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Research on Efficiency and Sustainability of Agricultural Product Logistics in Liaocheng Region based on Entropy Weight-TOPSIS Method

Tian Zeng[1], Fuhao Cao[2], Qinghua Wang[2], Liang Chen[2] corresponding author
1.Guilin University, Guilin 541006, China;
2.Guilin University of Technology, Guilin 541004, China

Abstract: This study uses the entropy weight-TOPSIS method to evaluate agricultural product logistics efficiency and sustainability in Liaocheng region. As a significant agricultural production base in Shandong Province, Liaocheng's agricultural logistics significantly impacts regional economic development and agricultural product supply. Collecting data from 2015 to 2021, this research comprehensively assesses agricultural logistics. The findings will guide enhancements, boosting efficiency and sustainability in Liaocheng's agricultural product logistics.
Keywords: Entropy Weight; TOPSIS; Agricultural Product Logistics

Introduction

In recent years, agricultural product logistics has grown in importance, connecting farms and markets, driving agricultural development, and boosting economic growth. Challenges persist in Shandong's logistics sector, including small enterprises and urban-rural disparities. Despite this, Liaocheng's role as a key agricultural hub remains crucial.

1. Research design

1.1 Construction of an evaluation index system for logistics competitiveness

Informed by Gan Weihua [2] and Chen Yuancai [3], this study constructs an evaluation index system for regional agricultural product logistics capacity. It encompasses economic foundation, infrastructure, informatization, and sustainability. This system evaluates efficiency and sustainability in Liaocheng's agricultural logistics, allowing detailed assessment across dimensions, with 11 selected secondary indicators, as presented in Table 1.

Table 1 Indicator system for assessing the efficiency and sustainability of agricultural logistics in Liaocheng area

	Level1 indicators	Level 2 indicators	Directivity
Efficiency and Sustainability Assessment Indicator System of Agricultural Product Logistics in Liaocheng City	Basis of Affordability A1	Regional GDP B1	Forward
		Total retail sales of social consumption B2	Forward
		Disposable income per capita B3	Forward
	Logistics infrastructure level A2	Number of road miles B4	Forward
		Cargo turnover on rural roads B5	Forward
		Civilian car ownership B6	Forward
	Logistics informatization level A3	Total rural postal and telecommunications business B7	Forward
		Number of Internet broadband access subscribers B8	Forward
	Level of sustainability of logistics operations A4	Agricultural diesel fuel consumption B9	Downward
		Agricultural transportation loss rate B10	Downward
		Carbon dioxide emissions from logistics and transportation B11	Downward

1.2 Data sources and evaluation methods

This paper combines methods to conduct evaluation, using literature research to identify key factors and applying entropy weight-TOPSIS for comprehensive assessment of Shandong Province's logistics. This method overcomes traditional TOPSIS method's subjectivity issues, ensuring objective index weight determination [1]. To comprehensively assess agricultural product logistics in Liaocheng, the study will employ the entropy weight-TOPSIS method, converting weight calculation into entropy values to objectively derive indicator weights based on differences and importance. The TOPSIS method will rank and score county-level agricultural product logistics, revealing competitiveness.

2. Efficiency and Sustainability Evaluation Model of Agricultural Product Logistics in Liaocheng Area

Entropy weighting method for calculating indicator weights ensures objectivity. Entropy, a state function, measures system chaos [4]. Entropy-based TOPSIS incorporates interval fuzzy numbers and information entropy to calculate weights, improving accuracy compared to fuzzy evaluation and entropy weight-TOPSIS methods. It effectively avoids subjective weight calculation errors.

