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Comprehensive evaluation of the level of rural digital governance based on fuzzy median information or methods

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SUMMARY: *The study takes the practice of village digital governance in village A as an example, and applies the fuzzy median information synthesis evaluation method as an instrumental evaluation system to comprehensively analyze the six aspects of village digital governance of village A, including digital party building, government affairs, and village affairs. Based on the entropy weighting method, it is concluded that digital government governance is the biggest factor affecting the total score, with a weight of 0.224, while the impact of digital village governance is relatively small, with a weight of 0.124. The field evaluation of 316 villagers in Village A shows that the development of the digital governance level of Village A is not balanced, and the comprehensive score for digital emergency governance reaches 3.124 (out of a possible 4), which is an excellent performance. Digital government governance, on the other hand, only scored 2.3496 points, which is its obvious shortcoming, especially in terms of satisfaction with the government platform, the score is as low as 2.092 points, and the villagers' poor evaluation rate is as high as 24.1%, which is the biggest pain point in village digital governance. By comparing the independent scores of 30 experts, it is found that experts and villagers are highly consistent in the judgment of the majority of dimensions, which doubly verifies the validity of the fuzzy model and the reliability of the evaluation results. The study reveals the specific performance of each dimension in the digital governance of Village A, and provides data support and a clear course of action for its precise improvement.*

KEYWORDS: *village digital governance; fuzzy median information; fuzzy evaluation; entropy weight method*

1 Introduction

Rural governance suffers from problems such as fragmentation of power, suspension of regime, and formalization of government work, which seriously impedes the process of rural modernization and even restricts the construction of national socialist modernization [1-3]. In order to solve these problems, the Chinese government has innovated the governance methods and means of rural governance, and explored ways of digitally empowering rural development [4, 5]. In 2019, Chinese government documents for the first time elevated the digital countryside to the level of a national strategy, proposing the strategy of rural revitalization. The Digital Rural Development Strategy Outline formulated by the government made a more detailed plan for the development direction and construction content of digital villages, clearly implementing the rural digital governance strategy and making full use of digital means to innovate the rural governance model. Subsequently, several policy documents have been issued to guide the unfolding of rural digital governance, such as the Action Plan for the Development

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of Digital Villages (2022-2025) and the Key Points for the Development of Digital Villages in 2023. As a grassroots governance unit, rural digital governance has an important position in the process of promoting the modernization of the national governance system and governance capacity [6, 7]. Therefore, rural digital governance is "the most important thing in the country", and it is a global and historic task for China to comprehensively build a socialist modernization country in the new era.

On the basis of clarifying the important position of rural digital governance, local governments have set off the practice of rural digital governance to optimize the rural economic and environmental development [8, 9]. 2020, the "Notice on the National Pilot Work on Digital Villages" was issued, and the specific construction contents and focuses varied from place to place in response to the government's pilot work. For example, the construction of the "Longyou Tong" APP in Zhejiang focuses on the participation of villagers in rural digital governance; the construction of the "Smart Party Building" platform in Hubei focuses on the development of party building in villages and towns; and the development of rural e-commerce for poverty alleviation through rural digital governance in Guizhou, etc. [10-12]. Since the digital countryside was proposed, the practice of digital governance around the countryside has been carried out for several years, and has also achieved certain results, such as the 2020 outbreak of the new crown epidemic, digital technology and its application effectively enhance the effectiveness of rural epidemic prevention and control and the governance of the rural environment, which fully proves the value of digital governance in the countryside [13-16]. However, there is a lack of a set of evaluation standards and methods for the level of rural digital governance, and government departments cannot comprehensively and accurately grasp the current situation of digital governance in various places, nor can they timely identify problems in practice. The one-sided construction and development, without timely checking and mending, is easy to cause the waste of government resources, which is not conducive to the long-term development of rural digital governance [17, 18]. Therefore, it is urgent to establish a set of evaluation standards and methods for the level of rural digital governance.

Most scholars evaluate and discuss rural digital governance as a dimension of digital countryside. From the viewpoint of the evaluation content and indicators of digital villages, scholars have mainly studied the factors influencing the governance of digital villages, the current state of construction and the current state of development. Literature [19] established an evaluation framework for digital villages, taking governance as one of the dimensions (also including technology, resources, rural services, life, and tourism), and evaluating the contents including public services, governance transparency, and policy decisions. Literature [20] establishes an evaluation index system for digital governance capacity of Hunan local government, i.e., basic resource input, online public opinion management and digital service effectiveness, and introduces entropy power method and obstacle degree model to evaluate its digital governance capacity. Literature [21] designed an assessment index system for rural digital development in Jiangxi using the Delphi method and principal component analysis, combined the objective empowerment method and subjective empowerment method based on the correlation between the indicators to calculate the weights of the indicators, and introduced the extended element method to grade the level of development, so as to comprehensively assess the development of the digital countryside. Literature [22] developed a multi-dimensional indicator evaluation system for the digital rural governance model of the "Fengqiao Experience" in the new era, and used regression analysis to analyze the governance data, pointing out that the governance level of the model is high, and digital technology promotes digital rural governance through digital inclusive finance. Literature [23] used hierarchical analysis to propose a unified digital rural management information system evaluation index system for assessing the impact factors of differences in the level of economic development and infrastructure development on digital rural management information systems in digital rural governance. Literature [24] assessed the level of digital rural governance in 2021 through the entropy weight-approximation ideal solution ranking method model, and established an evaluation system for five digital governance indicators in economy, ecology, culture, livelihood and government. Literature [25] constructed a comprehensive evaluation index system section based on the entropy value method for the effect and development of digital rural construction in Pujiang County, and made it clear that Pujiang County needs to strengthen government support, optimize the service system, and improve the cooperation mechanism.

Government support is an important pillar to promote rural digital construction. And literature [26] constructs an evolutionary game model to show that three stakeholders, local government, village collectives and villagers, can obtain a balance of interests under certain conditions, in which digital literacy and government subsidies are internal and external factors affecting the strategic development of the other two stakeholders. Literature [27] explored the synergistic mechanism among the three stakeholders, namely village government, new agricultural management subjects and farmers, in rural digital governance in China with an evolutionary game approach, in which the village government is affected by multiple factors, while the new agricultural management subjects and farmers have a high degree of stability, and it also revealed that the rural digital governance has a solid economic foundation and social foundation. Literature [28] used the assessment theory of reflective interaction to assess broadband technology changes and digital rural social changes in Canada, and concluded that the government needs to correctly position itself, play a leading role in the government, and improve the level of governance of digital technology in the countryside. Literature [29] provides a multi-source fusion method based on weighted multi-granularity fusion operator for the data of rural revitalization and development in the context of digital governance, which guarantees the quality and efficiency of data fusion and ensures its security at the same time, and provides technical support for the assessment of the level of digital governance in villages. Based on the “environment-economy-society” analytical framework, literature [30] reveals that the geographic distribution pattern of digital village development level at the county level in China is spatially clustered and affected by the digital infrastructure by combining factor detection and interaction detection. Literature [31] analyzes the case of national-level digital village strategy pilot areas, and points out that the implementation flexibility and other characteristics of digital grid governance in rural areas of China are affected by bureaucratic constraints and grass-roots facts, and that relational labor is the core driver for maintaining digital network governance.

To summarize the study, scholars mainly chose to adopt common evaluation methods such as regression analysis, hierarchical analysis, entropy weighting method, and approximation of the ideal solution ranking method to evaluate the development level, governance effects and influencing factors of digital rural governance using objective data at the county and provincial levels. However, the evaluation index system lacks the consideration of dynamic indicators such as policy changes, and its quantitative assessment is hindered in the face of villager-related fuzzy indicators based mainly on their subjective narratives only. The fuzzy neutral information is an information processing method based on fuzzy logic, which provides support for the quantification of fuzzy and uncertain information. With the help of fuzzy set qualitative comparative analysis (fsQCA) method, literature [32] identified four rural digital governance models, namely, digital resource allocation, digital governance + infrastructure development, digital life + infrastructure, and digital life and economy, as effective in promoting the rapid growth of the economy of county-level regions. Literature [33] is oriented to the technical-organizational environment analysis framework, using the fsQCA method and the system dynamics method to identify the influencing factors and simulate the developmental changes of rural digital life, respectively, and is able to determine the key factors and the degree of influence, and the level of its development has increased over time.

The kernel of rural digital governance is full of ambiguity and complexity - villagers' satisfaction, participation in governance, and high or low sense of security - these key dimensions are difficult to be encapsulated in a simple yes or no way, which introduces a comprehensive treatment of fuzzy information to solve this problem. Based on the Delphi expert correspondence method, a rural digital governance indicator system with six dimensions and 17 secondary indicators, including digital party building, digital government, digital village affairs, digital rule of law, digital public security and digital emergency response, is finally constructed. And the entropy weighting method was introduced to determine the weights and transform the subjective evaluation of experts into objective analysis. Subsequently, an interval intuitionistic fuzzy set that can finely characterize the four attitudes {excellent, good, moderate, and poor} is introduced, and the final fuzzy comprehensive evaluation results are calculated.

