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Using the FAHP, ISM, and MICMAC Approaches to Study the Sustainability Influencing Factors of the Last Mile Delivery of Rural E-Commerce Logistics

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Abstract: The development of rural e-commerce has rapidly driven the development of rural logistics in China. Improving the service quality of the last mile delivery is an important measure to promote the sustainable development of rural e-commerce logistics. However, such work is challenging because the current rural last mile delivery is inefficient and unsustainable and is influenced by a set of interacting factors. It is necessary to explore the relationships among the sustainability influencing factors of rural last mile delivery. A total of 15 sustainability influencing factors are selected. The improved fuzzy analytic hierarchy process (FAHP) is used to assign the weights of the factors and then the interpretative structural model (ISM) is used to determine the hierarchical structure of each factor. The driving force-dependency quadrant graph is constructed by cross-impact matrix multiplication (MICMAC). The research results show that four factors, including "convenience of returning goods", "integrity of goods", "advance reservation of goods pickup", and "delivery costs", are the most basic factors affecting the sustainability of rural last mile delivery and are the deepest and most indispensable factors. This research provides valuable information for decision makers to develop proactive strategies and reinforcement policies to improve the service quality of rural last mile delivery, which could promote the sustainable development of rural logistics.

Keywords: rural e-commerce logistics; last mile delivery; sustainability influencing factors; fuzzy analytical hierarchy process (FAHP); interpretative structural modeling (ISM); cross-impact matrix multiplication applied to classification (MICMAC)

1. Introduction

The development of rural e-commerce has rapidly driven the development of rural e-commerce logistics. Figure 1 shows the online retail sales and growth rate from 2014 to 2018 in rural China, where the year-on-year growth rate was 156.44% in 2017. The policy support for the development of rural e-commerce logistics has continuously increased and the rural e-commerce logistics distribution network has gradually formed. However, the following problems exist: The distribution network has little coverage, the distribution speed is slow, the logistics information level is low, the logistics cost is high, and the e-commerce logistics activities have adverse effects on the rural environment. Sustainability is a way of life today. In the last mile delivery of rural e-commerce logistics systems, sustainability is achieved through different approaches and involves strengthening infrastructure and information construction, reducing logistics costs, energy conservation, environmental protection, and integrating e-commerce and logistics. In general, sustainability refers to people, planets, and profits under which human beings and value exist in productive harmony with the social, environmental, and economic requirements of the current and next generations [1,2]. Sustainability is mapped to the last mile delivery of rural e-commerce logistics in terms of facilities, transportation, information, and pricing, with a goal for every company to measure their triple bottom line according to four categories of sustainability, as follows: Energy consumption, water consumption, greenhouse gas emissions, and waste generation [3].

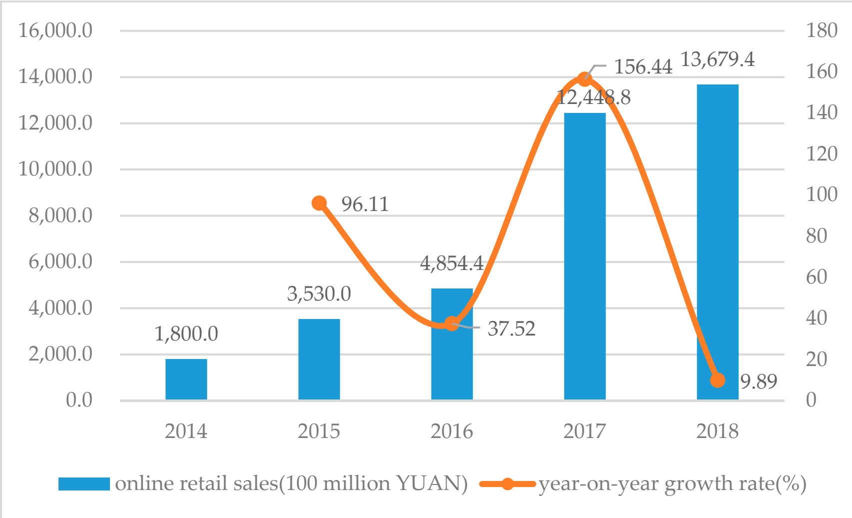

Figure 1. The online retail sales and growth rate from 2014 to 2018 in rural China (Data source: China rural e-commerce market forecast and investment planning analysis report released by Chinese Qianzhan industry research institute.).

Improving the service quality of the rural last mile delivery is an important measure to promote the sustainable development of rural e-commerce logistics. However, such work is challenging because the current rural last mile delivery is inefficient and unsustainable and is influenced by a set of interacting factors. The characteristics of consumer shopping in rural areas are obvious, showing the following two points: (1) In terms of the economic environment and due to income level restrictions, consumers will be more inclined to buy cheap goods when shopping online. In 2017, the per capita disposable income of urban residents was 36,396 YUAN and that of rural residents was 13,432 YUAN. (2) The concept of online shopping consumption is relatively undeveloped. Since farmers are less exposed to smartphones and the Internet, trust in online shopping is still relatively low and consumers are more willing to go shopping in physical stores. Compared with urban areas, rural areas have fewer online retail sales, accounting for 15.18% of the country's total retail sales in 2018. However, according to data from the national bureau of statistics, in recent years the growth rate of per capita consumption expenditure in rural areas is significantly higher than that in urban areas, which indicates that the consumption consciousness of rural people is gradually approaching that of urban areas. The last mile of rural logistics distribution is the last link of logistics [4]. The service quality directly affects the shopping experience of e-commerce consumers. The service quality is critical for the sustainability of rural e-commerce and the logistics delivery system [5,6]. The characteristics of rural last mile delivery are obvious and are shown in the following four points: (1) Dispersion: The rural population is scattered and the density is low, which leads to the relatively scattered orders for rural e-commerce. Therefore, the logistics distribution cost is much higher than that of urban areas. (2) In general, the delivery to the home is not realized. Basically, the pick-up points are set at the town-level distribution points and the villagers need to go to the town and pick up their packages themselves. (3) Safety: Electric tricycles are commonly used in the last mile of rural logistics and it is difficult to guarantee the quality of the delivered packages and the safety of the distribution process. (4) Efficiency: Due to the limitations of rural road driving conditions, the delivery vehicles travel at slow speeds and have a limited loading capacity, resulting in low distribution efficiency. The above four issues will directly affect the rural consumer shopping experience, which is not conducive to rural e-commerce and logistics development, leading to a vicious circle. Some research has indicated that satisfaction with the physical distribution quality and cost is positively related with customer's purchase satisfaction and customer retention [7,8]. Improving the service quality of rural last mile logistics and promoting the sustainable development of rural e-commerce logistics is an urgent problem to be solved.

