Research and Application of Rural Revitalization Power Index Evaluation Model Construction Based on Big Data Analysis

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Abstract: Through the interpretation of policies related to rural revitalization, combined with existing electricity data, the rural revitalization power index evaluation system was constructed. The evaluation index index weight is calculated based on massive power data and principal component analysis method to obtain the rural revitalization power index evaluation model. Based on the calculated evaluation model,a rural revitalization power index evaluation platform is designed and developed, which is used to quantitatively evaluate rural development in multiple dimensions and reflect the effectiveness of power advance work , and provide decision support for power supply companies and governments to implement rural revitalization strategies.

Keywords: Rural Revitalization Evaluation Index; Electric Power Big Data; Principal Component Analysis Algorithm; Rural Development Level

1 Introduction

The issues of agriculture, rural areas and farmers are fundamental issues related to the national economy and people's livelihood, and rural revitalization is an important starting point to solve the "three rural" issues. Rural revitalization is the result of the coordinated evolution and interaction of multiple factors [1-3]. In recent years, some scholars in my country have begun to pay attention to the evaluation issues in the field of rural revitalization [4-9]. In terms of the construction of the index system, most studies take the five dimensions of the general requirements of "prosperous industry, livable ecology, civilized rural customs, effective governance, and prosperous life" as the first-level indicators for the evaluation of rural revitalization strategies. In terms of the selection of indicators, each has its own emphasis, and an indicator evaluation system is constructed from the dimensions of economy, politics, society, culture, ecology, etc. [8-13]. However, many evaluation systems have a relatively subjective evaluation mechanism, and lack of accurate big data, objective, fair and reasonable evaluation system to quantify the situation of rural revitalization.

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As an important guarantee for people's livelihood, electricity is an important means of production and living for the people. In rural areas, electricity is the most indispensable source of energy for the people. To develop rural areas, electricity must go first. At the same time, with the construction of the information system of power companies and the accumulation of a large number of user data, the power big data can objectively evaluate the affluent level of rural people's living and production and the level of rural development. Based on the big data of electric power, this paper takes multi-dimensional consideration, rational quantification, and objective evaluation of the level of rural revitalization from the electricity consumption of the people in production and life, quantitatively reflects the effectiveness of rural revitalization work, finds the strengths and weaknesses of rural revitalization, and comprehensively supports power companies and local governments in rural areas. Revitalize decision making and implementation.

2 Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate statistical method, and it is one of the most commonly used dimensionality reduction methods. It transforms a set of variable data with possible correlations into a set of linearly uncorrelated variable data through orthogonal transformation, and the transformed variables are called principal components. In this paper, the principal component analysis algorithm is used to carry out the index weight analysis corresponding to the rural revitalization power index, starting from the relationship between multiple indexes, using the idea of dimensionality reduction, and transforming multiple variables into a few uncorrelated comprehensive variables [9-11].

2.1 Extract standardized data

Standardized data matrix

$$R(m\times n)=\begin{bmatrix} r_{11} & r_{1j} & r_{1n} \\ r_{21} & r_{2j} & r_{2n} \\ r_{m1} & r_{mj} & r_{mn} \end{bmatrix}_{m\times n} \quad (1)$$

is a m×n matrix, where m is equal to the data volume of rural areas in the province in 4 years, n=4 represents the number of secondary indicators, and the matrix has the following attributes:

$$r_{ij} \in [0,1]\ ;1\leq i\leq n\ ;1\leq j\leq m \quad (2)$$

2.2 Characteristic Index Loading Analysis

Apply principal component analysis to calculate the loading matrix C(n×n) between each feature

2.3 Feature Index Contribution Analysis

Calculate the contribution rate of each principal component based on the load matrix:

$$P_i = \lambda_i / \sum_{i=1}^{n} \lambda_i \times 100 \quad (3)$$

where λ_i represents the i-th principal component eigenvalue.