2 Entropy power-fuzzy evaluation theory and rural digital governance level evaluation system

2.1 Establishment of an evaluation system for the level of rural digital governance

2.1.1 Initial establishment of a system for evaluating the level of digital governance in villages

The purpose of the evaluation in this paper is to reflect the current situation of the level of rural digital governance in a comprehensive and integrated way, and the evaluation results can be used to understand the implementation of the governance content under the various constituent dimensions of rural digital governance in various places. Combined with the policy and practice content, concepts and connotations of rural digital governance, the evaluation index system of rural digital governance level is preliminarily determined. The study is mainly carried out in six dimensions: digital party building governance, digital government governance, digital village governance, digital rule of law, digital public security governance, and digital emergency governance. And from the three levels of governance digitalization, participation, and subjective feelings, respectively, to establish the secondary evaluation indicators under each level of indicators. The preliminary construction of the evaluation system for the level of rural digital governance is shown in Table 1.

Table 1: Initial Evaluation System for Rural Digital Governance Level

Primary indicator	Secondary indicator
Digital Party Building Governance	Digitalization of Party Building Education
	Digitalization of Party Affairs Disclosure
	Satisfaction of Party Building Platform
Digital Government Affairs Governance	Digitalization of Government Affairs Disclosure
	Online Government Processing
	Satisfaction of Government Affairs Platform
	Digitalization of Three-Sector Management
Digital Village Governance	Online Governance of Village Affairs
	Satisfaction of Village Affairs Platform
Digital Governance	Online Legal Services
	Online Legal Publicity
	Satisfaction of Legal Affairs Platform
Digital Public Security Governance	Digital Public Health Governance
	Public Health Security
	Digital Social Security Management
	Social Security Security
Digital Emergency Governance	Digitalization of Disaster Monitoring
	Digitalization of Disaster Warning
	Digital Security

2.1.2 Expert correspondence based on the Delphi method

(1) Basic information of experts

In order to make the indicator system more in line with the actual situation, 30 experts in the research fields related to the level of rural digital governance were interviewed, and the indicators were optimized according to the experts' knowledge of rural digital governance and relevant work experience. The information of the interviewed experts is shown in Figure 1.

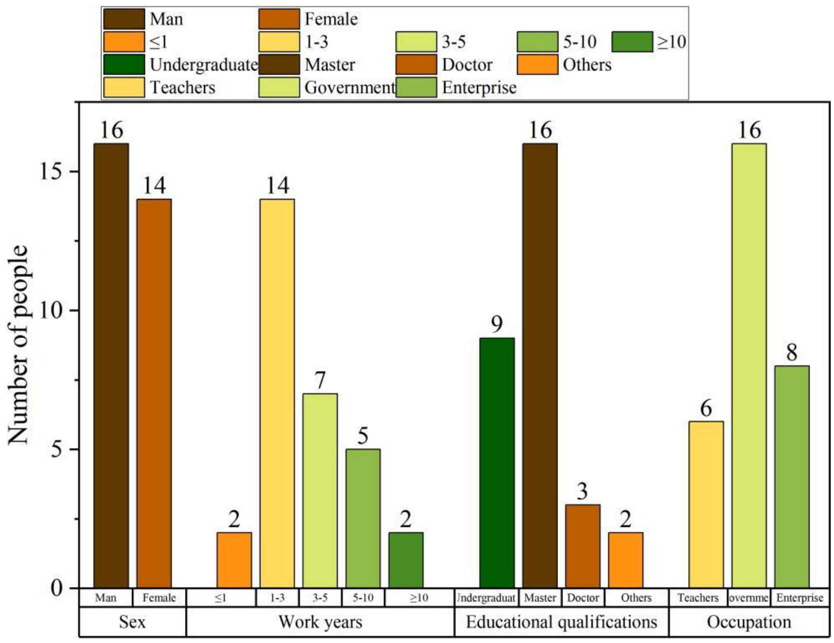

Figure 1: Information of the interviewed experts

The ratio of men and women among the 30 experts was relatively balanced. In terms of years of experience, 14 of them have 1-3 years of experience, followed by 23.33% with 3-5 years of experience, and 2 each with more than 10 years and less than 1 year of experience. Master's degree accounted for the highest proportion of 16 people, while bachelor's degree accounted for 30% and doctoral degree accounted for 10%. Occupational background is mainly government staff, enterprise staff accounted for 26.67%, and there are 6 teachers in colleges and universities. On the whole, the expert group has a high level of education and diversified occupational backgrounds, and the proposed expert modifications include academic research, government management, market operation and other perspectives, which have both academic and practical significance.

(2) Degree of Expert Authority

The study of the degree of expert authority is mainly judged from the degree of influence (Ca) of the experts on the basis of the judgment of the entry, and the experts in the correspondence conducted self-assessment based on four aspects: practical experience, theoretical analysis, reference to domestic and foreign materials, and intuitive feeling. Table 2 shows the frequency of expert judgment coefficient (Ca).

Table 2: Expert judgment coefficient frequency

	Judgment criteria	High	Middle	Low
Round 1	Practical experience (0.5)	23	7	0
	Theoretical analysis (0.3)	20	8	2
	Reference to domestic and foreign materials (0.1)	14	20	6
	Intuitive perception (0.1)	8	12	0
Round 2	Practical experience (0.5)	25	4	1
	Theoretical analysis (0.3)	24	5	1
	Reference to domestic and foreign materials (0.1)	18	6	6
	Intuitive perception (0.1)	6	13	11

Expert judgment factor for the first round Ca=(23*0.5+7*0.4+*0.3+20*0.3+8*0.2+2*0.1+ 14*0.1+20*0.1+6*0.1+8*0.1+12*0.1+0*0.1)/30=0.94

Expert judgment factor for the second round Ca=(25*0.5+4*0.4+1*0.3+24*0.3+ 5*0.2+1*0.1+18*0.1+6*0.1+6*0.1+6*0.1+13*0.1+11*0.1)/30=0.99

In the two rounds of correspondence and inquiries, the experts relied mainly on practical experience and theoretical analysis to make their judgments, with a solid basis of authority. The self-assessment judgment coefficients of the two rounds of experts are 0.94 and 0.99. The basis of expert judgment is reliable and the degree of authority is high.

(3) Expert coordination coefficient

The coordination coefficient (Kendall'sW) is between 0 and 1. The larger the coefficient, the higher the degree of coordination of experts on entries. The coordination coefficient of expert opinions in two rounds is shown in Table 3.

Table 3: Two-round expert opinion coordination coefficient

		Kendall'sW	X^2	df	P
Round 1	Digital Party Building Governance	0.447	24.385	3	0.000
	Digital Government Affairs Governance	0.323	19.727	4	0.000
	Digital Village Governance	0.229	14.712	2	0.004
	Digital Governance	0.359	19.399	3	0.004
	Digital Public Security Governance	0.184	9.938	4	0.021
	Digital Emergency Governance	0.288	16.944	3	0.003
	Overall questionnaire	0.305	93.264	19	0.000
Round 2	Digital Party Building Governance	0.421	23.137	3	0.000
	Digital Government Governance	0.228	11.511	4	0.004
	Digital Village Governance	0.272	16.392	2	0.002
	Digital Governance	0.284	16.009	3	0.002
	Digital Public Security Governance	0.215	10.063	4	0.003
	Digital Emergency Governance	0.313	20.198	3	0.001
	Overall questionnaire	0.291	98.292	19	0.001

The coordination coefficients of all dimensions are between 0.184 and 0.447, and the coordination coefficients of the two rounds of correspondence questionnaires are 0.305 and 0.291, respectively, which are between 0 and 1, and the significance test P is less than 0.05, which indicates that the overall experts' opinions are better unified. Among them, the coordination coefficient of digital party building governance level is the highest, 0.447 and 0.421 in the two rounds respectively, indicating that experts' opinions are highly unified in this dimension; the coordination coefficients of digital public security governance level are the lowest in the two rounds, 0.184 and 0.215 respectively, and experts' opinions are relatively dispersed in this dimension indicator.

2.1.3 Results of the Expert Consultation and Revision of Opinions

The degree of concentration of experts' opinions was expressed by the agreement rate of the indicator, which was calculated using the dichotomous variable method, in which those who chose the results of 1 and 2 in the assignment were regarded as disagreeing (unimportant), and those who chose the results of 4 and 5 in the assignment were regarded as agreeing (important). The screening criteria for the indicators were: 1) the mean value of the importance score was ≥4; 2) the coefficient of variation was ≤0.25; and 3) the rate of expert agreement was ≥75%.

(1) Results of the first round of expert correspondence

The results of the first round of expert correspondence are shown in Table 4.