A large amount of research on evaluating logistics service quality has been carried out in recent decades. The importance of each influencing factor can be clarified by assigning a weight, but the relationships among all of the influencing factors cannot be revealed. Past studies on the sustainability of logistics service quality were limited to the evaluation method and results. However, very few articles have focused on the relationships among the influencing factors of the logistics service quality in order to to put forward more targeted measures to improve the quality of logistics services. This study focuses on analyzing the relationships among the influencing factors.

The content of the rest of the paper is organized as follows. Section 2 contains a literature review. Section 3 proposes the sustainability influencing factors of the last mile delivery of rural e-commerce logistics. Section 4 describes the integrated research method proposed. Section 5 details the analysis results. Conclusions are presented in Section 6.

2. Literature Review

In recent decades, a large amount of research on improving the quality of logistics services has been carried out. Research on the quality of logistics service was first proposed by Parasuranman, Zeitham, Berry, and others [9]. Mentzer proposed the classic SERVQUAL model, which analyzes the service quality according to five dimensions, namely, tangibility, reliability, responsiveness, guarantee, and empathy [10,11]. Matzler and Stank proposed a three-factor model of service quality, namely, the physical environment quality, the interaction quality, and the quality of results [12,13]. The logistics quality was divided into the basic quality of the logistics work and the strategic quality that reflects the long-term impact [14,15]. Most of the current research on evaluating the quality of logistics services is from the perspective of customer satisfaction [16]. There are also some studies from the perspective of the entire logistics service process [17,18]. The existing quantitative methods for evaluating the service quality mainly include gap analysis [17,18], analytic hierarchy process (AHP) [19–21], the technique for order preference by similarity to an ideal solution (TOPSIS) [22,23], fuzzy comprehensive evaluation (FCE), and the gray evaluation method.

Two analysis results can be proposed through the service quality evaluation. (1) The scores of each indicator/influencing factor and the gap between the ideal and the actual can be calculated. Then, the problems in the rural logistics distribution service can be accurately identified and measures to improve the service quality can be proposed. (2) The importance of each indicator/influencing factor can be clarified by calculating the weight, but the relationships among the indicators/influencing factors cannot be revealed. Past studies on the sustainability of logistics service quality were limited to the evaluation method and results. However, very few articles have focused on the relationships among the influencing factors of the logistics service quality in order to put forward more targeted measures to improve the quality of logistics services.

The interpretative structural model (ISM) is a commonly used model for analyzing the influencing factors that clearly express the relationships among various influencing factors. The conceptual and analytical details of the ISM process were given by Warfield in 1974 [24].

Many applications of the ISM have been identified by a variety of researchers in various areas, such as identifying the critical success factors for safety management, the factors influencing e-diplomacy implementation, assessing contributory factors in potential systemic accidents, and analyzing the influencing factors of food safety [25–36]. The ISM is also applied in the supply chain, but there are few applications in logistics [37,38]. However, the shortcoming of the ISM is its subjectivity, as the determination of the key factors depends on experience. Some scholars have proposed analyzing the influencing factors by integrating an ISM and AHP; Tian studied the affecting factors of risks in the workplace [39], Duleba analyzed the connecting factors in a public transport system [40], and Song revealed the vulnerability factors of an urban rail transit system [41]. First, the AHP is used to establish the hierarchical impact factors and then the ISM is used to find the hierarchical relationships among the influencing factors. Kannan used ISM and fuzzy TOPSIS for the selection of reverse logistics providers [42]. In addition, some scholars integrated ISM and MICMAC (cross-impact matrix multiplication applied to classification) to analyze the supply chain management framework and the knowledge flow enablers [43,44]. The MICMAC approach was proposed based on the multiplication properties of matrices [28]. This approach is often used to identify the driving power and dependence power of various factors of the system [45]. Although the technologies of ISM, AHP, and MICMAC have been used for more than 30 years, their flexibility and robustness make them widely used in many fields.

Similarly, this present literature also has shortcomings, that is, there have been studies on the integration of AHP and ISM or the integration of ISM and MICMAC, but rarely on the integration of AHP, ISM, and MICMAC. In addition, the feature vector is not easy to obtain and the expert scoring is subjective, which directly affects the efficiency of the evaluation work and the accuracy of the evaluation result. As a result, the improved fuzzy analytic hierarchy process (FAHP) is adopted to determine the weight of each influencing factor. In the FAHP, the fuzzy consistency matrix that is modified from the priority judgment matrix satisfies the consistency condition and there is no need for a consistency test. As the initial iteration value of the eigenvalue method, the target weight can greatly reduce the number of iterations, improve the convergence speed, and meet the accuracy requirements.

To fill in these knowledge gaps, this study aimed to analyze the sustainability influencing factors of the last mile delivery of rural e-commerce logistics based on an integration of the FAHP, ISM, and MICMAC. After stratifying the different dimensions and their influencing factors, the FAHP was adopted to determine the weight of each influencing factor and determine the degree of influence of the factors on the results, so the evaluation was carried out with emphasis and objectivity. Then, the ISM was adopted to conduct a quantitative analysis on the sustainability influencing factors, to analyze the correlations among some of the typical influencing factors, and to clarify their order of importance. Finally, MICMAC was used to identify the driving force and dependency by cross-impact matrix multiplication.

3. Sustainability Influencing Factors of the Last Mile Delivery of Rural E-Commerce Logistics

The collection of sustainable development influencing factors was the key process of the research, which provided the basis for the subsequent analysis. The two typical methods, a literature review and expert interviews, were used to analyze the influencing factors. First, a comprehensive literature review was conducted on the evaluation of the logistics service quality. Based on the classic SEVQUAL model and combined with the development status and characteristics of rural e-commerce logistics, the following modifications were made to the SEVQUAL model.