2.1 Creation and standardization of analytical matrices

1.Determine the matrix elements according to the established evaluation system, so that xij is the ith indicator o f t h e evaluation object j.

$$X = (x_{ij})_{m\times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \cdots & \cdots & \cdots \\ x_{n1} & \cdots & x_{nn} \end{bmatrix}$$

2.Normalize the original indicator data and perform indicator translation. The original data were standardized using the extreme value method. Since the indicators used in the evaluation index system include positive indicators and negative indicators, two kinds of publicity are required to obtain the standardized matrix Y. Calculated as follows:

$$Y = (y_{ij})_{m\times n}$$

Among them:

$$\text{Positive indicators: } y_{ij} = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}$$

$$\text{Negative indicators: } y_{ij} = \frac{x_{max} - x_{ij}}{x_{max} - x_{min}}$$

2.2 Calculation of indicator weights using the entropy weight method

1.Calculate the weight of thejth indicator of year i in the standardized matrix Y, get the new matrix Z and calculate the information entropy of the indicator ej, the formula is as follows:

$$Z_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \qquad e_j = -k\sum_{i=1}^{m} (Z_{ij} \times \ln Z_{ij})$$

Where k is a constant, $k = 1/\ln m$, If Z_{ij}=0, then define $\lim_{zij0} z_{ij} \ln z_{ij} = 0$.

2.The calculation of indicator weights Wj using indicator information entropy is shown in Table 2:

$$W_j = \frac{1 - e_i}{\sum_{i=1}^{m}(1 - e_j)}$$

Table 2 Weights of Each Level of Evaluation Indicators

Level 1 indicators	Weight (%)	Secondary indicators	information entropy e	information utility value d	Weight (%)
Economic capacity base	24.051	Regional GDP (billion yuan)	0.818	0.182	9.374
		Total retail sales of social consumption	0.865	0.135	6.936
		Per capita disposable income	0.85	0.15	7.741

Level of logistics infrastructure	30.696	Number of road miles	0.75	0.25	12.887
		Road cargo turnover	0.814	0.186	9.556
		Civilian car ownership	0.84	0.16	8.253
Logistics informatization level	16.849	Total postal and telecommunication operations	0.839	0.161	8.299
		Number of Internet broadband access subscribers	0.834	0.166	8.55
Sustainable level of logistics operations	28.402	Agricultural diesel use	0.679	0.321	16.534
		Agricultural transportation loss rate	0.907	0.093	4.781
		Carbon dioxide emissions from logistics and transportation	0.862	0.138	7.087

2.3 Evaluation of indicators using the TOPSIS method to determine ideal solutions

1.On the basis of calculating the weights of the indicators, the normalized weighting matrix S is constructed and the elements of S are:

$$S_{ij} = w_i z_{ij}$$

2.Determine the maximum and minimum values S+ and S- for each evaluation object, also known as positive and negative ideal solutions. The formula and is the formula for calculating the positive and negative ideal solutions:

$$S^+ = (S_1^+, S_2^+, ..., S_m^+) = \{maxS_{ij} | i = 1,2, ..., m\}$$

$$S^- = (S_1^-, S_2^-, ..., S_m^-) = \{minS_{ij} | i = 1,2, ..., m\}$$

3. Calculate the differences between each element and the maximum and minimum values within each evaluation unit, referred to as proximity degrees. They are denoted as Di+ and Di-:

$$D_i^+ = \sqrt{\sum_{i=1}^{m} (S_{ij} - S_i^+)^2} \qquad D_i^- = \sqrt{\sum_{i=1}^{m} (S_{ij} - S_i^-)^2}$$

4. Compute the Ci proximity degree (also known as Comprehensive Score Index) for each evaluation object concerning the ideal solution. The proximity degree corresponds positively to agricultural product logistics capacity; Ci=1 denotes the optimal state. The calculation formula is as follows:

$$C_i = \frac{D_i^-}{D_i^- + D_i^+}$$

5. The classification of the degree of closeness to the ideal solution. According to the research of Luo Wenbin et al. [4], the status of the evaluation object is divided into five grades, and the results are shown in Table 3.