Table 4: The results of the first round of expert inquiries

Primary indicator	Secondary indicator	Approval%	Mean	SD	CR
Digital Party Building Governance	Digitalization of Party Building Education	100%	4.90	0.19	0.04
	Digitalization of Party Affairs Disclosure	96.67%	4.73	0.38	0.08
	Satisfaction of Party Building Platform	90%	4.60	0.66	0.14
Digital Government Affairs Governance	Digitalization of Government Affairs Disclosure	86.67%	4.13	1.15	0.28
	Online Government Processing	80%	4.43	0.88	0.20
	Satisfaction of Government Affairs Platform	83.33%	4.37	0.96	0.22
	Digitalization of Three-Sector Management	80%	4.07	0.94	0.23
Digital Village Governance	Online Governance of Village Affairs	76.67%	4.03	1.03	0.26
	Satisfaction of Village Affairs Platform	76.67%	4.17	0.95	0.23
Digital Governance	Online Legal Services	90%	4.53	0.76	0.17
	Online Legal Publicity	90%	4.33	0.88	0.20
	Satisfaction of Legal Affairs Platform	73.33%	4.00	1.07	0.27
Digital Public Security Governance	Digital Public Health Governance	80%	4.50	1.01	0.22
	Public Health Security	63.33%	3.70	1.34	0.36
	Digital Social Security Management	90%	4.53	0.74	0.16
	Social Security Security	76.67%	4.03	0.82	0.20
Digital Emergency Governance	Digitalization of Disaster Monitoring	90%	4.23	1.19	0.28
	Digitalization of Disaster Warning	83.33%	4.00	0.78	0.20
	Digital Security	83.33%	4.43	0.66	0.15

Most of the indicators in the table pass the screening criteria, indicating that the preliminary constructed indicator system is widely recognized by the expert community. However there are still a few failed indicators, mainly reflected in the high coefficient of variation.

For the digitization of open government affairs, although it achieved a pass rate of 86.67% agreement and a mean score of 4.13, its large standard deviation resulted in a coefficient of variation of 0.28, which exceeded the 0.25 threshold, and was deleted because of the disagreement of the experts;

The coefficient of variation for online village governance is 0.26, and although its agreement rate (76.67%) and mean score (4.03) meet the threshold, the experts' evaluation of the importance of this indicator is highly dispersed and there is insufficient consensus. It was deleted;

Sense of public health security, this indicator is the only one whose agreement rate is lower than the standard of 75%, while its coefficient of variation is 0.36, higher than the standard value of 0.25. It indicates that experts consider the importance of this indicator relatively low and there is significant divergence of opinions, so it should be deleted.

At the same time, after the discussion of the expert group, the indicator “digitalization of financial disclosure of village affairs" was added to the dimension of digital village governance. Experts believe that financial disclosure is the core aspect of village affairs governance and one of the most important concerns of villagers. The original online governance of village affairs fails to highlight this focus, so it is suggested that a separate secondary indicator be added to emphasize the importance of digitized financial disclosure of village affairs.

(2) Results of the Second Round of Expert Correspondence

After the first round of expert consultation, the three indicators of digitization of government affairs, online governance of village affairs and sense of public health and safety were deleted, and a new indicator of digitization of financial disclosure of village affairs was added, and the results of the second round of expert consultation are shown in Table 5.

Table 5: The results of the second round of expert inquiries

Primary indicator	Secondary indicator	Approval%	Mean	SD	CR
Digital Party Building Governance	PB1: Digitalization of Party Building Education	100%	4.90	0.19	0.04
	PB2: Digitalization of Party Affairs Disclosure	96.67%	4.80	0.31	0.06
	PB3: Satisfaction of the Party Building Platform	90%	4.60	0.66	0.14
Digital Government Affairs Governance	GA1: Online Government Affairs Processing	90%	4.53	0.78	0.17
	GA2: Satisfaction of the Government Affairs Platform	80%	4.37	0.96	0.22
	GA3: Digitalization of Three-Self Management	80%	4.27	0.64	0.15
Digital Village Governance	VG1: Digitalization of Village Affairs and Financial Disclosure	93.33%	4.70	0.33	0.07
	VG2: Satisfaction of the Village Affairs Platform	80%	4.23	0.65	0.15
Digital Governance	DG1: Online Legal Services	90%	4.40	0.56	0.13
	DG2: Online Legal Publicity	90%	4.33	0.88	0.20
	DG3: Satisfaction of the Legal Affairs Platform	73.33%	4.13	0.87	0.21
Digital Public Safety Governance	PS1: Digital Public Health Governance	80%	4.50	1.01	0.22
	PS2: Digital Social Security Management	90%	4.53	0.74	0.16
	PS3: Social Security Security Perception	80%	4.03	0.82	0.20
Digital Emergency Governance	EG1: Digital Disaster Monitoring	90%	4.50	0.69	0.15
	EG2: Digital Disaster Warning	83.33%	4.47	0.58	0.13
	EG3: Digital Emergency Security Perception	83.33%	4.43	0.66	0.15

The adjusted indicator system was highly recognized by the experts. The agreement rate of all indicators reached or exceeded 73.33%, the average value was higher than 4 points, and the coefficient of variation was below the threshold of 0.25, indicating that the experts' opinions were highly concentrated and the consensus was strong. The new indicator "digitalization of village financial disclosure" has an agreement rate of 93.33%, with a mean value of 4.70, and a low coefficient of variation of 0.07, which highlights the high degree of agreement among experts on its importance. The optimized indicator system is ideal in terms of importance and consensus, and can be used for subsequent research.

2.2 Determination of weights based on the entropy weight method

After establishing a system of evaluation indicators that meets the criteria of importance and consensus, the entropy weighting method is now introduced to determine the weights of the indicators and accurately measure their relative importance in the comprehensive evaluation.

The relative importance of evaluation indicators can be measured by assigning weights to each indicator, and entropy can be used to measure the amount of information and the useful information provided by the acquired data.

There are m evaluation indicators, n evaluation objects, according to the principle of combining qualitative and quantitative to obtain the evaluation matrix of multiple objects about multiple indicators:

$$R' = \begin{bmatrix} r'_{11} & r'_{12} & \cdots & r'_{1n} \\ r'_{21} & r'_{22} & \cdots & r'_{2n} \\ \vdots & \vdots & & \vdots \\ r'_{m1} & r'_{m2} & \cdots & r'_{mn} \end{bmatrix} \tag{1}$$

Normalization of R' is obtained:

$$R = (r_{ij})_{m\times n} \tag{2}$$

where r_{ij} is called the value of the j th evaluation object over the indicator, and $r_{ij} \in [0,1]$, and

$$r_{ij} = \frac{r'_{ij} - \min_j \left\{ r'_{ij} \right\}}{\max_j \left\{ r'_{ij} \right\} - \min_j \left\{ r'_{ij} \right\}} \tag{3}$$

Then the entropy of the evaluation metrics is defined as the entropy of the i th evaluation metric in an evaluation problem with m evaluation metrics and n evaluation objects:

$$H_i = -k \sum_{j=1}^{n} f_{ij} \ln f_{ij} \quad i = 1, 2, \cdots, m \tag{4}$$

Format:

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \tag{5}$$

$$k = \frac{1}{\ln n} \tag{6}$$

When $f_{ij} = 0$, $f_{ij} \ln f_{ij} = 0$.

In the (m,n) evaluation problem, the entropy weight ω_i of the i th indicator is defined as:

$$\omega_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{7}$$

From the above definition and the nature of entropy function, we can get the following properties of entropy weight:

(1) The entropy value reaches the maximum value of 1 and the entropy weight is zero when each evaluated object has exactly the same value on the indicator j. This also means that the indicator does not provide any useful information to the decision maker, and the indicator can be considered to be canceled.

(2) When the value of each evaluated object on the indicator j has a large difference, the entropy value is small, and the entropy weight is large, it means that the indicator provides useful information to the decision maker. It also indicates that there is a significant difference between the objects on the indicator in the question, which should be focused on.

(3) The larger the entropy of the indicator and the smaller its entropy weight, the less important the indicator is and the satisfaction of the

$$0 \le \omega_i \le 1 \text{ And} \sum_{i=1}^{m} \omega_i = 1 \tag{8}$$

(4) Entropy weight as a weight has its own special significance. It is not a coefficient of importance in the actual sense of a certain indicator in the decision-making or assessment problem, but a coefficient of relative intensity of each indicator in the sense of competition in the case of a given set of evaluated objects and the value of various evaluation indicators is determined.

(5) Considered from the information point of view, it represents the extent to which the indicator provides useful information in the problem.

(6) The size of the entropy weight is directly related to the evaluated object. When the evaluation object is determined, then according to the entropy weight of the evaluation index to adjust, increase or decrease, in order to facilitate the making of more accurate and reliable evaluation. At the same time, the entropy right can also be used to adjust the precision of the evaluation value of certain indicators, and when necessary, to re-establish the evaluation value and precision.