3.1. Change "Tangibility" to "Convenience"

Tangibility refers to that of the traditional service industry, where customers have an intuitive understanding and experience of the environment of physical stores, the service attitude of service personnel, and the appearance and quality of goods. However, online browsing, ordering, payment, and customer service are all virtual in the process of e-commerce purchasing, so customers cannot have an intuitive understanding of the production environment and facilities of the logistics enterprises. Compared with physical stores, online products are more comprehensive, which is why consumers prefer online shopping. In addition, the payment method can be an online payment or cash on delivery. Additionally, online shopping also provides door-to-door delivery, logistics information inquiry, and other convenient services. Therefore, "tangibility" should be replaced by "convenience" in this study. Considering the underdeveloped consumption concept of rural consumers, the influencing factor of “convenience of payment” was added.

3.2. Add "Economy"

The economy is rarely concerned with previous evaluation models, but it is an important factor affecting the sustainable development of rural e-commerce logistics. Logistic costs may not only be generated in the distribution activities, but also in the return and replacement process. The income level of consumers in rural areas is lower than that of urban consumers. Most rural consumers will still measure the rationality of the logistics costs as an accessory consumption of online shopping. The online shopping goals they pursue are quality and affordability. In this study, the two influencing factors, "cost of delivery" and "rationality of value-added services", were selected.

3.3. "Reliability" and "Assurance" are Combined to Form "Reliability"

In the classic SEVQUAL model, reliability refers to the ability of enterprises and employees to guarantee and provide a service commitment that is very reliable and accurate. Assurance refers to the professional skills, professional quality, and service level of enterprise employees as being very credible. Reliability and assurance reflect the service required by customers from the perspective of enterprises and customers, respectively. In online shopping, the reliability of the logistics service quality refers to the completeness and accuracy of the goods. Customers feel that the quality of service is affected by the reliability of enterprises and employees. Therefore, this study considers that the two can be combined into one dimension.

3.4. Retain "Responsiveness"

Responsiveness refers to the timeliness of customer service replies to customers' questions, delivery, return and replacement processing speed, etc. Customers expect e-commerce and logistics companies to respond to and deal with these problems in a timely manner. Therefore, responsiveness is preserved.

3.5. Retain "Empathy"

Empathy refers to the willingness of enterprises and employees to put themselves in the shoes of customers and provide personalized services to customers. In logistics service quality, empathy reflects the working ability, service attitude, and external dress of enterprise employees. Therefore, empathy needs to be preserved. Considering the scattered residences of rural consumers and their low educational level, the influencing factor "advance reservation of goods pickup" is added.

In summary, the SERVQUAL model and the characteristics of the rural logistics service quality were combined to form a preliminary set of influencing factors for sustainability. Furthermore, five professors from Southeast University and Nanjing Forestry University were invited to review this set of influencing factors. Each of the professors have more than ten years of experience in the field of logistics management. After reviewing the preliminary set of influencing factors, the professors agreed that all the proposed influencing factors were reasonable and significant. Finally, Table 1 shows the 15 influencing factors of sustainable development in five dimensions, as follows: Convenience, responsiveness, reliability, empathy, and economy.

Table 1. Sustainability influencing factors of the last mile delivery of rural e-commerce logistics.

Dimension	Influencing Factors
Service convenience (D1)	Convenience of payment (S_{01})
	Convenience of setting the pick-up time (S_{02})
	Convenience of returning goods (S_{03})
Service responsiveness (D2)	Timeliness of customer service response (S_{04})
	Timeliness of goods return processing (S_{05})
	Timeliness of goods delivery (S_{06})
	Timeliness of goods arrival (S_{07})
Service reliability (D3)	Integrity of goods (S_{08})
	Accuracy of goods arrival (S_{09})
	Accuracy of logistics information (S_{10})
Service empathy (D4)	Employee service attitude (S_{11})
	Employees actively remind customers to open the inspection (S_{12})
	Advance reservation of goods pickup (S_{13})
Service economy (D5)	Delivery costs (S_{14})
	Rationality of the value-added services (S_{15})

4. Research Methodology

In this study, the method used to better understand the 15 sustainable development factors was an integrated method consisting of the fuzzy analytic hierarchy process (FAHP) and interpretative structural modeling (ISM). The FAHP was used to assign weights to each sustainable development influencing factor and to correctly evaluate the relative importance of each factor. The ISM was used to intuitively evaluate and describe the relationships among these factors. Finally, a driving-dependence quadrant diagram was constructed by means of cross-influence matrix multiplication (MICMAC). Although the technologies of ISM, AHP, and MICMAC have been used for more than 30 years, their flexibility and robustness make them widely used in many fields.

4.1. Improved Fuzzy Analytical Hierarchy Process (FAHP)

The traditional analytic hierarchy process (AHP) has the following two shortcomings: (1) The reciprocal scale is used to establish the judgment matrix. However, due to the difference between the subjective cognition and objective reality, the judgment matrix usually cannot satisfy the consistency condition, so the consistency test and correction are needed. (2) The square root method and the row normalization method are used to solve the order of importance of each scheme. Since only the influence of the row of elements corresponding to the judgment matrix is considered, the calculation accuracy is low, the weight cannot be controlled according to the accuracy requirement, and the actual situation cannot be accurately reflected. Therefore, the improved FAHP is used to calculate the weights of the service quality influencing factors. The improved FAHP method is calculated as follows:

Step 1: Construction of a complementary fuzzy judgment matrix, F, using the 0.1–0.9 scale method. The value $F = \left(f_{ij}\right)_{n\times m}$ is called the priority judgment matrix. The comparison is made by assigning numerical values to express the strength of the preference of the former factor over the latter, as shown in Table 2.

Table 2. Preference scale between two factors in the FAHP.

Intensity of Importance	Definition	Explanation
0.5	Equally	Two factors contribute equally to the objective
0.6	Moderately	Experience and judgment slightly favor the former factor over the latter
0.7	Strongly	Experience and judgment strongly favor the former factor over the latter
0.8	Very strongly	Experience and judgment very strongly favor the former factor over the latter
0.9	Extremely	The evidence favoring the former factor over the latter is of the highest possible order of affirmation
0.1,0.2, 0.3, 0.4	Opposites	Used for the inverse comparison

Step 2: Calculate the sum of the rows of the matrix, F, defined as $r_i = \sum_{j=1}^{n} f_{ij}$. Using the conversion formula r_{ij}, transform the matrix, F, into a fuzzy consistency judgment matrix, R, $r_{ij} = \frac{r_i - r_j}{2n} + 0.5$, $R = \left(r_{ij}\right)_{n\times m}$.

