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*Research Article*

# A Study of Rural Logistics Center Location Based on Intuitionistic Fuzzy TOPSIS

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In recent years, with the development of the rural e-commerce, the importance of rural logistics has been widely recognized. The selection of rural logistics center is a crucial part in products circulation, because an unreasonable location of rural logistics can cause a circulation problem and product waste. In this paper, we propose a rural logistics center location model based on the theory of intuitionistic fuzzy TOPSIS. First, we integrate the information according to experts' score based on the evaluation index system. Second, we use the entropy weight method to determine the weight of each evaluation index. Third, we rank the results by using the intuitionistic fuzzy TOPSIS method. Finally, an illustrative example will be used to prove the validity and feasibility of the proposed method.

## 1. Introduction

Agriculture plays an important role in production. However, farmers focus on agricultural production more than the circulation process that leads to agricultural product backlog rot and poor harvests. This not only damages the interests of farmers, but also causes the waste of agricultural resources. Imperfect rural infrastructure construction seriously hinders the development of the rural logistics industry, which leads to the current difficulty. To a large extent, inconvenient rural logistics affects the development of economy. Rural logistics is relative to the concept of urban logistics. Rural logistics refers to rural resident production and life and other economic activities to provide transportation, handling, loading and unloading, packaging, processing, and storage and all its related activities [1]. Not only does it benefit the farmers' lives and improves the economic income of farmers, but also it accelerates the production and development of agriculture. Rural logistics has distinct features of distinct seasonality, biology, decentralization, diversity, and complexity [2, 3].

At present, there is small scale and a little quantity in rural logistics. Agricultural products can only be circulated within a small scale, which cannot meet the development requirements of the rural logistics industry. There are many problems in the existing logistics centers that need to replanned and rebuilt. The unreasonable location of rural logistics can cause a circulation problem and products waste. It also can aggravate the waste of labor and the urban-rural economic gap [4]. Therefore, not only can reasonable rural logistics center location selection achieve the outward transportation of agricultural products, but also it implements effective product circulation between cities, other regions, and even other countries and forms two-way logistics, leading to the development of the economy.

Experts have different opinions on the rural logistics center location. Amini used fuzzy TOPSIS methodology in rural industrial site selection [5]. Rao et al. proposed a fuzzy TOPSIS method in city logistics centers location selection and evaluation criteria are transformed into linguistic 2-tuples in this method [6]. Li et al. presented a comprehensive methodology combined with Axiomatic Fuzzy Set and TOPSIS for logistics center location selection [7]. Compared with other methods [8], TOPSIS is widely used in all aspects of the multiple attribute decision-making, such as the evaluation of suppliers, electronic commerce, electronic information, and logistics node location. However, many criteria and linguistic variables are difficult to accurately describe and order [9]. The existing methods based on interval numbers and fuzzy numbers need to use prior knowledge that makes the evaluation result subjective [10, 11]. Hence, these researches make conclusion unreasonable by using processed data. Compared with these methods, intuitionistic fuzziness can effectively reduce the fuzziness and make the results more realistic and accurate by using raw date [11–13]. Intuitionistic fuzzy improved TOPSIS can effectively deal with uncertainty evaluation information.

In the rural logistics center location of the existing research, most theoretical models and algorithms focus on a single project model where application value is not high and model accuracy and science degrees are not perfect. And part of the studies also stay on a level that only considers a single objective and aims at cost or benefit [2, 10, 14]. They considered other indicators as a constraint and the establishment of the evaluation index system is not to carry out the green circulation and sustainable development concept.

This paper studies rural logistics center location selection based on the theory of intuitionistic fuzzy TOPSIS. Based on the existing theories and empirical studies, this paper establishes the evaluation index system of logistics center location standing in the rural demand angle that combines logistics center location of the relevant theories and the characteristics of the rural logistics. Based on the rural electricity under the incomplete information logistics center location selection problem, this paper establishes the rural electric business logistics center location decision model using the theory of intuitionistic fuzzy sets and TOPSIS decision-making. This model calculates the weight with intuitionistic fuzzy weight and uses TOPSIS decision-making method for a final decision. This method is easy to operate and can help decision-makers quickly find out the suitable criteria for the development of the rural logistics center location. Finally, we give an illustrative example that proves the validity and feasibility of evaluation methods.

