

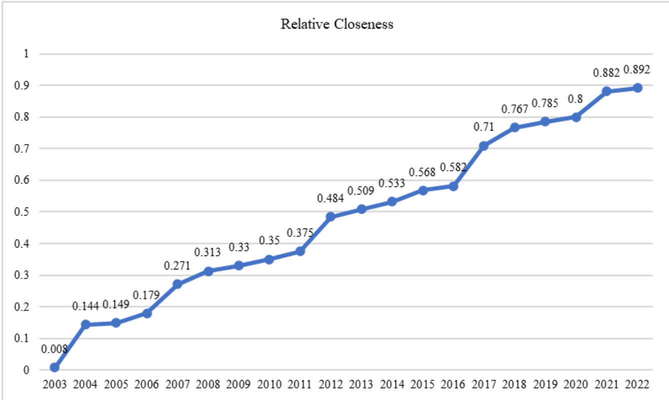


Fig. 4. Results of the evaluation of Beijing's emergency logistics capabilities

## CONCLUSION

This study conducted a growth evaluation of Beijing's emergency logistics capability from 2003 to 2022 using the Cloud Weight-Approaching Ideal Solution Ordering Method (TOPSIS). By constructing an evaluation indicator system for urban emergency logistics capability, the study systematically analyzed the development trends and periodic changes in Beijing's emergency logistics capability over the past twenty years. The research results indicate that Beijing's emergency logistics capability has shown a year-on-year enhancement, with five significant improvements during this period. By 2022, Beijing's emergency logistics capability had reached a relatively high level. Additionally, the evaluation indicator system and methodology developed in this study provide valuable references for the evaluation and optimization of emergency logistics capabilities in other cities. In the future, further strengthening of emergency command functions, enhancing emergency material support capabilities, improving emergency transportation capabilities, promoting the socialization of emergency logistics, and advancing the intelligentization of emergency logistics will be key to improving the comprehensive emergency capabilities of cities.

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