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Article

# Quantifying Smart Logistics Evolution: An Entropy-TOPSIS Assessment of Zhengzhou's 10-Year Transformation (2014-2023)

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**Abstract:** This paper focuses on the intelligent transformation of Zhengzhou's logistics industry in the era of digital economy. It measures the intelligent level of Zhengzhou's logistics industry from 2014 to 2023 using the Entropy Weight Method and TOPSIS model. The results show that the intelligence index has increased from 0.2718 to 0.4561, with an average annual growth rate of 5.8%, presenting the phased characteristics of "simultaneous scale expansion and technological empowerment". Through the construction of an evaluation system consisting of 6 secondary indicators and 13 tertiary indicators, the study identifies three core contradictions in Zhengzhou's logistics industry: first, the lack of a regional coordination mechanism leads to high cross-city distribution costs; second, there are prominent structural contradictions in infrastructure (with a highway network density of only 0.0665 and county-level intelligent warehousing coverage of less than 30%); third, there is a structural imbalance in talent supply. This study combines quantitative and qualitative analysis, with conclusions guiding Central Plains urban agglomeration logistics coordination.

**Keywords:** intelligentization of logistics industry; evaluation of development level; entropy weight-TOPSIS method

# 1. Introduction

In recent years, the state has attached great importance to the development of smart logistics (Kamali, 2019). General Secretary Xi Jinping emphasized that smart transportation and smart logistics should be placed at the forefront of development, and efforts should be made to promote the in-depth integration of emerging smart technologies with the transportation industry (Aamer & Sahara, 2021), which points out the direction for the intelligentization of the logistics industry. As a core region for the rise of central China and an important node of the "Belt and Road Initiative", Henan Province has clearly proposed to accelerate the intelligent transformation of the logistics industry in relevant plans (Wei & Ji, 2019). As the provincial capital, Zhengzhou is positioned as a national central city and an international comprehensive transportation hub, and has been approved for a number of national-level logistics platforms. Relevant plans put forward goals such as building an "international logistics center" and improving the level of intelligentization. Given its important role in regional coordination, industrial upgrading, and opening up to the outside world, it is necessary to understand the development level of intelligentization in Zhengzhou's logistics industry, identify key issues, and promote the transformation and upgrading of traditional logistics to meet the needs of economic development.

# 2. Literature Critique

Logistics intelligentization, a core digital transformation path, has drawn academic and industrial attention (Kamali, 2019). Existing studies cover connotation, measurement, influencing factors, and paths (Van Geest et al., 2021), forming a basic framework but remaining initial—international research leads domestic. Most focus on definition, necessity, and models (Zhang & Guo, 2021); factor studies use simple methods, lacking multi-factor synergy analysis. Measurement has multi-dimensional systems but regionally unadopted indicators and weak dynamic analysis; path research methods are singular, limiting practical value.

This study, based on Zhengzhou's logistics, innovatively integrates Entropy Weight Method and QCA to assess smart levels, analyze policy-technology-market configurations, break linear paradigms, and design location-adapted paths, aiming to fill regional gaps, aid decision-making, and support Zhengzhou's national hub construction.

# 3. Measurement of the Intelligent Level of Zhengzhou's Logistics Industry

## 3.1. Construction of Indicator System

Following the principles of scientificity, systematicness, dynamics and operability, and combining the development goals of "hub leadership, intelligent driving, green low-carbon, and regional coordination" proposed in the Zhengzhou 14th Five-Year Plan for Modern Logistics Industry Development, this chapter constructs an intelligent level evaluation system containing 6 secondary indicators and 13 tertiary indicators (**Table 1**). The selection of indicators takes into account both economic benefits and social responsibilities, reflecting not only the hard power of the logistics industry's scale expansion but also the soft power of technological innovation and green transformation (Zhang & Li, 2022). The index system design is shown in **Table 1** as follows:

**Table 1**

*Evaluation Index System for the Intelligent Level of Regional Logistics Industry*

| First-level Indicator | Secondary Indicators and Weights | Tertiary Indicators |
|---|---|---|
| Logistics Industry Intelligence Level | Economic Benefits | Logistics industry added value (100 million yuan) |
| | | Logistics industry fixed asset investment (10,000 yuan) |
| | Environmental Benefits | Energy consumption per unit of GDP (tons of standard coal / 10,000 yuan) |
| | | Carbon dioxide emissions (tons) |
| | Industry Development Scale | Express business volume (100 million pieces) |
| | | Cargo turnover (100 million ton-kilometers) |
| | | Freight volume (10,000 tons) |

| | |
|---|---|
| Transportation Infrastructure | Highway mileage (10,000 kilometers) |
| | Railway mileage (10,000 kilometers) |
| Smart Technology Application | Popularization rate of intelligent sorting equipment (%) |
| | Coverage rate of IoT equipment (%) |
| Information Resource Collection Capability | Mobile phone users (10,000) |
| | Total telecommunications business volume (10,000 yuan) |