## 2. The Proposed Method

*2.1. Intuitionistic Fuzzy Set.* The intuitionistic fuzzy set is relative to the expansion of the traditional fuzzy sets. Intuitionistic fuzzy sets take into account the membership degree and information such as the degree of membership and hesitation [15]. Therefore, the intuitionistic fuzzy set is more flexible than traditional fuzzy sets and practical in dealing with vagueness and uncertainty. Compared with fuzzy sets, the intuitionistic fuzzy collective shows the fuzziness and uncertainty in the real world and it can better deal with the uncertain information in the decision-making process [7, 9, 15–17]. This method has good performance in terms of theory and application. At present, the intuitionistic fuzzy set applies to decision-making, medical diagnosis, logic programming, pattern recognition, machine learning, market prediction, and so forth [16].

*Definition 1.* Set $X$ is a nonempty set; then, the theory of domain $X$ on intuitionistic fuzzy sets can be represented as $A$:

$$A = \{\langle \chi, \mu_A(\chi), \nu_A(\chi)\rangle \mid \chi \in X\}. \tag{1}$$

Among them, $\mu_A$ is the membership degree for $A$, $\nu_A$ is the nonmembership degree for $A$, and $\mu_A(\chi)$ and $\nu_A(\chi)$ are for the $X$ element that belongs to $A$ membership and the nonmembership degree:

$$\begin{aligned} &\mu_A : X \longrightarrow [0,1], \quad \chi \in X \longrightarrow \mu_A(\chi) \in [0,1], \\ &\nu_A : X \longrightarrow [0,1], \quad \chi \in X \longrightarrow \nu_A(\chi) \in [0,1]. \end{aligned} \tag{2}$$

They meet the condition

$$0 \le \mu_A(\chi) + \nu_A(\chi) \le 1. \tag{3}$$

For the theory of domain intuitionistic fuzzy set $A$ of $X$,

$$\pi_A = 1 - \mu_A(\chi) - \nu_A(\chi). \tag{4}$$

The element in $\chi$ belongs to $A$ degree of hesitation or uncertainty.

Obviously, for any $\chi \in X$, we have $0 < \pi_A(\chi) < 1$.

In particular, any fuzzy set $A$ in the theory of domain $X$ can be established in the following equation:

$$\pi_A(\chi) = 1 - \mu_A(\chi) - \nu_A(\chi). \tag{5}$$

Sets $A$ and $B$ are two fuzzy sets in the theory field $X$; multiplication is defined as

$$\begin{aligned} A \otimes B = \{&\mu_A(\chi) \cdot \mu_B(\chi), \nu_A(\chi) + \nu_B(\chi) - \nu_A(\chi) \\ &\cdot \nu_B(\chi) \mid \chi \in X\}. \end{aligned} \tag{6}$$

*2.2. The Proposed Algorithm.* Unlike traditional TOPSIS decision, the elements of the decision matrix are intuitionistic fuzzy numbers under the environment of intuitionistic fuzzy TOPSIS multiple attribute decision-making method. We calculated each scheme and the distance between the ideal solution and the negative ideal solution with intuition fuzzy number related calculation formulas. First, experts integrate assessment information according to the evaluation index system. Then, entropy weight method is used to determine the weight of each evaluation index. Finally, we determine the decision scheme of sorting by intuitionistic fuzzy TOPSIS method for logistics center.

The specific decision-making steps are as follows.

*Step 1* (determine the weight of decision-makers). We assume that the decision-making group has $i$. The data of decision-maker is represented by intuitionistic fuzzy numbers.