2.3 Theories related to fuzzy evaluation

After solving the problem of lightness in the evaluation, in order to further deal with the evaluation of the level of rural digital governance, there is a large amount of ambiguity and subjective judgment, which is used in the fuzzy middle information method to solve such problems.

2.3.1 Interval intuitionistic fuzzy sets

Definition 1: Let the set $A=\left\{\langle x,[\underline{\mu}_A(x),\bar{\mu}_A(x)],[\underline{\nu}_A(x),\bar{\nu}_A(x)]\rangle \mid x\in X\right\}$ be a non-empty interval intuitionistic fuzzy set on the domain X, where the degree interval of subordination and the degree interval of non-subordination of the element x to the set A are $[\underline{\mu}_A(x),\bar{\mu}_A(x)]\subseteq[0,1]$, $[\underline{\nu}_A(x),\bar{\nu}_A(x)]\subseteq[0,1]$, and $\forall x\in X$, $\bar{\mu}_A(x)+\bar{\nu}_A(x)\le 1$. Then the hesitancy interval is $[\underline{\pi}_A(x),\bar{\pi}_A(x)]=[1-\bar{\nu}_A(x)-\bar{\mu}_A(x),1-\underline{\mu}_A(x)-\underline{\nu}_A(x)]$.

Definition 2: Let $a=\langle[\bar{a}^-,\bar{a}^+],[\underline{a}^-,\underline{a}^+]\rangle$ be the interval intuitionistic fuzzy number on a nonempty domain X where $[\bar{a}^-,\bar{a}^+]\in[0,1]$. $[\underline{a}^-,\underline{a}^+]\in[0,1]$, $\bar{a}^+ +\underline{a}^+\le 1$. $\bar{a}^*=\langle[1,1],[0,0]\rangle$ is the largest interval intuitionistic fuzzy number.

Definition 3: Let the two interval intuitionistic fuzzy numbers on $X=\{X_1,X_2,\ldots,X_n\}$ be $A=\{A_1,A_2,\ldots,A_n\}$ and $B=\{B_1,B_2,\ldots,B_n\}$, the correlation coefficient (i.e., cosine of the angle of entanglement) of A and B is defined as in Eq. (9), where $A_i=\langle[\underline{\mu}_A(x_i),\bar{\mu}_A(x_i)],[\underline{\nu}_A(x_i),\bar{\nu}_A(x_i)]\rangle$, $B_i=\langle[\underline{\mu}_B(x_i),\bar{\mu}_B(x_i)],[\underline{\nu}_B(x_i),\bar{\nu}_B(x_i)]\rangle$.

$$K_{IVIFS}(A,B)=\frac{C_{IVIFS}(A,B)}{\sqrt{E_{IVIFS}(A)}\sqrt{E_{IVIFS}(B)}} \tag{9}$$

Among them,

$$\begin{aligned}C_{IVIFS}(A,B)=\frac{1}{2}\sum_{i=1}^{n}\Big[&\underline{\mu}_A(x_i)\underline{\mu}_B(x_i)+\bar{\mu}_A(x)\bar{\mu}_B(x)+\underline{\nu}_A(x_i)\underline{\nu}_B(x_i)\\&+\bar{\nu}_A(x_i)\bar{\nu}_B(x_i)+\underline{\pi}_A(x_i)\underline{\pi}_B(x_i)+\bar{\pi}_A(x_i)\bar{\pi}_B(x_i)\Big]\end{aligned} \tag{10}$$

$$\begin{aligned}E_{IVIFS}(A)=\frac{1}{2}\sum_{i=1}^{n}\Big\{&\big[\underline{\mu}_A(x_i)\big]^2+\big[\bar{\mu}_A(x_i)\big]^2\\&+\big[\underline{\nu}_A(x_i)\big]^2+\big[\bar{\nu}_A(x_i)\big]^2+\big[\underline{\pi}_A(x_i)\big]^2+\big[\bar{\pi}_A(x_i)\big]^2\Big\}\end{aligned} \tag{11}$$

$$\begin{aligned}E_{IVIFS}(B)=\frac{1}{2}\sum_{i=1}^{n}\Big\{&\big[\underline{\mu}_B(x_i)\big]^2+\big[\bar{\mu}_B(x_i)\big]^2+\big[\underline{\nu}_B(x_i)\big]^2\\&+\big[\bar{\nu}_B(x_i)\big]^2+\big[\underline{\pi}_B(x_i)\big]^2+\big[\bar{\pi}_B(x_i)\big]^2\Big\}\end{aligned} \tag{12}$$

Theorem: For an interval intuitionistic fuzzy set A,B on a non-empty domain X, $K_{IVIFS}(A,B)$ has the following properties:

(1) $K_{IVIFS}(A,B)=K_{IVIFS}(B,A)$

(2) $0\le K_{IVIFS}(A,B)\le 1$

(3) $A=B\Leftrightarrow K_{IVIFS}(A,B)=1$

Definition 4: Let the set of alternatives $X=\{X_1,X_2,\ldots,X_n\}$ for a particular research area, the criterion set be $G=\{G_1,G_2,\ldots,G_m\}$ and $U=(u_{ij})_{n\times m}=\left(\langle[\underline{\mu}_{ij},\bar{\mu}_{ij}],[\underline{\nu}_{ij},\bar{\nu}_{ij}],[\underline{\pi}_{ij},\bar{\pi}_{ij}]\rangle\right)_{n\times m}$ is the evaluation matrix containing interval intuitionistic fuzzy information, where u_{ij} is the evaluator's evaluation of the effectiveness of program X_i under criterion G_j. Then $X_p = \left(\langle[\underline{\mu}_{pj}, \overline{\mu}_{pj}],[\underline{\nu}_{pj}, \overline{\nu}_{pj}],[\underline{\pi}_{pj}, \overline{\pi}_{pj}]\rangle\right)$, $X_q = \left(\langle[\underline{\mu}_{qj}, \overline{\mu}_{qj}],[\underline{\nu}_{qj}, \overline{\nu}_{qj}],[\underline{\pi}_{qj}, \overline{\pi}_{qj}]\rangle\right)$ form vectors defined as shown in Eq. (13) with $p,q = 1,2,\ldots,n$ and $j = 1,2,\ldots,m$.

$$
\begin{aligned}
X_p X_q &= \left(\langle|\underline{\mu}_{qj} - \underline{\mu}_{pj}|,|\overline{\mu}_{qj} - \overline{\mu}_{pj}|\rangle, \langle|\underline{\nu}_{qj} - \underline{\nu}_{pj}|,|\overline{\nu}_{qj} - \overline{\nu}_{pj}|\rangle\right. \\
&\quad \left.\langle|\underline{\pi}_{qj} - \underline{\pi}_{pj}|,|\overline{\pi}_{qj} - \overline{\pi}_{pj}|\rangle\right) \\
&= \left(\langle|\underline{\mu}_{qj} - \underline{\mu}_{pj}|,|\overline{\mu}_{qj} - \overline{\mu}_{pj}|\rangle, \langle|\underline{\nu}_{qj} - \underline{\nu}_{pj}|,|\overline{\nu}_{qj} - \overline{\nu}_{pj}|\rangle,\right. \\
&\quad \left.\langle 1-(\overline{\mu}_{qj} - \overline{\mu}_{pj})-(\overline{\nu}_{qj} - \overline{\nu}_{pj}), 1-(\underline{\mu}_{qj} - \underline{\mu}_{pj})-(\underline{\nu}_{qj} - \underline{\nu}_{pj})\rangle\right)
\end{aligned}
\tag{13}
$$

Definition 5: Let the interval intuitionistic fuzzy ideal program $X^+ = \left(\langle[\underline{\mu}_j^+, \overline{\mu}_j^+],[\underline{\nu}_j^+, \overline{\nu}_j^+],[\underline{\pi}_j^+, \overline{\pi}_j^+]\rangle\right)$, critical scheme $X^- = \left(\langle[\underline{\mu}_j^-, \overline{\mu}_j^-],[\underline{\nu}_j^-, \overline{\nu}_j^-],[\underline{\pi}_j^-, \overline{\pi}_j^-]\rangle\right)$, scheme X_p, where X^* and X^- are shaped as equations (14) and (15), respectively.