Table 3 Relative proximity of agricultural logistics efficiency to the ideal solution of sustainability in Liaocheng city

Particular year	（D+）	（D-）	C_i	Arrange in order	Coordinated state
2015	0.95511521	0.26722519	0.21861765	7	Less coherent
2016	0.87196794	0.26598781	0.23374178	6	Less coherent
2017	0.77140469	0.32178925	0.29435696	5	Less coherent
2018	0.56857727	0.50101204	0.46841534	4	General coordination
2019	0.39757097	0.67991016	0.63101816	3	More harmonious
2020	0.31511427	0.76992662	0.70958304	2	More harmonious
2021	0.26972638	0.95156683	0.77914691	1	More harmonious

2.4 Empirical research

This study assesses agricultural logistics efficiency and sustainability in Liaocheng City from 2015 to 2021. Data is extracted from Liaocheng and China Statistical Yearbooks, with logistics industry output value used for transportation, storage, and postal sectors. Employing the entropy weight-TOPSIS model, data from 2015 to 2021 is systematically analyzed. Anhui Province's raw data is presented in Table 2.

In the informatization level evaluation, diesel consumption holds a significant weight of 16.534%, indicating a crucial role in addressing long-standing energy-related challenges in agricultural logistics. The synergy between energy optimization and logistics industry development is evident. Recent "double carbon" initiatives and e-commerce growth have surged agricultural product logistics demand, raising expectations for logistics industry sustainability and driving rapid growth.

Broadband internet users' fixed weight is 8.55%, directly impacting agricultural product demand through online shopping, contributing to their upward movement. Logistics infrastructure is pivotal, with total highway mileage influencing heavily. Logistics industry output mirrors regional mileage and scale, encompassing overall capacity measurement. Positive highway mileage-scale correlation fosters a promising industry, attracting investment to refine logistics chains and expand. Agricultural product logistics capacity aligns with logistics industry growth; swifter logistics boost this capacity.

Economic capacity foundation slightly lags behind logistics operation sustainability in weight. Highway mileage and cargo-carrying vehicles hold higher weights. Efficient logistics reduce losses, enhancing agricultural product profit margins due to perishability. Effective circulation mitigates market volatility and emergencies, such as pandemics.

3. Countermeasures for the efficiency and sustainability of agricultural logistics in Liaocheng area

3.1 Upgrading of transport technology and equipment

The introduction of advanced transportation technology and equipment improves loading and unloading efficiency and reduces time wastage and loss in the transportation process. Firstly, advanced loading and unloading equipment and automation systems, can be introduced to improve loading and unloading efficiency and reduce the time waste of manual operation.

3.2 Strengthening information management

Enhance agricultural product logistics informationization for shared and streamlined information flow, improving process visualization and efficiency by reducing information asymmetry-related losses. Set up a unified platform and database to integrate data across production, procurement, transportation, and warehousing stages. This promotes sharing, prevents silos, minimizes repetition, and enhances information accuracy and timeliness.

4. Conclusion

This study assesses Liaocheng City's agricultural logistics efficiency and sustainability from 2015 to 2021 using the entropy weight-TOPSIS method. This method minimizes biases by objectively analyzing and evaluating efficiency and sustainability. The established evaluation index system enhances accuracy, indicating logistics infrastructure's significant role, followed by logistics operation sustainability. Strategies to boost agricultural product logistics efficiency involve technology, equipment, and information management. In conclusion, this study provides recommendations to enhance efficiency and sustainability in Liaocheng City's agricultural logistics development.

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About the author:

Tian Zeng, Han nationality, Guilin University, native place: Shaoyang, Hunan, master's degree; research direction: regional economy, logistics economy, mixed restructuring of state-owned enterprises.

Fuhao Cao, Han nationality, Guilin University of Technology, research direction: logistics management

Qinghua Wang, Han nationality, Guilin University of Technology, research direction: logistics management

Liang Chen, corresponding author, Han nationality, Guilin University of Technology, third-level professor, Ph.D.