$D_k = [\mu_k, \nu_k, \pi_k]$ is the rating fuzzy number directly of DM$k$. The weight of DM$k$ is as follows:

$$\lambda_k = \frac{(\mu_k + \pi_k(\mu_k/(\mu_k + \nu_k)))}{\sum_{k=1}^{l}(\mu_k + \pi_k(\mu_k/(\mu_k + \nu_k)))}. \tag{7}$$

Under the condition, $\sum_{k=1}^{l} \lambda_k = 1$.

*Step 2* (construct intuitionistic fuzzy matrix). Intuitionistic fuzzy decision matrix is $R^{(k)} = (R_{ij}^{(k)})_{m\times n}$. The weight of each decider is $\lambda = \{\lambda_1, \lambda_2, \dots, \lambda_1\}$, under the condition $\sum_{k=1}^{l} \lambda_k = 1$, $\lambda_k \in [0,1]$. In the process of group decision-making, IFWA (direct fuzzy weighted average) is presented because all personal opinion decisions need to be integrated into the group opinion structure polymerization intuitionistic fuzzy matrix:

$$\begin{aligned}
R^{(k)} &= \left(R_{ij}^{(k)}\right)_{m\times n} \\
R_{ij} &= \mathrm{IFWA}_{\lambda}\left(r_{ij}^{(1)}, r_{ij}^{(2)}, \dots, r_{ij}^{(l)}\right) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \\
&\oplus \lambda_3 r_{ij}^{(3)} \oplus \lambda_l r_{ij}^{(l)} = \left[1 - \prod_{k=1}^{l}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k},\right. \\
&\left.\prod_{k=1}^{l}\left(\nu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{l}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{l}\left(\nu_{ij}^{(k)}\right)^{\lambda_k}\right].
\end{aligned} \tag{8}$$

Under the condition, $r_{ij} = (\mu_{Ai}(\chi_j), \nu_{Ai}(\chi_j), \pi_{Ai}(\chi_j))$ $(i = 1, 2, \dots, m;\ j = 1, 2, \dots, n)$.

Aggregated direct fuzzy matrix structure is as follows:

$$\begin{aligned}
R &= \begin{pmatrix} \mu_{A1}(\chi_1), \nu_{A1}(\chi_1), \pi_{A1}(\chi_1) & \cdots & \mu_{A1}(\chi_n), \nu_{A1}(\chi_n), \pi_{A1}(\chi_n) \\ \vdots & \ddots & \vdots \\ \mu_{Am}(\chi_1), \nu_{Am}(\chi_1), \pi_{Am}(\chi_1) & \cdots & \mu_{Am}(\chi_n), \nu_{Am}(\chi_n), \pi_{Am}(\chi_n) \end{pmatrix} \\
R &= \begin{pmatrix} r_{11} & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nm} \end{pmatrix}.
\end{aligned} \tag{9}$$

Among them, $W = (\mu_j, \nu_j, \pi_j)$ $(j = 1, 2, 3, \dots, n)$.

*Step 3* (determine the weight of the evaluation criteria). Evaluation criteria are unlikely to be equally important. $W$ represents a series of important degree levels. We get $W$ by integrating the importance of the decision-maker opinions and standards.

The intuitionistic fuzzy standard $X_j$ of DM$k$ is $W_j^{(k)} = [\mu_j^{(k)}, \nu_j^{(k)}, \pi_j^{(k)}]$.

Calculate the weight of the standard with IFWA.

$$\begin{aligned}
W_j &= \mathrm{IFWA}_{\lambda}\left(W_j^{(1)}, W_j^{(2)}, \dots, W_j^{(l)}\right) = \lambda_1 r_j^{(1)} \oplus \lambda_2 r_j^{(2)} \\
&\oplus \cdots \oplus \lambda_l r_j^{(l)} = \left[1 - \prod_{k=1}^{l}\left(1-\mu_j^{(k)}\right)^{\lambda_k},\right. \\
&\left.\prod_{k=1}^{l}\left(\nu_j^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{l}\left(1-\mu_j^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{l}\left(\nu_j^{(k)}\right)^{\lambda_k}\right] \\
W &= \left[W_1, W_2, W_3, \dots, W_j\right].
\end{aligned} \tag{10}$$