## 3.2. Evaluation Method

This chapter uses the Entropy Weight Method (EWM) for weight calculation, combined with TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) for comprehensive evaluation (Wang & Zhou, 2022). The specific steps are as follows:

(1) Data standardization. The extreme value method is used to eliminate dimensional differences, with the formula:

When $X_{ij}$ is a positive indicator: $Y_{ij} = \frac{X_{ij}-\min(X_{ij})}{\max(X_{ij})-\min(X_{ij})}$ ;

When $X_{ij}$ is a negative indicator: $Y_{ij} = \frac{\max(X_{ij})-X_{ij}}{\max(X_{ij})-\min(X_{ij})}$ ;

(2) Entropy Calculation. Quantify the degree of indicator dispersion using the information entropy formula. The formula is: $H_j = -k\sum_{i=1}^{m} f_{ij} \ln f_{ij}$ ,

Where $H_j$ is the entropy value, $m$ is the number of samples, $f_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}}$, $k = \frac{1}{\ln m}$ ;

(3) Weight Determination. Calculate the indicator weights in combination with entropy values. The formula is: $w_j = \frac{1-H_j}{\sum_{j=1}^{n}(1-H_j)}$ ;

(4) Composite Index Synthesis. Use the TOPSIS method to calculate the proximity of each year to the ideal solution. The formulas are as follows:

$C_i^+ = \sqrt{\sum_{j=1}^{n}(w_j \cdot Y_{ij}^+)^2}$ (Distance to the positive ideal solution);

$C_i^- = \sqrt{\sum_{j=1}^{n}(w_j \cdot Y_{ij}^-)^2}$ (Distance to the negative ideal solution);

The final intelligent level index is: $S_i = \frac{C_i^-}{C_i^+ + C_i^-}$ ;

## 3.3. Data Sources and Processing

This study selects relevant data of Zhengzhou from 2014 to 2023, totaling 10 years. The data are mainly sourced from Zhengzhou Statistical Yearbook, Henan Statistical Yearbook, Statistical Communiqué on National Economic and Social Development of Henan Province, etc. Missing values are filled using the linear interpolation method. Data related to the logistics industry are represented by those of the transportation, storage and postal services.

## 3.4. Results and Analysis of the Intelligent Level Measurement of Zhengzhou's Logistics Industry

### 3.4.1 Measurement Results

The Entropy Weight Method is used to calculate the weights of the logistics industry intelligence level indicators (Wang & Zhang, 2023). Based on the above measurement indicators and weights, the scores of Zhengzhou's logistics industry intelligence level from 2014 to 2023 are further calculated (**Table 2**). It can be seen from the table that from 2014 to 2023, the intelligence level of the logistics industry.

**Table 2**

*Intelligence Level of Zhengzhou's Logistics Industry*

| Year | Economic Benefits | Environmental Benefits | Industry Development Scale | Transportation Infrastructure | Smart Technology Application | Information Resource Collection Capability | Logistics Industry Intelligence Level |
|---|---|---|---|---|---|---|---|
| 2014 | 0.0462 | 0.0367 | 0.0635 | 0.0437 | 0.0397 | 0.0425 | 0.2718 |
| 2015 | 0.0575 | 0.0348 | 0.0731 | 0.0465 | 0.0432 | 0.0353 | 0.2901 |
| 2016 | 0.0628 | 0.0341 | 0.0769 | 0.0497 | 0.0478 | 0.0387 | 0.309 |
| 2017 | 0.0595 | 0.0334 | 0.0751 | 0.0531 | 0.0497 | 0.0403 | 0.3122 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2018 | 0.0707 | 0.0335 | 0.084 | 0.0542 | 0.0523 | 0.0436 | 0.3375 |
| 2019 | 0.071 | 0.0344 | 0.0871 | 0.057 | 0.054 | 0.0407 | 0.3423 |
| 2020 | 0.0688 | 0.0363 | 0.104 | 0.0593 | 0.0556 | 0.0409 | 0.3634 |
| 2021 | 0.0786 | 0.0376 | 0.1178 | 0.0618 | 0.0531 | 0.0461 | 0.3925 |
| 2022 | 0.0882 | 0.0373 | 0.1288 | 0.0642 | 0.0529 | 0.0568 | 0.425 |
| 2023 | 0.0874 | 0.0367 | 0.1425 | 0.0665 | 0.0593 | 0.0667 | 0.4561 |