2.4 Feature index weight analysis.

First, calculate the importance of each indicator:

$$v_i = \sum_{j=1}^{n} P_j \times c_{ij} \tag{4}$$

Second, calculate the indicator weights:

W(n), where $w_i = v_i / \sum_{i=1}^{n} v_i$.

3 Research on Model Construction of Power Index System for Rural Revitalization

3.1 System construction and definition:

3.1.1 System construction

By interpreting relevant policy documents such as "Strategic Plan for Rural Revitalization (2018-2022)"[12], "State Grid Corporation's Opinions on Serving the Rural Revitalization Strategy and Vigorously Promoting Rural Electrification"[13], it is possible to improve the efficiency of the rural revitalization from the perspective of electricity. Effective evaluation of five aspects in rural revitalization, "industrial prosperity, ecological livability, rural culture, effective governance, and affluent life", provides the government with decision-making in strengthening poverty return monitoring, coordinating urban and rural development, building beautiful countryside, and integrating rural industries. For reference, see Table 1 for details:

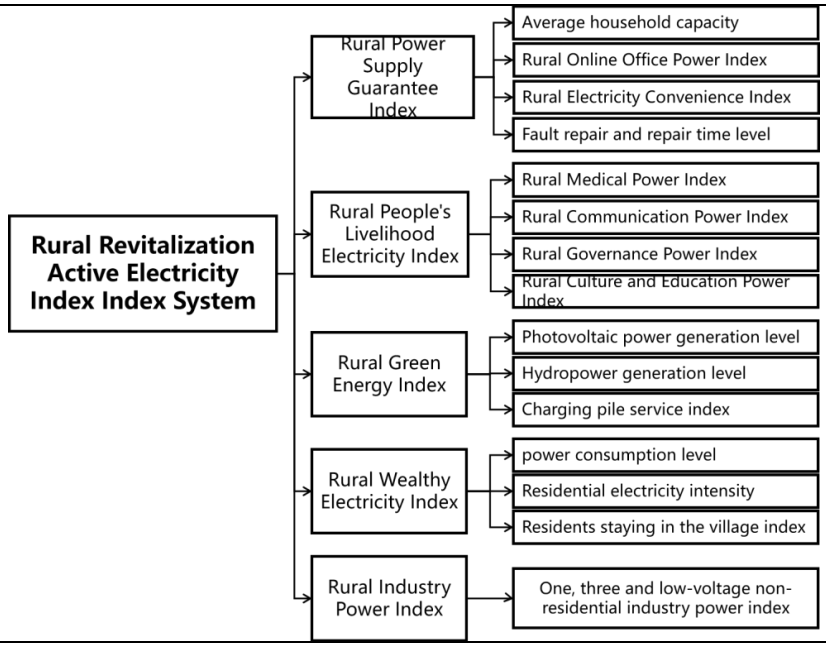

Figure 1. Rural Revitalization Power Index System.

3.1.2 Definition of evaluation indicators

By sorting out the current data types, the specific corresponding data content and calculation method of each evaluation index are proposed. The results are shown in Table 1.

Table 1. Definition of each evaluation index.

Name	Definition
Average household capacity	Average household capacity level = unit average household capacity in the current month / unit average household capacity in the same period in 2017
Fault repair and repair time level	Repair time ratio = 1 - average failure repair repair time in each village of the unit / average failure repair repair time in all villages in the province;
Rural Online electricity handling rate	Online electricity handling rate = unit online electricity handling rate in the current month / unit online electricity handling rate during the same period in 2017
Rural electricity convenience Index	Rural electricity convenience index = low-voltage residential industry expansion time up to standard rate * 0.5 + low-voltage non-residential industry expansion time * 0.5 (1) The standard rate of expansion time of low-voltage residential industry = 1- average duration of low-voltage residential industry expansion in the village/average connection time of low-voltage residential industry expansion in the whole province (2) Low-voltage non-residential industry expansion time-to-standard rate = 1- average duration of low-voltage non-residential industry expansion in the village/average connection time of low-voltage non-residential industry expansion in the province
Industrial power index of primary, tertiary and low-voltage non-residential industries	Electricity Consumption Index of the Month / Electricity Consumption Index of the Same Period in 2017
Rural Medical Power Index	Electricity consumption per household in medical-related industries in each village in the current month / Electricity consumption per household in medical-related industries in each village in the same period in 2017
Rural Communication Power Index	The average electricity consumption of communication base station households in each village in the current month/The average electricity consumption of communication base station households in each village in the same period in 2017
Rural Governance Power Index	Electricity consumption per household in village management-related industries in the current month / Electricity consumption per household in village management-related industries in the same period in 2017
Rural Culture and Education Power Index	Electricity consumption per household in cultural and educational related industries in each village in the current month / Electricity consumption per household in cultural and educational related industries in each village in the same period in 2017