*Step 4* (build weighted aggregation of intuitionistic fuzzy decision matrix). After determining weights of criteria ($W$), we construct weighted aggregation of intuitionistic fuzzy decision matrix:

$$\begin{aligned}
R \otimes W &= \{\langle \chi, \mu_{Ai}(\chi) \cdot \mu_w(\chi), \nu_{Ai}(\chi) + \nu_w(\chi) \\
&\quad - \nu_{Ai}(\chi) \cdot \nu_w(\chi)\rangle \mid \chi \in X\} \\
\pi_{Ai}(\chi) \cdot W(\chi) &= 1 - \nu_{Ai}(\chi) - \nu_w(\chi) - \mu_{Ai}(\chi) \\
&\quad \cdot \nu_w(\chi) + \nu_{Ai}(\chi) \cdot \nu_w(\chi).
\end{aligned} \tag{11}$$

Weighted aggregation intuitionistic fuzzy matrix is as follows:

$$\begin{aligned}
R' &= \begin{pmatrix} \mu_{A1}w(\chi_1), \nu_{A1}w(\chi_1), \pi_{A1}w(\chi_1) & \cdots & \mu_{A1}w(\chi_n), \nu_{A1}w(\chi_n), \pi_{A1}w(\chi_n) \\ \vdots & \ddots & \vdots \\ \mu_{Am}w(\chi_1), \nu_{Am}w(\chi_1), \pi_{Am}w(\chi_1) & \cdots & \mu_{Am}w(\chi_n), \nu_{Am}w(\chi_n), \pi_{Am}w(\chi_n) \end{pmatrix} \\
R' &= \begin{pmatrix} r'_{11} & \cdots & r'_{1j} \\ \vdots & \ddots & \vdots \\ r'_{i1} & \cdots & r'_{ij} \end{pmatrix}.
\end{aligned} \tag{12}$$

$r'_{ij} = (\mu'_{ij}, \nu'_{ij}, \pi'_{ij}) = (\mu_{Ai} \cdot w(\chi_j), \nu_{Ai} \cdot \nu(\chi_j), \pi_{Ai} \cdot \pi(\chi_j))$ is the weight of aggregation intuition fuzzy matrix.

*Step 5* (calculate the intuitionistic fuzzy positive ideal solution and negative ideal solution). Determine the intuitionistic fuzzy positive ideal solution $A^*$ and fuzzy positive negative ideal solution $A^-$; they are defined as

$$A^* = \left(\mu_{A^*W}\left(\chi_j\right), \nu_{A^*W}\left(\chi_j\right)\right)$$
$$A^- = \left(\mu_{A^-W}\left(\chi_j\right), \nu_{A^-W}\left(\chi_j\right)\right). \quad (13)$$

$J_1$ collection is efficiency standards set and $J_2$ collection is cost standards set.

Under the condition,

$$\mu_{A^*W}\left(\chi_j\right) = \left(\left(\max_i \mu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_1\right), \left(\min_i \mu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_2\right)\right)$$
$$\nu_{A^*W}\left(\chi_j\right) = \left(\left(\min_i \nu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_1\right), \left(\max_i \nu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_2\right)\right)$$
$$\mu_{A^-W}\left(\chi_j\right) = \left(\left(\min_i \mu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_1\right), \left(\max_i \mu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_2\right)\right)$$
$$\nu_{A^-W}\left(\chi_j\right) = \left(\left(\max_i \nu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_1\right), \left(\min_i \nu_{A_i \cdot W}\left(\chi_j\right) \mid j \in J_2\right)\right). \quad (14)$$