$$
\begin{aligned}
X_j^+ &= \left(\left\langle[\underline{\mu}_j^+, \overline{\mu}_j^+],[\underline{\nu}_j^+, \overline{\nu}_j^+],[\underline{\pi}_j^+, \overline{\pi}_j^+]\right\rangle\right) = \left(\left\langle \max_{1\le i\le n} \underline{\mu}_{ij}, \max_{1\le i\le n} \overline{\mu}_{ij}\right\rangle,\right. \\
&\quad \left.\left\langle \min_{1\le i\le n} \underline{\nu}_{ij}, \min_{1\le i\le n} \overline{\nu}_{ij}\right\rangle \left\langle 1-\max_{1\le i\le n} \overline{\mu}_{ij} - \min_{1\le i\le n} \overline{\nu}_{ij}, 1-\max_{1\le i\le n} \underline{\mu}_{ij} - \min_{1\le i\le n} \underline{\nu}_{ij}\right\rangle\right)
\end{aligned}
\tag{14}
$$

$$
\begin{aligned}
X_j^- &= \left(\left\langle[\underline{\mu}_j^-, \overline{\mu}_j^-],[\underline{\nu}_j^-, \overline{\nu}_j^-],[\underline{\pi}_j^-, \overline{\pi}_j^-]\right\rangle\right) = \left(\left\langle \min_{1\le i\le n} \underline{\mu}_{ij}, \min_{1\le i\le n} \overline{\mu}_{ij}\right\rangle,\right. \\
&\quad \left.\left\langle \max_{1\le i\le n} \underline{\nu}_{ij}, \max_{1\le i\le n} \overline{\nu}_{ij}\right\rangle \left\langle 1-\min_{1\le i\le n} \overline{\mu}_{ij} - \max_{1\le i\le n} \overline{\nu}_{ij}, 1-\min_{1\le i\le n} \underline{\mu}_{ij} - \max_{1\le i\le n} \underline{\nu}_{ij}\right\rangle\right)
\end{aligned}
\tag{15}
$$

Definition 6: Let two interval intuitionistic fuzzy numbers X_p, X_q, then the length of X_p can be defined in the form of Eq. (16) and the projection of X_p on X_q can be defined in the form of Eq. (17).

$$
\left|X_p\right| = \sqrt{E_{IVIFS}(X_p)} \tag{16}
$$

$$
\mathrm{Prj}_{X_q}(X_p) = \left|X_p\right| K_{IVIFS}(X_p, X_q) = \frac{C_{IVIFS}(X_p, X_q)}{\sqrt{E_{IVIFS}(X_q)}} \tag{17}
$$

2.3.2 Fuzzy number intuitionistic fuzzy sets

This paper addresses the issue of comprehensive evaluation of rural governance levels under discussion. The data of the original index matrix $U = (u_{ij})_{n\times m}$ provided is in the form of intuitionistic fuzzy numbers, and its mathematical description is: The set of alternative categories is $X = \{X_1, X_2, \cdots, X_n\}$, the index set is G, the weight of the projection of the vector formed by the negative ideal category and the alternative category onto the vector formed by the positive ideal category and the negative ideal category is $\omega=\{\omega_1,\omega_2,\cdots,\omega_m\}$, and the weight of the projection of the vector formed by the positive ideal category and the negative ideal category onto the vector formed by the alternative category and the positive ideal category is $\rho=\{\rho_1,\rho_2,\cdots,\rho_m\}$. Among them, $\omega_j\in[0,1]$, $\sum_{j=1}^{m}\omega_j=1$, $\rho_j\in[0,1]$, $\sum_{j=1}^{m}\rho_j=1$.

From the above description, it can be seen that solving the problem of calculating the weights of multiple indicators of rural governance level based on fuzzy number intuition fuzzy information mainly lies in (1) the determination of the original matrix information of rural governance level evaluation; (2) the determination of the weight information of the evaluation indicators of rural governance level; (3) the construction of the weight determination model based on the original evaluation matrix determined by the evaluator; and (4) based on the rules of fuzzy number intuition fuzzy number operation (4) Solving the model and determining the evaluation level according to the fuzzy number intuitionistic fuzzy number operation rules.

In practice, the evaluator of rural governance level often has certain expected preferences for each indicator under different levels according to his own subjective preferences, and each level has its objective preference value, in order to obtain reasonable evaluation effect, it is necessary to consider the information of each indicator's weight, so that the smaller the gap between his subjective preference and objective preference value, the better the evaluation effect. In this regard, the fuzzy number intuitionistic fuzzy distance measure is introduced, and its mathematical description is as follows:

Let the domain Y be a non-empty finite set and a fuzzy number intuitionistic fuzzy set on Y be:

$$A=\left\{(y,\tilde{M}(y),\tilde{N}(y))\mid y\in Y\right\} \tag{18}$$

where: $\tilde{M}(y)$ and $\tilde{N}(y)$ are general fuzzy numbers with affiliation degree of $\mu_{\tilde{M}(y)}$ and $\mu_{\tilde{N}(y)}$ respectively on $[0,1]$; $\tilde{M}(y)$ and $\tilde{N}(y)$ denote the degree to which element y in Y belongs to A and does not belong to A respectively; $0\le\sup\tilde{M}(y)+\sup\tilde{N}(y)\le 1$ and $\forall y\in Y$.

If the regular fuzzy structural element E is taken, the structural element representation of a fuzzy number intuitionistic fuzzy set is:

$$A=\left\{(y,f_y(E),g_y(E))\mid y\in Y\right\} \tag{19}$$

where: $\tilde{M}(y)=f_y(E)$ and $\tilde{N}(y)=g_y(E)$; $f_y(x)$ and $g_y(x)$ are both homogeneous monotone functions on $[-1,1]$ to $[0,1]$; according to the definition of fuzzy number intuitionistic fuzzy numbers, it is known that $f_y(E)$ and $g_y(E)$ are positive fuzzy numbers.

Simplifying Eqs. (18) and (19) as $\tilde{\beta}=(\tilde{M}_\beta,\tilde{N}_\beta)$ and $\tilde{\beta}=\{f_\beta(E),g_\beta(E)\}$ respectively, Ω is the set of all fuzzy number set consisting of intuitionistic fuzzy numbers.

If $\tilde{\beta}_1$ and $\tilde{\beta}_2$ are two fuzzy numbers intuitionistic fuzzy numbers, d is a mapping, i.e., $d:\Omega\times\Omega\to R$. If $d(\tilde{\beta}_1,\tilde{\beta}_2)$ satisfies: $d(\tilde{\beta}_1,\tilde{\beta}_2)\ge 0$, $d(\tilde{\beta}_1,\tilde{\beta}_2)=0\Leftrightarrow\tilde{\beta}_1=\tilde{\beta}_2$, $d(\tilde{\beta}_1,\tilde{\beta}_2)=d(\tilde{\beta}_2,\tilde{\beta}_1)$, and if $\tilde{\beta}_3$ is any fuzzy number intuitionistic fuzzy number, and if there is $d(\tilde{\beta}_1,\tilde{\beta}_3) \le d(\tilde{\beta}_1,\tilde{\beta}_2)+d(\tilde{\beta}_2,\tilde{\beta}_3)$, then $d(\tilde{\beta}_1,\tilde{\beta}_2)$ is the distance between fuzzy number intuitionistic fuzzy numbers $\tilde{\beta}_1$ and $\tilde{\beta}_2$.

2.3.3 Fuzzy integrated evaluation

The fuzzy evaluation method is a method dedicated to describing and dealing with fuzzy problems based on fuzzy mathematics. The fuzzy comprehensive evaluation method is mainly to establish a fuzzy comprehensive evaluation model based on each evaluation factor of the fuzzy problem, the evaluation criteria, the state of nature, and the relative importance of each factor, and then carry out a comprehensive evaluation of each evaluated object.

The main elements of the fuzzy comprehensive evaluation method are:

(1) Establishment of factor set and rubric set. As the fuzzy comprehensive judgment is carried out on the basis of hierarchical analysis method, the evaluation indexes of the object have been established according to the hierarchical structure, which can be directly utilized; stipulate the rating of the rubrics, which should be understood as the fuzzy rating, such as: very good, good, average, poor, poor, etc., and these rubrics constitute the rubric set. For example, $V=\{V_1,V_2,V_3,V_4\}$, V_1,V_2,V_3,V_4 represent excellent, good, fair, and poor respectively. V is a collection of rubrics.

(2) Single-factor fuzzy evaluation. Single-factor evaluation judges the degree of affiliation of a factor to each rubric level based only on the factor being evaluated. When single-factor fuzzy evaluation is carried out, it is often started from the bottom of the hierarchy, and all the sub-factors under each factor are evaluated one by one for their affiliation to the rubrics, and a single-factor fuzzy evaluation matrix is obtained.

(3) Fuzzy comprehensive judgment. The single-factor fuzzy judgment only reflects the influence of a single factor on the evaluation object. Fuzzy comprehensive judgment is to consider the impact of all factors on the evaluation object and arrive at a scientific evaluation result. The specific approach is to deal with the single-factor fuzzy judgment matrix with the fuzzy comprehensive evaluation operator.

The basic model of fuzzy comprehensive evaluation is

$$B = A \circ R \tag{20}$$

In the formula:

A - fuzzy weight vector, the

R - comprehensive judgment matrix.

B - fuzzy synthesized evaluation result vector.

"$\circ$" - fuzzy synthesis operator.

The specific steps are:

(1) Establish factor set valence $U=\{u_1,u_2,\cdots,u_n\}$, and establish judgment set $V=\{v_1,v_2,\cdots,v_m\}$.