Step 3: Using the conversion formula e_{ij}, change the fuzzy consistency matrix, R, into a reciprocal matrix, E, $e_{ij} = \frac{r_{ij}}{r_{ji}}$, $E = (e_{ij})_{n\times m}$.

Step 4: Use the line normalization method to solve the sorting vector, $W^{(0)}$.

$$W^{(0)} = (w_1, w_2, \ldots, w_n)^T = \left[\frac{\sum_{j=1}^{n} r_{1j}}{\sum_{i=1}^{m}\sum_{j=1}^{n} r_{1j}}, \frac{\sum_{j=1}^{n} r_{2j}}{\sum_{i=1}^{m}\sum_{j=1}^{n} r_{1j}}, \ldots, \frac{\sum_{j=1}^{n} r_{nj}}{\sum_{i=1}^{m}\sum_{j=1}^{n} r_{1j}} \right]^T$$

Step 5: Using the sorting vector, $W^{(0)}$, as the iterative initial value, $V^{(0)}$, of the eigenvalue method the higher precision sorting vector, $W^{(k)}$ is obtained. The detailed steps are as follows:

① Determine the input comparison matrix, $E_{n\times m}$, the absolute error limit, ε, and the maximum number of iterations, N;

② Calculate the infinite norm, $||V_0||_\infty$, of the initial value, V_0, $||V_0||_\infty = \max\{v_{01}, v_{02}, \ldots, v_{0n}\}$;

③ Calculate the eigenvector, V_{k+1}, by the iterative formula $\begin{cases} \overline{y_k} = ||V_0||_\infty \\ V_{k+1} = E_{\overline{y_k}} \end{cases}$;

④ Judge the inequality,

If $||V_{k+1}||_\infty - ||V_k||_\infty < \varepsilon$, $||V_{k+1}||_\infty$ is the maximum eigenvalue, normalize the eigenvector, V_{k+1}, to obtain the target weight vector, $V = \left[\frac{v_{k+1,1}}{\sum_{i=1}^{n} v_{k+1,i}}, \frac{v_{k+1,2}}{\sum_{i=1}^{n} v_{k+1,i}}, \ldots, \frac{v_{k+1,n}}{\sum_{i=1}^{n} v_{k+1,i}} \right]$, then end the iteration.

Otherwise, $V_k = \frac{V_{k+1}}{||V_{k+1}||_\infty} = \left[\frac{v_{k+1,1}}{||V_{k+1}||_\infty}, \frac{v_{k+1,2}}{||V_{k+1}||_\infty}, \ldots, \frac{v_{k+1,n}}{||V_{k+1}||_\infty} \right]^T$ is taken as the new initial value. Iterate again until the maximum number of iterations, N, is reached and end the iteration.

The obtained sorting vector, $W^{(k)}$, consists of the weights of the sustainability influencing factors, determined by the improved FAHP.

4.2. The Interpretative Structural Model (ISM)

The interpretative structural model (ISM) is a commonly used influencing factor analysis model that clearly expresses the relationships among various influencing factors. The conceptual and analytical details of the ISM process were given by Warfield in 1974 [27]. The model is mainly based on a qualitative analysis, which can transform fuzzy ideas and views into intuitive models with good structural relationships. The ISM is suitable for a system analysis with many variables, complex relationships, and an unclear structure [1]. The general process of developing the ISM is described below.

Step 1: Taking the sustainability influencing factors constructed in Section 3 as the influencing factor set, the influencing factors are denoted as $S_n, n = 1, 2, 3, \ldots\ldots$ The influencing factor set is denoted as $S = \{S_1, S_2, S_3, \ldots\ldots S_n\}$.

Step 2: Quantify the factor strength and determine the key factor column. Based on the factor weights calculated by the FAHP, the AEIOU method is used to classify the factors and determine the key factors, where A represents very important, accounting for 10%; E represents especially important, accounting for 20%; I represents important, accounting for 30%; O represents ordinary, accounting for 40%; and U represents unimportant and is set to 0.

Step 3: Construct the adjacency Boolean matrix, A, based on the direct binary relationships among the influencing factors. Depending on the situation and the factors, a contextual relationship is chosen from the following options: "Depends on", "leads to", "impacts", "increases", and "decreases". When judging the relationship between any two factors, a direct binary relationship,a_{ij}, is formed by the following five principles:

(1) For the relationship a_{ij}, if i has an impact on j, $a_{ij} = 1$; if not, $a_{ij} = 0$ and vice versa;
(2) If the two factors do not impact each other, then $a_{ij} = a_{ji} = 0$;
(3) If the two factors impact each other, then $a_{ij} = a_{ji} = 1$;
(4) When $i = j$, then $a_{ij} = a_{ji} = 0$;
(5) $a_{ij} = a_{ji} = 0$ for any key factors.

Step 4: Generate the reachability matrix. According to the transition law characteristics, the reachability matrix, R, can be calculated by the following formula:

$$(A+I) \neq (A+I)^2 \neq \ldots \neq (A+I)^k = (A+I)^{k+1} = R$$

The matrix multiplications satisfy the Boolean algebra algorithms, where I is the unit matrix. The power, k, in the equation is defined as less than or equal to the number of factors. The reachability matrix is obtained by an algorithm-based process. Specifically, *(A + I)* is multiplied by itself according to the Boolean algebraic algorithms until a power of the product reaches the identical matrix.

Step 5: Partition the reachability matrix into different levels. According to the reachability matrix, the reachability sets and antecedent sets of every factor must be determined. The reachability sets consist of the factor itself and the other factors it may affect, and the antecedent sets consist of the factor itself and other factors that may affect it. If $R(S_i) \cap A(S_i) = R(S_i)$, there is a strong relationship. The factor in R will be located in the top layer and removed from consideration. Repeat the above steps to obtain the next level of factors. By repeating the above steps, the factors of each level can be obtained.

Step 6: Draw a multilevel ladder directed graph according to hierarchy. Based on the results of partitioning the reachability matrix, the top-level factor is placed at the top of the hierarchy and the second-level factor is below the top level. Repeat this process until the underlying factor is placed at the lowest position in the hierarchy.