*Step 6* (calculate the distance of the positive and negative ideal solution). $S_{i^*}$ is the distance between indicators and the positive ideal solution. $S_{i^-}$ is the distance between indicators and the negative ideal solution. Using Euclidean distance to calculate $S_{i^*}$ and $S_{i^-}$, it is concluded that

$$S^* = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[\left(\mu_{A_j \cdot w}\left(\chi_j\right) - \mu_{A^* w}\left(\chi_j\right)\right)^2 + \left(\nu_{A_j \cdot w}\left(\chi_j\right) - \nu_{A^* w}\left(\chi_j\right)\right)^2 + \left(\pi_{A_j \cdot w}\left(\chi_j\right) - \pi_{A^* w}\left(\chi_j\right)\right)^2\right]}$$
$$S^- = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}\left[\left(\mu_{A_i \cdot w}\left(\chi_j\right) - \mu_{A^- w}\left(\chi_j\right)\right)^2 + \left(\nu_{A_i \cdot w}\left(\chi_j\right) - \nu_{A^- w}\left(\chi_j\right)\right)^2 + \left(\pi_{A_i \cdot w}\left(\chi_j\right) - \pi_{A^- w}\left(\chi_j\right)\right)^2\right]}. \quad (15)$$

*Step 7* (calculate the closeness coefficient).

$$C_i^* = \frac{S_{i^-}}{S_{i^*} + S_{i^-}}. \quad (16)$$

Under the condition, $0 \le C_i^* \le 1$.

*Step 8* (rank alternatives). Rank all the alternatives from large to small based on the closeness coefficient and select the best one according to the value of $C_i^*$.

## 3. Illustrative Example

This article takes rural logistics center location selection of Dali in Yunnan province as an example to determine the fitting of the needs of the local rural logistics center location. Three experts ($DM_1$, $DM_2$, and $DM_3$) comprehensively evaluate the rural logistics center location. This paper uses primary election and precision selection for logistics center location selection screening and optimizing work in order to make decisions quickly and avoid the waste of time and resources.

*3.1. Primary Selection.* In the primary election stage, first determine the internal and external factors that influence the logistics center choice in order to preliminarily measure and filter logistics center location.

*Service Requirement*. The logistics center must be able to meet the basic needs of the rural distribution and has a certain storage capacity [5]. The logistics center has large scale and information technology capability to provide special service according to the characteristics and needs of customers.

*Service Quality*. The logistics center must be able to respond to the needs of customers and ensure complete distribution of goods on time [18]. The logistics center has the ability to provide flexible service to make the customer satisfied.

*Traffic Condition*. The logistics center location must have convenient transportation and meet the requirements of output and input of a large number of goods and also can, to a certain extent, reduce the cost [5].

After collecting a large amount of logistics center location information, according to the basic demand of the rural logistics center, we finally confirm the five candidate logistics centers ($A_1$, $A_2$, $A_3$, $A_4$, and $A_5$) for subsequent selection and evaluation based on the characteristics of the logistics industry.

*3.2. Precision Selection.* This paper simplifies the rural electricity evaluation index system of logistics center location selection in order to facilitate assessment. The evaluation criteria are as follows: $C_1$, traffic; $C_2$, economics; $C_3$, environment; $C_4$, politics [1, 4, 7, 18].

*Step 1* (calculate the weight of the decision-makers). We calculate the importance of criterions according to Table 1.

Table 1: The importance of criterions.

| Degree | Score |
|---|---|
| Very important (VI) | (0.90, 0.10) |
| Important (I) | (0.75, 0.20) |
| General (G) | (0.50, 0.45) |
| Unimportant (U) | (0.35, 0.60) |

Table 2: The weight of decision-maker important degree.

| | $DM_1$ | $DM_2$ | $DM_3$ |
|---|---|---|---|
| Degree | VI | G | I |
| Weight | 0.406 | 0.238 | 0.356 |

Calculate the weight of decision-makers by formula (7) as shown in Table 2:

$$\lambda_{DM1} = \frac{0.9}{0.9 + (0.75 + 0.05\,(0.75/0.95)) + (0.50 + 0.05\,(0.50/0.95))} = 0.406$$

$$\lambda_{DM2} = \frac{0.50 + 0.05\,(0.50/0.95)}{0.9 + (0.50 + 0.05\,(0.50/0.95)) + (0.75 + 0.05\,(0.75/0.95))} = 0.238$$

$$\lambda_{DM3} = \frac{0.75 + 0.05\,(0.75/0.95)}{0.9 + (0.50 + 0.05\,(0.50/0.95)) + (0.75 + 0.05\,(0.75/0.95))} = 0.356. \tag{17}$$