(2) Establish the fuzzy weight vector A of n evaluation factors.

$$A=\left(a_1,a_2,\cdots,a_n\right)\sum_{i=1}^{n} a_i = 1 \tag{21}$$

(3) Establish a comprehensive judgment matrix.

For each evaluation object, a comprehensive judgment matrix R is established.

$$R=\begin{bmatrix}R_1\\R_2\\\cdots\\R_n\end{bmatrix}=\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1m}\\r_{21}&r_{22}&\cdots&r_{2m}\\\cdots&\cdots&\cdots&\cdots\\r_{n1}&r_{n2}&\cdots&r_{nm}\end{bmatrix}\tag{22}$$

r_{ij} denotes the frequency distribution of the i th factor u_i over the j th rubric v_j, which is generally normalized so that it satisfies

$$\sum_{j=1}^{m}r_{ij}=1\tag{23}$$

(4) Compound operation is carried out to get the fuzzy comprehensive judgment results.

From the weight vector A and fuzzy judgment R substituting into the formula (20) to calculate can be obtained

$$B=A\circ R=\left(a_1,a_2,\cdots,a_n\right)\circ\begin{bmatrix}r_{11}&r_{12}&\cdots&r_{1m}\\r_{21}&r_{22}&\cdots&r_{2m}\\\cdots&\cdots&\cdots&\cdots\\r_{n1}&r_{n2}&\cdots&r_{nm}\end{bmatrix}=\left(b_1,b_2,\cdots,b_m\right)\tag{24}$$

B is the comprehensive judgment result set, which is the possible degree of n evaluation levels obtained by the comprehensive judgment of all judgment levels.

(5) Processing of judgment results.

First of all, the principle of maximum affiliation is applied to determine the level of assessment.

Based on the comprehensive judging results B, determine the appraisal grade according to the principle of maximum affiliation.

That is, $\max(b_i)=b_k$, then the appraisal grade is rated as b_k.

Fuzzy comprehensive evaluation method is to apply and absorb the idea of comprehensive evaluation in fuzzy mathematics, comprehensively and reasonably consider all the factors affecting the assessment object, and take the form of calculation under the unified mathematical model to synthesize the assessment results. It is more objective, fair, scientific and accurate, with less subjective influence.

3 Empirical analysis of the level of rural digital governance based on fuzzy comprehensive evaluation

3.1 Establishment of indicator weights based on the entropy weight method

Based on the specific steps of the entropy weighting method of section 2.2 to give weights to the indicators, the weights of each indicator of the constructed rural digital governance level evaluation system are obtained as shown in Table 6.

Table 6: Weight of indicator in the evaluation system for rural digital governance

Primary indicator	Secondary indicator	Information entropy	Information utility	Weight
Digital Party Building Governance 0.156	PB1: Digitalization of Party Building Education	0.933	0.067	42.95%
	PB2: Digitalization of Party Affairs Disclosure	0.949	0.051	32.69%
	PB3: Satisfaction of the Party Building Platform	0.962	0.038	24.36%
Digital Government Affairs Governance 0.224	GA1: Online Government Affairs Processing	0.911	0.089	39.73%
	GA2: Satisfaction of the Government Affairs Platform	0.939	0.061	27.23%
	GA3: Digitalization of Three-Self Management	0.926	0.074	33.04%
Digital Village Governance 0.124	VG1: Digitalization of Village Affairs and Financial Disclosure	0.927	0.073	58.87%
	VG2: Satisfaction of the Village Affairs Platform	0.949	0.051	41.13%
Digital Governance 0.181	DG1: Online Legal Services	0.928	0.072	39.78%
	DG2: Online Legal Publicity	0.936	0.064	35.36%
	DG3: Satisfaction of the Legal Affairs Platform	0.955	0.045	24.86%
Digital Public Security Governance 0.150	PS1: Digital Public Health Governance	0.957	0.043	28.67%
	PS2: Digital Social Security Management	0.953	0.047	31.33%
	PS3: Social Security Security Perception	0.94	0.06	40.00%
Digital Emergency Governance 0.165	EG1: Digital Disaster Monitoring	0.942	0.058	35.15%
	EG2: Digital Disaster Warning	0.949	0.051	30.91%
	EG3: Digital Emergency Security Perception	0.944	0.056	33.94%

In terms of the first-level indicators, digital government governance has the highest weight of 0.224, reflecting the fact that the onlineization of government services, the platform experience and the management of the three capitals provide clear distinguishing information in the current practice of digital governance in the countryside, which is the key to measuring the level of governance. This is consistent with the fact that digital governance also scores the highest in the harmonization coefficient obtained from the expert correspondence results in Table 3. The digital rule of law and digital emergency governance weights are 0.181 and 0.165, respectively, highlighting the role of legal services and emergency management capacity as pillars in village governance.

In the secondary indicators, the distribution of weights for each dimension reveals different focuses of attention. In digital party building, the weight of digitization of party building education is much higher than that of platform satisfaction, which is 42.95% and 24.36% respectively. The utility value of online government affairs is the most prominent, with a utility value of 0.089 and a weight of 39.73% in digital government affairs, emphasizing the importance of the office function itself. The new indicator VG1: digitalization of village financial disclosure, proposed by the experts, has a weight of 58.87%, indicating that financial transparency is the most sensitive part of the current construction of digital village affairs, and also the part with the greatest difference in the level of development of villages, highlighting the prior nature of the indicators developed by the experts.

3.2 Comprehensive evaluation of the level of rural digital governance in village A based on fuzzy evaluation

3.2.1 Evaluation results of indicators for villagers

Village A is selected as the research object, and 316 residents of Village A are invited to participate in the evaluation, based on the method of fuzzy comprehensive evaluation in section 2.3, and the fuzzy judgment matrix of secondary indicators is constructed based on the evaluation standard set of V={excellent, good, medium, poor}={4, 3, 2, 1}. The villagers' evaluation results obtained are shown in Table 7.

Table 7: Villagers' evaluation results

Primary indicator	Secondary indicator	Excellent	Good	Generally	Poor
Digital Party Building Governance	PB1: Digitalization of Party Building Education	71	107	118	20
	PB2: Digitalization of Party Affairs Disclosure	90	170	41	15
	PB3: Satisfaction of the Party Building Platform	111	137	54	14
Digital Government Affairs Governance	GA1: Online Government Affairs Processing	44	80	143	49
	GA2: Satisfaction of the Government Affairs Platform	32	68	140	76
	GA3: Digitalization of Three-Self Management	49	83	148	36
Digital Village Governance	VG1: Digitalization of Village Affairs and Financial Disclosure	65	115	115	21
	VG2: Satisfaction of the Village Affairs Platform	53	133	99	31
Digital Governance	DG1: Online Legal Services	53	104	133	26
	DG2: Online Legal Publicity	89	170	45	12
	DG3: Satisfaction of the Legal Affairs Platform	76	154	70	16
Digital Public Security Governance	PS1: Digital Public Health Governance	53	85	133	45
	PS2: Digital Social Security Management	49	107	123	37
	PS3: Social Security Security Perception	112	120	70	14
Digital Emergency Governance	EG1: Digital Disaster Monitoring	134	118	45	19
	EG2: Digital Disaster Warning	156	104	42	14
	EG3: Digital Emergency Security Perception	112	102	77	25

This yields a composite score from villagers for each of the secondary evaluation indicators

Digital Party Governance:

PB1=(71*4+107*3+118*2+20*1)/316=2.7247

PB2=(90*4+170*3+41*2+15*1)/316=3.0595

PB3=(111*4+137*3+54*2+14*1)/316=3.0918

From Table 6, we can see that the second level of weights of digital party governance PB1:PB2:PB3=42.95%:32.69%:24.36%

Composite score = (2.7247*0.4295)+(3.0595*0.3269)+(3.0918*0.2436)=2.9230

Digital government governance:

GA1=(44*4+80*3+143*2+49*1)/316=2.3766

GA2=(32*4+68*3+140*2+76*1)/316=2.1772

GA3=(49*4+83*3+148*2+36*1)/316=2.4589

Secondary weights GA1:GA2:GA3:=39.73%:27.23%:33.04%

Composite score = (2.3766*0.3973)+(2.1772*0.2723)+(2.4589*0.3304)=2.3496

Digital village governance:

VG1=(65*4+115*3+115*2+21*1)/316=2.7089

VG2=(53*4+133*3+99*2+31*1)/316=2.6582

Secondary weights VG1:VG2=58.87%:41.13%

Composite score = (2.7089*0.5887)+(2.6582*0.4113)=2.6880

Digital Rule of Law:

DG1=(53*4+104*3+133*2+26*1)/316=2.5823

DG2=(89*4+170*3+45*2+12*1)/316=3.0633

DG3=(76*4+154*3+70*2+16*1)/316=2.9177

Secondary weights DG1:DG2:DG3=39.78%:35.36%:24.86%

Composite score = (2.5823*0.3978)+(3.0633*0.3536)+(2.9177*0.2486)=2.8350

Digital Public Safety:

PS1=(53*4+85*3+133*2+45*1)/316=2.4620

PS2=(49*4+107*3+123*2+37*1)/316=2.5316

PS3=(112*4+120*3+70*2+14*1)/316=3.0443

Secondary weights PS1:PS2:PS3=8.67%:31.33%:40.00%

Composite score = (2.4620*0.2867)+(2.5316*0.3133)+(3.0443*0.4000)=2.7162

Digital Emergency Governance:

EG1=(134*4+118*3+45*2+19*1)/316=3.1614

EG2=(156*4+104*3+42*2+14*1)/316=3.2722

EG3=(112*4+102*3+77*2+25*1)/316=2.9525

Secondary weights EG1:EG2:EG3=35.15%:30.91%:33.94%

Composite score = (3.1614*0.3515)+(3.2722*0.3091)+(2.9525*0.3394)=3.1240

3.2.2 Comprehensive evaluation score of village digital governance in village A

The overall evaluation score of digital governance in village A is shown in Table 8.