4.3. The MICMAC Approach

The MICMAC approach (cross-impact matrix multiplication applied to classification) was proposed based on the multiplication properties of matrices [28]. This approach is often used to identify the driving power and dependence power of various factors of the system. The driving power indicates the degree to which this factor affects other factors, and the dependence power indicates how much the factor is affected by other factors. The driving power, DR_i, and dependence power, DE_j, can be determined by the following formulae:

$$DR_i = \sum_{j=1}^{n} a_{ij}(i = 1, 2, 3, \ldots n), DE_j = \sum_{i=1}^{n} a_{ji}(j = 1, 2, 3, \ldots n).$$

Various factors are mapped according to their driving and dependence power. By using the dependence driving force as the abscissa and driving power as the ordinate, the driving-dependence quadrants of the influencing factors can be drawn by representing each factor in the coordinate system. The factors are divided into four clusters, as follows: Autonomous cluster (I), dependent cluster (II), linkage cluster (III), and independent cluster (IV). Autonomous factors have weak dependence power, weak driving power, and few interactions with other factors. Dependent factors have weak driving power, strong dependence power, and strong dependencies on other factors. Linkage factors have strong driving and dependence power. Factors belonging to this cluster have an impact on other factors and they can also be affected by other factors. Driving factors have strong driving power but weak dependence power. Factors belonging to this cluster have a significant influence on other factors [46,47].

4.4. The Integrated Methodology

This research was divided into three steps. A flowchart of the integrated methodology combining the FAHP, ISM, and MICMAC approaches, adopted here, is presented in Figure 2. First, the sustainability influencing factors of the last mile delivery of rural e-commerce were constructed using two typical methods, a literature review and expert interviews. The weight value of each factor was assigned by the FAHP. Second, the hierarchical level of the mutual relationships among the influencing factors was clarified by the ISM. Based on the weight results of each influencing factor determined by the FAHP, they were applied to the intensity analysis of the quantitative influencing factors in the ISM analysis process. Then, the interrelationships among the influencing factors was clarified and the key factors were identified. Third, a driving-dependence quadrant diagram was constructed using the MICMAC approach and the influencing factors were divided into four categories, as follows: Spontaneity, dependence, linkage, and independence. Finally, based on the analysis results of the FAHP, ISM, and MICMAC, the importance of the influencing factors for sustainable development was obtained.

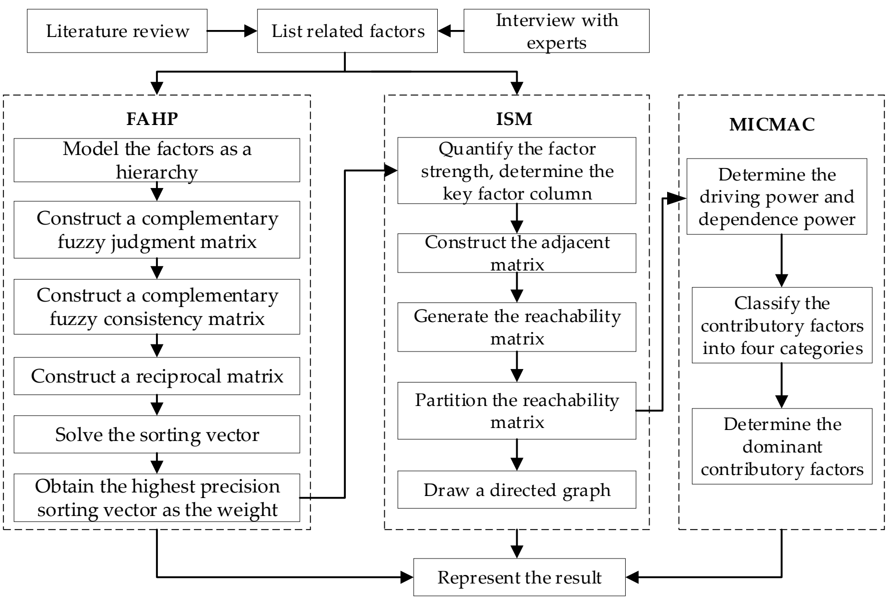

Figure 2. Flow chart of the integrated methodology.

5. Results

5.1. FAHP Results

Expert discussions to determine the weights of the 15 sustainable development influencing factors were completed in November 2018 and January 2019. A panel invited nine experts, including three professors from Southeast University, two professors from Nanjing Forestry University, two senior managers from the Suning Logistics Company, and two senior managers from the SF Express Company, to judge the influencing factors of sustainable development. These experts each have more than 10 years of experience, which makes their judgments more reliable and consistent. Before making a judgment, several experts were consulted to ensure that the questions were phrased appropriately. It took five rounds of discussion to reach an agreement. Two of them discussed the importance of the factors and the other three discussed the relationships among the factors.

According to the specific steps of the FAHP, the weights and rankings of the sustainability influencing factors of the last mile delivery of rural e-commerce are calculated as shown in Table 3. These weights indicate the importance of the factors themselves. As seen from the second row of Table 3, the service convenience dimension (D1) ranks first in the criteria level, with an evaluation of 0.2581. With an evaluation of 0.2169, the service empathy dimension (D4) ranks second, followed by the service economy dimension (D5), with an evaluation of 0.1746. The weight values of the five dimensions do not differ much. In addition, the ranks of the 15 sustainability influencing factors of last mile delivery in the sub criteria level are shown in the last column of Table 3. The five most important factors are "convenience of setting pick-up (S_{02})", "delivery costs (S_{14})", "advance reservation of goods pickup (S_{13})", "convenience of returning goods (S_{03})", and "integrity of goods (S_{08})".

Table 3. Weights and ranks of the influencing factors of the last mile delivery service quality.

Factor	D1	D2	D3	D4	D5	Weight	Rank
	0.2581	0.1608	0.1896	0.2169	0.1746		
S_{01}	0.2648	0	0	0	0	0.0683	7
S_{02}	0.4019	0	0	0	0	0.1037	1
S_{03}	0.3333	0	0	0	0	0.0860	4
S_{04}	0	0.2223	0	0	0	0.0357	13
S_{05}	0	0.1868	0	0	0	0.0300	14
S_{06}	0	0.3165	0	0	0	0.0509	10
S_{07}	0	0.2743	0	0	0	0.0441	12
S_{08}	0	0	0.4054	0	0	0.0769	5
S_{09}	0	0	0.2420	0	0	0.0459	11
S_{10}	0	0	0.3527	0	0	0.0669	8
S_{11}	0	0	0	0.2648	0	0.0574	9
S_{12}	0	0	0	0.3333	0	0.0723	6
S_{13}	0	0	0	0.4019	0	0.0872	3
S_{14}	0	0	0	0	0.5505	0.0961	2
S_{15}	0	0	0	0	0.4495	0.0785	15

5.2. ISM Results

According to the ISM introduced in 4.2, the calculation results of each step are as follows.