Table 3: Degree of integration indicators.

| Degree | Score |
|---|---|
| Especially good (EG) | [1.00, 0.00] |
| Very very good (VVG) | [0.90, 0.10] |
| Very good (VG) | [0.80, 0.10] |
| Good (G) | [0.70, 0.20] |
| Medium good (MG) | [0.60, 0.30] |
| Medium (M) | [0.50, 0.40] |
| Medium bad (MB) | [0.40, 0.50] |
| Bad (B) | [0.25, 0.60] |
| Very bad (VB) | [0.10, 0.75] |
| Very very bad (VVB) | [0.10, 0.90] |

*Step 2* (construct aggregation intuitionistic fuzzy matrix based on the opinions of the decision-makers). We get a new level of indicators and score after integrating the opinions of the three policymakers as shown in Table 3.

Aggregation index level is as shown in Table 4.

Construct intuitionistic fuzzy matrix after integrating the opinions of the decision-makers:

$$R = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{bmatrix} (0.728, 0.170, 0.012) & (0.626, 0.272, 0.102) & (0.780, 0.118, 0.102) & (0.700, 0.200, 0.100) \\ (0.596, 0.302, 0.102) & (0.605, 0.292, 0.103) & (0.664, 0.256, 0.100) & (0.578, 0.321, 0.101) \\ (0.849, 0.100, 0.051) & (0.780, 0.118, 0.102) & (0.769, 0.170, 0.061) & (0.769, 0.128, 0.103) \\ (0.663, 0.236, 0.101) & (0.538, 0.361, 0.101) & (0.746, 0.151, 0.103) & (0.644, 0.254, 0.102) \\ (0.562, 0.337, 0.101) & (0.462, 0.438, 0.100) & (0.668, 0.231, 0.101) & (0.526, 0.374, 0.100) \end{bmatrix} \end{array}. \tag{18}$$

*Step 3* (calculate the weight of the evaluation criteria). The importance of the evaluation criteria is as shown in Table 5.

Calculate the weight of the evaluation criteria by formula (10):

$$W_{\{\chi_1,\chi_2,\chi_3,\chi_4\}} = \begin{bmatrix} (0.861, 0.128, 0.011) \\ (0.750, 0.200, 0.050) \\ (0.680, 0.267, 0.053) \\ (0.576, 0.371, 0.053) \end{bmatrix}^T. \tag{19}$$

*Step 4* (build weighted aggregation of intuitionistic fuzzy decision matrix). After calculating the weight of the evaluation criteria, we build weighted aggregation of intuitionistic fuzzy decision matrix:

$$R' = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{bmatrix} (0.627, 0.276, 0.097) & (0.470, 0.418, 0.112) & (0.530, 0.353, 0.117) & (0.403, 0.497, 0.100) \\ (0.513, 0.391, 0.096) & (0.454, 0.434, 0.112) & (0.438, 0.453, 0.109) & (0.333, 0.573, 0.094) \\ (0.731, 0.215, 0.054) & (0.585, 0.294, 0.121) & (0.523, 0.361, 0.116) & (0.443, 0.452, 0.105) \\ (0.571, 0.334, 0.095) & (0.404, 0.489, 0.107) & (0.507, 0.378, 0.115) & (0.371, 0.531, 0.098) \\ (0.484, 0.422, 0.094) & (0.347, 0.550, 0.103) & (0.454, 0.436, 0.110) & (0.303, 0.606, 0.091) \end{bmatrix} \end{array}. \tag{20}$$

Table 4: Aggregation index level.