Table 8: The comprehensive evaluation score of rural digital governance in Village A

Primary Indicator	Score	Secondary Indicator	Score
Digital Party Building Governance	2.9230	PB1: Digitalization of Party Building Education	2.7247
		PB2: Digitalization of Party Affairs Disclosure	3.0595
		PB3: Satisfaction of the Party Building Platform	3.0918
Digital Government Affairs Governance	2.3496	GA1: Online Government Affairs Processing	3.0918
		GA2: Satisfaction of the Government Affairs Platform	2.1772
		GA3: Digitalization of Three-Self Management	2.4589
Digital Village Governance	2.6880	VG1: Digitalization of Village Affairs and Financial Disclosure	2.7089
		VG2: Satisfaction of the Village Affairs Platform	2.6582
Digital Governance	2.8350	DG1: Online Legal Services	2.5823
		DG2: Online Legal Publicity	3.0633
		DG3: Satisfaction of the Legal Affairs Platform	2.9177
Digital Public Security Governance	2.7162	PS1: Digital Public Health Governance	2.4620
		PS2: Digital Social Security Management	2.5316
		PS3: Social Security Security Perception	3.0443
Digital Emergency Governance	3.1240	EG1: Digital Disaster Monitoring	3.1614
		EG2: Digital Disaster Warning	3.2722
		EG3: Digital Emergency Security Perception	2.9525

From the final score in Table 8, it can be seen that the development of rural digital governance in Village A is not leading and is not balanced, according to the weight distribution of the six dimensions 0.156: 0.224: 0.124: 0.181: 0.15: 0.165, resulting in the final Village A rural digital governance score of 2.752, which is in the middle level. Specifically, the best performance is in digital emergency governance, with a composite score of 3.124, which is “good”. Under the disaster early warning and monitoring digital score of 3.161 and 3.272, respectively, indicating that Village A in the use of scientific and technological means of disaster prevention and mitigation of good results, so that the villagers feel the real digital guardianship. In contrast, A village government governance is slightly behind, the score is 2.35, especially the satisfaction of the government platform, the score is as low as 2.18, indicating that the online process is cumbersome, the user experience is poor, and has become the villagers spit the hardest-hit area, which is the most urgent need to solve the current pain points.

Through fuzzy evaluation analysis we learn that A village has advantages in hardcore areas such as emergency management, but also exposes its government services as a short board. Future governance optimization must focus on overcoming the difficulties of government services while consolidating the advantages.

3.3 Layer-by-Layer Analysis of Rural Digital Governance in Village A

In order to show more clearly the level of village digital governance in each dimension of Village A, 30 experts in the above mentioned village governance fields were invited to rate each of its dimensions, analyze the problems in the actual village digital governance of Village A and give corresponding solutions.

3.3.1 Digital party governance

The experts' ratings of the digital party governance aspects of Village A are shown in Figure 3.

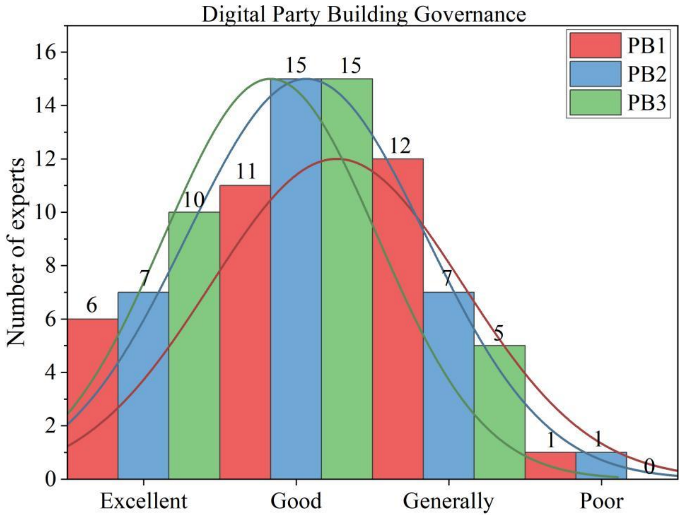

Figure 3: Expert evaluation of digital party building governance in Village A

Village A's digital party building governance performed well, with high ratings from experts, and was also one of the areas where villagers had a better perception, with a composite score of 2.923. PB3: Satisfaction with the party building platform received the most recognition, with 25 out of 30 experts giving it either “excellent” or “good”. It is consistent with the high recognition of 78.5% of villagers in Table 7. It shows that the online publicity and platform services of party building work in Village A are recognized by most expert villagers. However, PB1: the digitalization of party building education is slightly inferior, with 12 experts and villagers evaluating it as “medium” only, while the proportion of villagers with “medium” evaluation is as high as 37.3%, indicating that there is still room for improvement of digitalized party building education in terms of content and form.

3.3.2 Digital governance

The ratings of the various experts in digital government governance are shown in Figure 4.

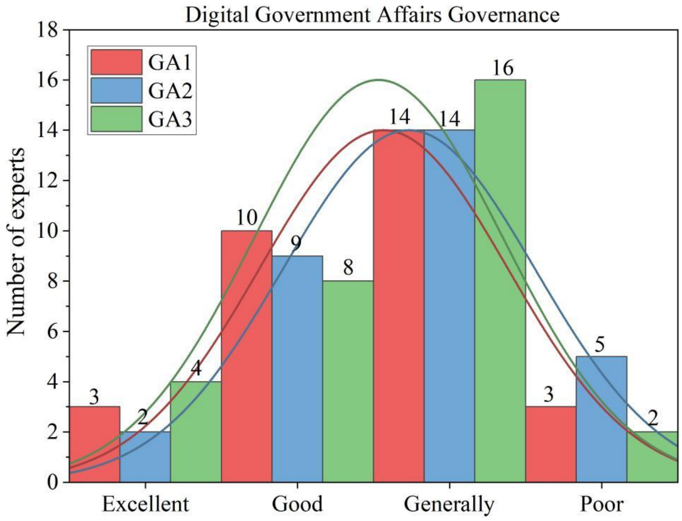

Figure 4: Expert evaluation of digital government affairs governance in Village A

This dimension is the weakest among the six dimensions, exposing the core pain points of online government services in Village A. GA2: Satisfaction with the government platform and GA1: Online processing of government affairs received the fewest number of “excellent” ratings in the expert evaluations, with only two and three, and the number of “moderate” ratings was 14, resonating with the high rate of 24.1% poor ratings and over 44% moderate ratings in the villagers' evaluations. The number of “excellent” ratings is only 2 and 3, and the number of “moderate” ratings is 14, which resonates with the 24.1% poor rating and more than 44% moderate rating in the villagers' evaluation. This shows that both from the professional perspective and the actual perception of the villagers, there are systematic problems in the online government services of Village A. For example, the online process is complicated, inconvenient or inefficient, resulting in a poor user experience, which enhances the direction of the future digitalization reform in Village A.

3.3.3 Digital village governance

The expert scores for digital village governance are shown in Figure 5.