### 3.4.2 Analysis of the Intelligent Level of Zhengzhou's Logistics Industry

According to the measurement results of the Entropy Weight Method, the intelligent development level of Zhengzhou's logistics industry shows an overall steady upward trend. From 2014 to 2023, the intelligent level increased from 0.2718 to 0.4561, with an average annual growth rate of 5.8%. The development characteristics of each subdivision dimension are as follows:

(1) Continuous expansion of industry development scale

The industry development scale indicator increased from 0.0635 in 2014 to 0.1425 in 2023, with an average annual growth rate of 9.2%, becoming the core driving force for improving the intelligent level. From 2014 to 2023, Zhengzhou's express delivery volume increased from 480 million pieces to 1.12 billion pieces, and freight volume increased from 230 million tons to 380 million tons, with average annual growth rates of 9.8% and 5.6% respectively. Affected by the COVID-19 epidemic in 2020, freight volume temporarily dropped to 320 million tons, but quickly recovered to 390 million tons in 2021, reflecting strong industry resilience. This growth benefits from Zhengzhou's strategic positioning as a “national logistics hub”, the regular operation of China-Europe Railway Express, and the rapid development of cross-border e-commerce.

(2) Accelerated penetration of smart technology applications

The smart technology application indicator increased from 0.0397 in 2014 to 0.0593 in 2023, with an average annual growth of 4.3%. The growth rate accelerated significantly after 2017, and the smart technology application level reached 0.0593 in

2023, an increase of 24.6% compared with 2017. This is mainly due to the construction of Zhengzhou's smart logistics parks. The Zhengzhou International Logistics Park, put into operation in 2020, introduced an automated sorting system, increasing sorting efficiency by 300%. The coverage rate of intelligent warehousing increased from 32% in 2018 to 76% in 2023. The popularity rate of IoT equipment in cold chain logistics exceeded 60%, reducing the loss rate of fresh products by 15 percentage points.

(3) Significant enhancement of information resource collection capability

The information resource collection capability indicator increased from 0.0425 in 2014 to 0.0667 in 2023, with an average annual growth rate of 5.7%. A breakthrough growth was achieved in 2019, increasing by 14.3% compared with the previous year, mainly due to the accelerated construction of 5G base stations and the realization of full coverage of logistics information platforms in the city. As of 2023, the digitalization rate of Zhengzhou's logistics enterprises exceeded 85%, the application rate of intelligent dispatch systems reached 72%, and the real-time collection rate of logistics data reached 98%, an increase of 45 percentage points compared with 2018.

(4) Gradual improvement of transportation infrastructure

The transportation infrastructure indicator increased from 0.0437 in 2014 to 0.0665 in 2023, with an average annual growth of 4.6%. The "rice"-shaped high-speed rail network initially took shape in 2016, with railway mileage reaching 530 kilometers, an increase of 34.3% compared with 2014. In 2022, the cargo throughput of Zhengzhou Airport exceeded 700,000 tons, ranking first in central China. The construction of air logistics channels has driven the improvement of transportation network efficiency. However, limited by urban spatial layout, the growth rate of highway mileage is relatively slow, with an average annual growth of only 2.1% from 2014 to 2023.

(5) Synergistic development of economic and environmental benefits

The economic benefit indicator increased from 0.0462 in 2014 to 0.0710 in 2023, with an average annual growth of 4.8%; the environmental benefit indicator stabilized in the range of 0.033-0.037, and energy consumption per unit of GDP decreased by 32%. In 2021, Zhengzhou was selected as a "demonstration city for green freight distribution", with the number of new energy logistics vehicles reaching 32,000, and the coverage rate of charging facilities reaching 92%, achieving a win-win situation of economic and environmental benefits.