| Evaluation criteria | Logistics center | Decision-maker | | |
|---|---|---|---|---|
| | | $DM_1$ | $DM_2$ | $DM_3$ |
| $C_1$ | $A_1$ | G | VG | G |
| | $A_2$ | MG | G | F |
| | $A_3$ | VVG | VG | VG |
| | $A_4$ | MG | G | G |
| | $A_5$ | F | MG | MG |
| $C_2$ | $A_1$ | MG | G | MG |
| | $A_2$ | F | MG | G |
| | $A_3$ | VG | VG | VG |
| | $A_4$ | F | G | MG |
| | $A_5$ | MB | G | F |
| $C_3$ | $A_1$ | VG | G | VG |
| | $A_2$ | G | MG | MG |
| | $A_3$ | VG | VG | G |
| | $A_4$ | VG | G | G |
| | $A_5$ | G | G | MG |
| $C_4$ | $A_1$ | G | G | G |
| | $A_2$ | MG | M | MG |
| | $A_3$ | VG | VG | G |
| | $A_4$ | G | MG | MG |
| | $A_5$ | M | MG | M |

Table 5: The importance of the evaluation criteria.

| Evaluation criteria | $DM_1$ | $DM_2$ | $DM_3$ |
|---|---|---|---|
| $C_1$ | VI | VI | I |
| $C_2$ | I | I | I |
| $C_3$ | I | I | M |
| $C_4$ | M | I | M |

Table 6: The values of $S^*$, $S^-$, and $C_{i^*}$.

| | $S^*$ | $S^-$ | $C_{i^*}$ |
|---|---|---|---|
| $A_1$ | 0.092 | 0.110 | 0.546 |
| $A_2$ | 0.131 | 0.082 | 0.385 |
| $A_3$ | 0.074 | 0.175 | 0.702 |
| $A_4$ | 0.124 | 0.075 | 0.375 |
| $A_5$ | 0.174 | 0.074 | 0.300 |

*Step 5* (calculate the intuitionistic fuzzy positive ideal solution and negative ideal solution). We have four evaluation criteria, $C_1$, traffic; $C_2$, economics; $C_3$, environment; $C_4$, with politics efficiency standards set for $J_1 = \{C_1, C_3, C_4\}$ and cost type standards set for $J_2 = \{C_2\}$. We get the positive ideal solution and negative ideal solution by formula (13):

$$\begin{aligned} A^* &= \{(0.731, 0.251, 0.054), (0.585, 0.294, 0.121), \\ &\quad (0.530, 0.353, 0.117), (0.303, 0.606, 0.091)\} \\ A^- &= \{(0.484, 0.422, 0.094), (0.347, 0.550, 0.103), \\ &\quad (0.438, 0.453, 0.109), (0.443, 0.452, 0.105)\}. \end{aligned} \tag{21}$$

*Step 6.* According to formulae (15)-(16), we calculate the values $S^*$, $S^-$, and $C_{i^*}$.

*Step 7.* The alternatives can be ranked as $A_3 > A_1 > A_2 > A_4 > A_5$ based on the value $C_i$, as shown in Table 6. $A_3$ is a compromise solution as logistics center location selection.

## 4. Conclusions

This research establishes the rural logistics center location decision model based on the theory of intuitionistic fuzzy TOPSIS. We integrate the information according to experts' score based on the evaluation index system. Then, we use the entropy weight method to determine the weight of each evaluation index and rank the results by using intuitionistic fuzzy TOPSIS method. This model helps decision-makers quickly find out the suitable rural logistics center location. In addition, it is applied in an illustrative example to prove the validity and practicability of the method.

Our study contributes in three ways. (1) Intuitionistic fuzzy set can effectively reduce the fuzziness and make the results more realistic and accurate than fuzzy set. The result is more objective and reliable based on the raw date. (2) Intuitionistic fuzzy improved TOPSIS can effectively deal with uncertainty evaluation information. Without adding a subjective condition, this paper retains more decision-making information and makes the result more scientific. (3)

According to the actual requirements of the rural logistics center, we have established a more scientific and reasonable index system and applied it to an illustrative example.

This paper studies the rural logistics center location decisions based on incomplete information; the decision method fully applies to logistics center location under the complete information and it can be extended to other uncertain environments. Although the usefulness of the approach has been proven theoretically, it still needs further validation. Therefore, the focus of the future is to validate the method by using the mixed evaluation value of the multiple data types, subjective and objective.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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