Based on the factor weights assigned by the FAHP, the AEIOU method is used to classify the factors and determine the key factors. Factors S_{02} and S_{14} are very important factors, factors S_{13},

S_{03}, and S_{08} are especially important factors, factors S_{12}, S_{01}, S_{10}, S_{11}, and S_{06} are important factors, and factors S_{09}, S_{07}, S_{04}, S_{05}, and S_{15} are ordinary factors. Based on the results of the importance analysis, factors S_{02}, S_{14}, S_{13}, S_{03} and S_{08} are listed as source points when the adjacency matrix is established and the value is 0. A source point represents a fundamental factor that affects the service quality of the terminal distribution. All the elements in line 16 are set to 0; that is, S_{16} represents the sink point. The adjacency matrix, A, is shown in Figure 3.

$$A = \begin{bmatrix}
0&0&0&1&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&1\\
0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&1\\
1&0&0&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
0&0&0&0&0&1&0&0&0&0&1&0&0&0&0&1\\
0&0&0&0&0&1&1&0&0&0&1&0&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&1&1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&0&0&1&1&0&0&0&1&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&1&1&0&1&0&0&0&0\\
0&0&0&1&0&0&0&0&1&1&1&1&0&0&1&1\\
1&0&0&0&1&0&0&0&0&0&1&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{bmatrix}$$

Figure 3. Adjacency matrix.

The reachability matrix was generated according to the transition law characteristics. The calculation process was implemented in MATLAB and the final result is presented in Figure 4.

$$R = \begin{bmatrix}
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
0&1&0&0&1&0&0&0&0&0&0&0&0&0&0&1\\
1&0&1&1&1&1&1&0&1&1&1&1&0&0&0&1\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&1&1&1&1&1&0&0&0&1\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&0&0\\
1&0&0&1&1&1&1&0&1&1&1&1&1&0&0&1\\
1&0&0&1&1&1&1&0&1&1&1&1&0&1&1&1\\
1&0&0&1&1&1&1&0&1&1&1&1&0&0&1&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&1
\end{bmatrix}$$

Figure 4. Reachability matrix.

The reachability matrix was partitioned into several levels. The *Level* 1 partition of matrix M is presented in Table 4. The reachability set in the second column consisted of the factors shown as a 1 in each row of the reachability matrix, R. The antecedent sets consisted of the factors shown as a 1 in each column of Table 4. The last column was the intersection set, which contained the common factors in the reachability and antecedent set. These factors were the elements that would be placed in the first level of the structure. The factor S_{05} was found at *Level* 1 and subsequently removed before the next partition. The process was repeated four times until all the factors were well arranged. Factors S_{01}, S_{06}, S_{07}, and S_{12} were at *Level* 2. Factors S_{02}, S_{04}, S_{09}, S_{10}, S_{11}, and S_{15} were at *Level* 3. Factors S_{03}, S_{08}, and S_{13} were at *Level* 4. The factor S_{14} was found at the deepest level of this structure.

Table 4. Level 1 partition of the reachability matrix.

Factors	Reachability Set	Antecedent Set	Intersection Set
S_{01}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{02}	2,5,16	2	2
S_{03}	1,3–7,9–12,16	3	3
S_{04}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{05}	5	1–15	5
S_{06}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{07}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{08}	1,4–12	8	8
S_{09}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{10}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{11}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{12}	1,4–7,9–12	1,3,4,6–15	1,4,6,7,9–12
S_{13}	1,4–7,9–13,16	13	13
S_{14}	1,4–7,9–12,14–16	14	14
S_{15}	1,4–7,9–12,15	14,15	15

According to the results of hierarchical division and referring to the fifth step of the ISM program mentioned above, the interpretative structure model of the sustainability influencing factors, namely, the five-level model, is obtained. The hierarchy is shown in Figure 5. The factors on the first and second levels are S_{05}, S_{01}, S_{06}, S_{07}, and S_{12}. The factors on the third level are S_{02}, S_{04}, S_{09}, S_{10}, S_{11}, and S_{15}. The factors at the bottom are S_{03}, S_{08}, S_{13}, and S_{14}.

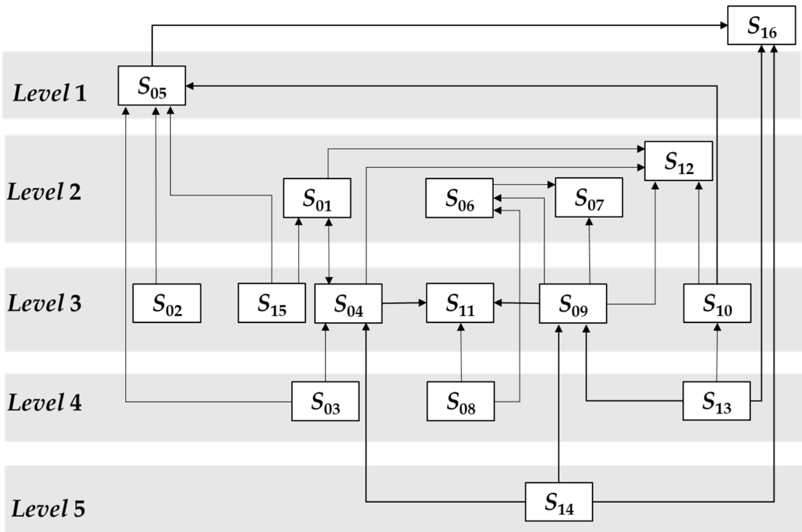

Figure 5. The ISM model.

5.3. MICMAC Results

Based on the results of the ISM and MICMAC approach, the factors are categorized into four clusters, as shown in Figure 6.