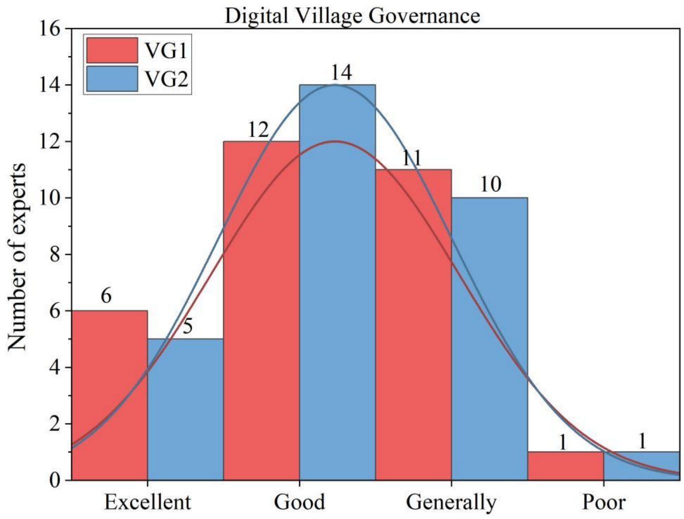

Figure 5: Expert evaluation of digital village governance in Village A

The performance of Village A in the dimension of digital village affairs governance is acceptable, with a comprehensive score of 2.688. Experts' evaluation of this is biased towards affirmation but leaves room for maneuver. Regarding the newly added "VG1: Digitalization of Village Affairs and Financial Transparency" proposed by experts, 18 people gave it an "excellent" or "good" evaluation, with only 1 giving it a "poor" one. This is in line with the 56.9% positive review rate among villagers. The construction of financial transparency has achieved certain results and has received dual recognition from both professionals and public opinion. However, experts still gave the VG2 village affairs platform a "medium" rating of 10, indicating that they believe there is still room for improvement in the platform's comprehensive functions and interactivity. This is in line with the dissatisfaction revealed by the nearly 10% negative review rate among villagers. It is noted that the integration of services on the village affairs platform still needs improvement.

3.3.4 Digital rule of law

Figure 6 shows the distribution of experts' ratings of the digital rule of law in village A.

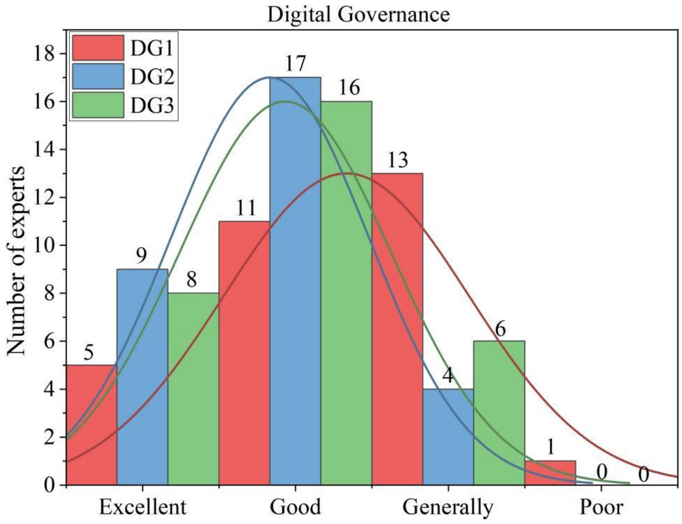

Figure 6: Expert evaluation of digital governance in Village A

The overall performance of digital public safety governance in Village A is generally good but internally uneven, with a composite score of 2.835. The expert evaluation clearly reveals the gap between advocacy and service delivery. DG2: The online legal publicity performance was extremely outstanding. 26 experts gave it an "excellent" or "good" rating, with no "bad" reviews. This was highly consistent with the villagers' 81.9% approval rate, and the legal education work was deeply rooted in people's hearts. However, the 13 “medium” ratings in the expert evaluation of DG1 online legal services accurately correspond to the 42.1% “medium” rating in the villagers' evaluation. This reflects that the online effect of practical services such as legal counseling and legal aid is not obvious. Transforming the effectiveness of legal literacy publicity into practical online legal advice and assistance services is the key to the next step.

3.3.5 Digital public security governance

Figure 7 illustrates the experts' ratings of Village A's digital public safety governance aspects.

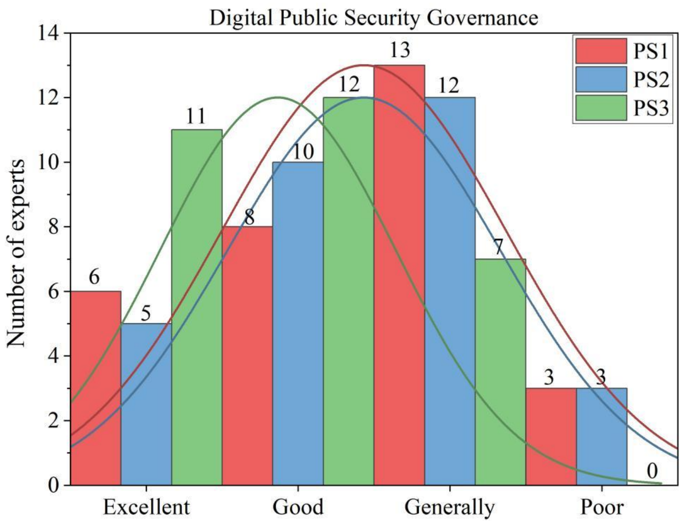

Figure 7: Expert evaluation of digital public security governance in Village A

As the digital governance dimension most recognized by villagers, experts also give it a relatively high score. However, further analysis reveals that digital public security governance presents a characteristic where a sense of security is higher than a sense of governance. The PS3 social security sense received an "excellent" evaluation from 23 experts, with no "bad" reviews. This is the same as the 73.4% positive review rate from villagers, affirming the security of the social security situation at the result level. However, for the process of achieving this result - PS1 digital public health governance and PS2 digital social security management, the number of "medium" evaluations (13 people and 12 people respectively) and "poor" evaluations (both 3 people) by experts has significantly increased. From a professional perspective, behind maintaining a high level of security, its digital governance methods and daily management measures have not fully gained recognition. The process of digital public security management and services provided by the government still needs to be highlighted.

3.3.6 Digital emergency governance

The ratings of each expert for the digital emergency governance dimension in Village A are shown in Figure 8, respectively.

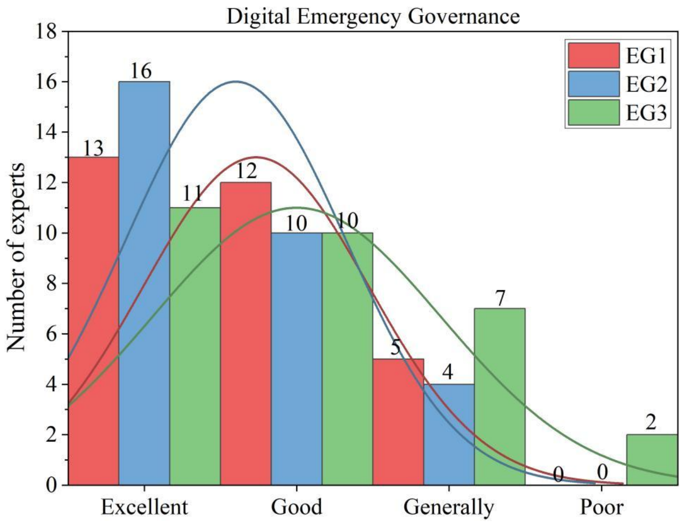

Figure 8: Expert evaluation of digital emergency governance in Village A

The expert evaluation highly affirms the emergency digitalization construction of Village A, especially the digitization of EG2 disaster early warning, which receives “excellent” and “good” from 26 experts, which coincides with the 82.3% favorable rate of the villagers in Table 7, indicating that Village A has invested a lot in the use of digital technology for prospective monitoring and early warning of disasters. This shows that Village A has invested a lot in the prospective monitoring and early warning of disasters using digital technology with good results, winning the trust and recognition of villagers and experts. At the EG3 digital emergency security level, there were two “poor” ratings and seven “moderate” ratings in the expert evaluations, which is consistent with the relatively low scores for this item in the villagers' evaluations. This indicates that there is a gap between the hardware construction of early warning and monitoring and the villagers' subjective sense of security. How to fully translate the technological advantages into a sense of stable psychological security for the residents is an area that needs attention and can be further advanced in terms of emergency drills and knowledge dissemination.

4 Conclusion

The “entropy weight-fuzzy synthesis” evaluation model constructed in the study proved to be an effective diagnostic tool. The fuzzy feelings of 316 villagers and the professional judgment of 30 experts were integrated to reach a credible conclusion. The weights of the indicators revealed by the entropy weighting method indicate the real influence of each governance dimension. With a weight of 0.224, digital government governance becomes an absolute factor affecting the whole situation, while its low performance (score of only 2.35) directly pulls down the overall level of digital governance in Village A.

The most central finding of this assessment is to reveal the long and shortcomings of Village A's governance structure. Digital emergency governance is undoubtedly the best performer, with a combined score of 3.272 for disaster warning digitization and 3.161 for monitoring digitization, constituting a safe and reliable barrier for the village. However, digital government as the first line of service to the public is the biggest loophole. The satisfaction of the government platform has the lowest score among all 17 secondary indicators, only 2.177, which is a concentrated reflection of the poor user experience of the 316 villagers.

This study points out the direction of attack for the digitalization of Village A and even similar villages. Future work should focus on advantageous resources, prioritize the attack on the core pain point of poor user experience of digital governance, while upgrading the medium level of party building education and legal services to excellent, and strive to make the excellent hardware capacity of digital governance transform into the soft trust that villagers can know and feel in all aspects.

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