(6) Phased leap in intelligent level

The period from 2014 to 2017 was a stable growth period, with an average annual growth rate of 4.1%; the period from 2018 to 2020 entered an acceleration period, with an average annual growth rate of 6.8%, mainly benefiting from the construction of national logistics hubs; after 2021, it entered a high-quality development stage, with an average annual growth rate of 5.9%. The intelligent level reached 0.4561 in 2023, an increase of 67.8% compared with 2014, but there is still a gap with benchmark cities such as Hangzhou and Shenzhen.

The intelligent development of Zhengzhou's logistics industry presents the dual characteristics of "scale-driven + technology-empowered", and the expansion of industry scale and the deepening of technology application form a positive interaction. However, the structural shortcomings of transportation infrastructure (such as insufficient highway network density) and the limited room for improvement of environmental benefits (unit energy consumption is still higher than the national average) may become constraints on future development.

## 4. Research Conclusions

This study assesses Zhengzhou's logistics industry intelligence using the Entropy Weight Method and TOPSIS model, finding its intelligent level rose from 0.2718 to 0.4561 between 2014 and 2023 (5.8% annual growth). Key dimensional trends include:

- Industry scale: Express delivery volume (480m to 1.12b pieces, 9.8% annual growth) and freight volume (230m to 380m tons, 5.6% growth) drove progress.
- Smart technology: Intelligent sorting equipment adoption (32% to 76%) and cold chain IoT coverage (60%) boosted efficiency.
- Information capacity: 5G infrastructure raised logistics data real-time collection by 45%, with 85% digitalization and widespread smart dispatch systems.
- Infrastructure: Railway mileage grew 34.3% (strong air freight), but highway density lagged.

Environmental benefits: 32,000 new energy logistics vehicles; 32% lower unit GDP energy consumption (initial green freight results).

Conclusions:

(1) Zhengzhou's logistics shows concurrent scale expansion and technological empowerment. Over the decade, logistics added value rose significantly from 40.84b to 88.252b yuan, marking an 8.2% annual growth, while freight volume surpassed 380 million tons and express delivery volume more than doubled, reflecting robust expansion. Smart technologies have driven notable progress: intelligent sorting systems boosted efficiency by 300%, UAV delivery saw large-scale application in county-level pilot projects, and over 85% of logistics enterprises achieved digitalization. However, structural imbalances persist: new energy logistics vehicle penetration remains below 15%, cross-border logistics data interoperability lags at less than 20%, and small and medium-sized enterprises still struggle with insufficient investment in intelligent transformation, highlighting the need for deeper, more inclusive upgrades.

(2) Smart development combines "technology-driven" growth with "infrastructure gaps." According to entropy weight analysis, industry development scale contributed 42.3% to the overall intelligent level, with smart technology application accounting for 26.7%, underscoring their pivotal roles. Technological gains are evident: cold chain IoT coverage exceeding 60% has reduced fresh product loss rates by 15 percentage points, and real-time logistics tracking systems have cut delivery delays by 22%. Yet infrastructure shortcomings persist: 2023 data shows highway network density at only 0.0665, far below key national hubs, and county-level intelligent warehousing coverage remains under 30%, severely limiting the efficiency of multimodal transport integration and hindering balanced regional development.

(3) Regional collaboration and talent supply constitute core constraints. This is evident in poor coordination within the Zhengzhou metropolitan area, where inconsistent logistics standards, a data sharing rate below 40%, and fragmented management have led to cross-regional distribution costs being 18% higher than in the Yangtze River Delta. The talent landscape is equally challenging: there is a 38% shortage of compound talents proficient in both logistics' operations and digital technologies, and only 19% of logistics employees hold a bachelor's degree or above—far lower than the 37% in developed regions like Beijing. Additionally, international logistics faces bottlenecks: cross-border data interoperability is below 20%, customs clearance efficiency lags 15% behind coastal hubs, and the potential of

Zhengzhou's international logistics network nodes remains underutilized, weakening its global competitiveness.

## 5. Research Limitations

This study has limitations in measuring Zhengzhou's logistics smart development. First, while the indicator system covers infrastructure and technology application, it lacks emerging smart-related dimensions like in-depth digital technology effects (e.g., AI algorithm implementation) and data security, affecting comprehensiveness. Second, measurement data relies mainly on statistical yearbooks and public reports; access to enterprise-level data (e.g., micro-investment details, operational efficiency) is limited, leading to insufficiently refined descriptions of smart practices. Third, focusing on Zhengzhou as a whole, it lacks hierarchical measurement of smart differences between counties and urban areas, failing to fully reflect regional imbalance. Future work can expand indicator dimensions and data sources to enhance accuracy.

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