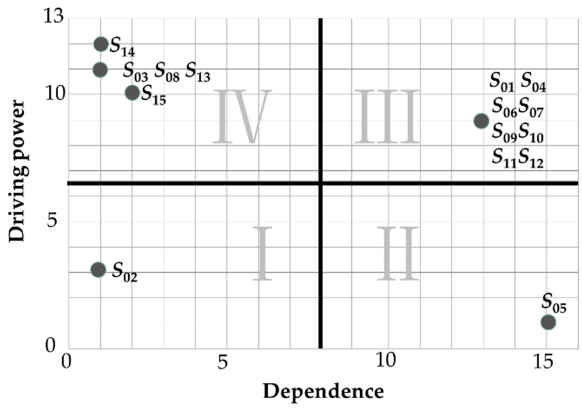

Figure 6. Driving power and dependence diagram.

Cluster I consists of the autonomous factors that have weak driving power and weak dependence. In this case, "convenience of setting pick-up time (S_{02})" belongs to Cluster I.

Cluster II consists of the dependent factors. In this case, the dependent variable is S_{05}, as shown in Figure 5. The value S_{05}, at the top level of the ISM, is the most direct factor affecting the sustainable development of rural last mile delivery and has weak driver power but strong dependence.

Cluster III consists of the linkage factors with strong driving power and strong dependence. They are S_{01}, S_{04}, S_{06}, S_{07}, S_{09}, S_{10}, S_{11}, and S_{12}, as shown in Figure 5. These factors are unstable. Any action on these factors will have an effect on the others and a feedback on themselves.

Cluster IV includes the independent factors that have strong driving power and weak dependence. These factors include S_{03}, S_{08}, S_{13}, S_{14}, and S_{15}, as shown in Figure 5. These factors are usually the most fundamental factors affecting the sustainable development of the rural last mile delivery. It is observed that a factor with a strong driving power is called the key factor that falls into the linkage or independent factor category.

6. Discussion

Knowing what sustainability factors influence and how these factors influence the last mile delivery of rural e-commerce logistics is necessary to promote and improve sustainable development levels. With the assistance of the expert elicitation and the application of an integrated method of the improved FAHP, ISM, and MICMAC, this study conducted a comprehensive exploration on the sustainability factors, in which the importance weights of each factor were obtained and the influence paths of each factor were elaborated in a more evident way.

Through the analysis of all of the factor scores, shown in Table 3, it was discovered that the service convenience dimension (D1) achieved the top score. Consistent with the current studies concerning logistics service evaluation [14,15], the service convenience dimension (D1) is believed to be the key factor influencing sustainable rural logistics development in China. With the highest weight in the criteria level, the factors under the service convenience dimension (D1) show the relative high importance in the sub-criteria level. Convenience of setting pick-up (S_{02}), convenience of returning goods (S_{03}), and convenience of payment (S_{01}) rank 1st, 4nd, and 7th, respectively. It can be seen that, for consumers, the convenience of the pick-up time is very important. The current market environment requires that the delivery staff deliver the goods at the expected time or consumers pick up the goods at the expected time. The speed and rationality of goods return and replacement can effectively avoid the second dissatisfaction of consumers and improve customer satisfaction to a certain extent. Therefore, logistics enterprises should fully consider the location of the goods self-pick-up point, the arrangement of distribution time and the limitation of consumers' time, and improve the handling ability of goods return and replacement. The service empathy dimension (D4) plays the second importance role in the last mile delivery of rural e-commerce logistics. Related factors involving "advance reservation of goods pickup (S_{13})", "employees actively remind customers to open the inspection (S_{12})", and "employee service attitude (S_{11})", also obtain the higher weights in the sub-criteria level. The above three factors are mainly from the perspective of logistics enterprises. If logistics enterprises complete the above actions in last mile delivery, they will provide customers with more comfortable logistics service experiences. This requires logistics companies to improve the training system for their delivery staff. The five most important factors are "convenience of setting pick-up (S_{02})", "delivery costs (S_{14})", "advance reservation of goods pickup (S_{13})", "convenience of returning goods (S_{03})", and "integrity of goods (S_{08})". As we can see, "delivery costs (S_{14})" and "integrity of goods (S_{08})" are also very important for rural customs. Moreover, it is worth noting that the factor of delivery costs (S_{14}) ranked second in the identified 15 factors. It is generally recognized that delivery costs are the immediate cause of the consumer dissatisfaction. Therefore, the logistics enterprises need to take corresponding measures to reduce rural last mile delivery costs and improve the working efficiency, so as to reduce the logistics economic burden on rural consumers.

The ISM model (Figure 5) revealed the contextual relationship of identified sustainability influencing factors and helped develop a hierarchical model. Figure 4 reveals some valuable insights into the relative importance of sustainability influencing factors, as well as the interdependencies among them. In Figure 4, all of the factors associated with rural last mile delivery can be classified into five levels. The factors at the bottom are "convenience of goods return (S_{03})", "integrity of goods (S_{08})", "advance reservation of goods pickup (S_{13})", and "delivery costs (S_{14})", meaning that these factors contribute significantly latent impacts on other factors. These four factors are the most basic factors affecting the sustainability of rural last mile delivery and are the deepest and most indispensable factors. More attention should be paid to these four factors and corresponding strategies and measures should be formulated by which the operation of rural last mile delivery could be more reliable and sustainable. The factors on the first and second levels are "timeliness of goods return processing (S_{05})", "convenience of payment (S_{01})", "timeliness of goods delivery (S_{06})", "timeliness of goods arrival (S_{07})", and "employees actively remind customers to open the inspection (S_{12})". These five factors are surface factors that have the most direct impact on the sustainability of rural last mile delivery. It's worth noting that the factors S_{05}, S_{06}, and S_{07} are all in the service responsiveness dimension (D2). These three timeliness factors are the first experience of consumers receiving goods. Once the timeliness is not satisfied, it will directly affect consumers' satisfaction with the last mile delivery service. In addition, the factors on the middle level (*Level* 3) are "convenience of setting the pick-up time (S_{02})", "timeliness of customer service response (S_{04})", "accuracy of goods arrival (S_{09})", "accuracy of logistics information (S_{10})", "employee service attitude (S_{11})", and "rationality of value-added services (S_{15})". These six factors are influenced by the lower levels and indirectly influence the sustainable development of rural last mile delivery, thus playing a role in connecting the levels above and below. It could be distinctly observed that "accuracy of goods arrival (S_{09})" has the maximum number of relationships, as it is influenced by factors S_{13} and S_{14} and directly influences factors S_{06}, S_{07}, S_{11}, and S_{12}, indicating that this factor plays vital roles in effectively promoting the sustainable development of rural last mile delivery. It is recommended that the improvement of the operation and the working ability of employees is essential in protecting the accuracy of goods arrival.

The results of the MICMAC analysis (Figure 6) indicate that "timeliness of goods return processing (S_{05})" is the most direct factor affecting the sustainable development of rural last mile delivery and has strong dependence but weak driver power. It reflects the path and achievements of rural last mile delivery. The sustainable development of rural last mile delivery depends on the bottom level factors "convenience of goods return (S_{03})", "integrity of goods (S_{08})", "advance reservation of goods pickup (S_{13})", "delivery costs (S_{14})", and "rationality of value-added services (S_{15})". These are strong drivers for improving sustainable development of rural last mile delivery. These variables help in achieving sustainability and have long-term implications. The improvement in middle-level factors helps to achieve the top-level factors. The factors such as "convenience of payment (S_{01})", "timeliness of customer service response (S_{04})", "timeliness of goods delivery (S_{06})", "timeliness of goods arrival (S_{07})", "accuracy of goods arrival (S_{09})", "accuracy of logistics information (S_{10})", "employee service attitude (S_{11})", and "employees actively remind customers to open the inspection (S_{12}) have high dependence and high driving power. These factors are unstable. Any action on these factors will have an effect on the others and a feedback on themselves. Therefore, this MICMAC analysis brings out the right priority and focus for decision makers to operate and manage the rural last mile delivery for sustainable development.

Based on the analysis results of the FAHP, ISM, and MICMAC, the importance of influencing factors for sustainable development could be described. The five most important factors assigned by the FAHP are S_{02}, S_{14}, S_{13}, S_{03}, and S_{08}. The factors at the bottom level of the ISM are S_{14}, S_{03}, S_{08}, and S_{13}. The factors that have strong driving power and weak dependence are S_{03}, S_{08}, S_{13}, S_{14}, and S_{15}. It is obvious that the intersection of these three results is "convenience of goods return (S_{03})", "integrity of goods (S_{08})", "advance reservation of goods pickup (S_{13})", and "delivery costs (S_{14})". These four factors not only have the highest weighting, but are located in the bottom of the structure model of the ISM and belong to the independent factor category. Thus, it could be revealed that these four factors are the most basic factors affecting the sustainability of rural last mile delivery and are also the deepest and most indispensable factors. Therefore, these four factors of the service quality need to be improved first. It is recommended that the improvement of the operation efficiency and the working ability of employees is essential. The improvement of the operation efficiency can be achieved through the following strategies. The first is to establish a public information platform for county circulation and to integrate the transportation resources within the county to reduce operating costs. The second is scientifically predicting the package data and optimizing the distribution routes to effectively reduce personnel and operating costs. The third is to provide diversified value-added services, such as commodity installation and maintenance, to increase revenue. In addition, the improvement of the working ability of the delivery staff mainly depends on perfect staff training and a professional operating system in order to achieve the service satisfaction for customers.

There have been studies on the integration of AHP and ISM [39–41], or the integration of ISM and MICMAC [43,44], but rarely on the integration of AHP, ISM, and MICMAC. By comparison, the proposed integration in this research was not only to identify sustainability influencing factors of rural last mile delivery, but also to understand the driving power and dependence and the relationships between different sustainability influencing factors. The list of factors affecting sustainable development extracted in this paper may not be exhaustive, but nine experts from the industry were invited to discuss them further. Therefore, it can be concluded that the factor set proposed in this paper contains most of the factors affecting the sustainable development of the last mile delivery of rural e-commerce logistics and the extraction process has high credibility.

7. Conclusions

The promotion of sustainable development in the last mile delivery of rural e-commerce logistics is complex, as it involves many uncertainty factors. Understanding the inherent properties of sustainability influencing factors of rural last mile delivery is conducive to retaining a high level of sustainable development. There have been many studies on the service quality evaluation of rural last mile delivery, but the importance quantification of each evaluation index/impact factor is often neglected, leading decision-makers to ignore those key influencing factors that are not classified at the lowest level when making optimization recommendations. To address this knowledge gap, the integrated method of the improved FAHP, ISM, and MICMAC is proposed to study the importance of the sustainability influencing factors of the rural last mile delivery. According to the literature review and expert interviews, a list of 15 sustainability influencing factors was determined and the weights were calculated using the improved FAHP. In combination with the AEIOU classification method, the importance of each influencing factor was quantified and the correlations among the factors were illustrated by the ISM model. A driving-dependence quadrant diagram of the sustainability influencing factors of rural last mile delivery was constructed by MICMAC. As the results show, "convenience of goods return (S_{03})", "integrity of goods (S_{08})", "advance reservation of goods pickup

(S_{13})", and "delivery costs (S_{14})" are the most basic factors affecting the sustainability of rural last mile delivery and are also the deepest and most indispensable factors. More attention should be paid to these four factors and corresponding strategies and measures should be formulated, through which the operation of rural last mile delivery could be more reliable and sustainable. The research findings provide valuable insights into the perception of and knowledge about the sustainable development of rural logistics.

In general, this research contributed to the improvement of rural logistics safety sustainability in China. The proposed integrated method of the improved FAHP, ISM, and MICMAC in this research was not only to identify the sustainability influencing factors of rural last mile delivery, but also to understand the driving power and dependence and lead to a better understanding of how various sustainability factors influence the operation of the last mile delivery of rural e-commerce logistics. In addition, the improved FAHP method is adopted here. The fuzzy consistency matrix, modified from the priority judgment matrix, satisfies the consistency condition and there is no need for a consistency test. As the initial iteration value of the eigenvalue method, the target weight can greatly reduce the number of iterations, improve the convergence speed, and meet the calculation accuracy requirements. The FAHP quantifies the influencing factors and divides the key factors, making the results more comprehensive and reliable and providing more reference value for the corresponding strategies and measures. However, there are still some shortcomings. In this paper, 0 and 1 are used to determine whether the influencing factors affect each other, while the degree of mutual influence between two factors is ignored. Thus, the establishment of the Boolean matrix still needs to be further studied. Nevertheless, from the perspective of the most important problem of revealing the relative importance of schemes and ranking, this paper combined the FAHP, ISM, and MICMAC analyses for a relatively effective method. The relative importance of the schemes with universal applicability can be obtained through the ISM analysis and a specific analysis can be carried out based on FAHP.

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