Photovoltaic power generation level	PV power generation of each village in the month / PV power generation of each village in the same period in 2017
Hydropower level	Hydroelectric power generation of each village in the current month/Hydroelectric power generation of each village in the same period in 2017
Charging pile service index	Charging pile service index = electricity consumption of charging piles in each village in the current month/electricity consumption of charging piles in each village in the same period in 2017*0.5+number of charging piles in each village in the current month/number of charging piles in each village in the same period in 2017*0.5
Electricity consumption level	min(electricity in the current month/electricity consumption in the same period in 2017,2)*70%+min(number of users in the current month/number of users in the same period in 2017,2)*30%
Residential electricity intensity	Residential electricity intensity = electricity consumption ratio of the current month / electricity consumption ratio of the same period in 2017;
Residents staying in the village index	Resident occupancy rate = current month's resident users / current month's total number of users * 100%; Rural resident mobility = current month resident occupancy rate / 2017 resident occupancy rate in the same period;

3.2 Evaluation Index Weight Calculation Based on Principal Component Analysis:

3.2.1 Data acquisition and preprocessing

3.2.1.1 Data acquisition

The original data of the rural revitalization power index index system model mainly comes from the power consumption information, power generation information, customer basic information, business information and other power-related data of the marketing system, 95598 system, service dispatch platform system and power consumption information collection system. See the table for details. 2 shown

Table 2. The original data source of the index system model of rural revitalization power index system

Number	Data Item	Data Type	Data Dimension	Data Source
1	Monthly electricity consumption	Electricity Information	Regional dimension: province, city, county, town, village; Time dimension: month; Industry dimension: primary industry, tertiary industry, low-voltage non-residential; medical treatment, communication, culture and education, governance; electric vehicle charging pile related industries	Marketing system
2	Daily electricity consumption	Electricity Information	Regional dimension: province, city, county, town, village; Time dimension: day;	Adoption system

			Industry dimension: primary industry, tertiary industry, low-voltage non-residential	
3	Electricity running capacity	Basic customer information	Regional dimension: province, city, county, town, village; Time dimension: month; Industry dimension: primary industry, tertiary industry, low-voltage non-residential	Marketing system
4	Number of electricity users	Basic customer information	Regional dimension: province, city, county, town, village; Time dimension: month; Industry dimension: primary industry, tertiary industry, low-voltage non-residential	Marketing system
5	Troubleshooting time	business information	Regional dimension: province, city, county, town, village; Time dimension: month;	95598 system
6	Online service rate	business information	Regional dimension: province, city, county, town, village; Time dimension: month;	Service scheduling platform
7	Industry expansion package market	business information	Regional dimension: province, city, county, town, village; Time dimension: month;	Marketing system
8	power generation	Power Generation Information	Regional dimension: province, city, county, town, village; Time dimension: month; Type dimension: photovoltaic, hydraulic;	Marketing system
9	Number of charging piles	business information	Regional dimension: province, city, county, town, village; Time dimension: month;	Marketing system

According to 11 basic characteristic indicators such as average household capacity, repair time ratio, online power service rate, rural power convenience index, rural medical power index, etc. Electricity consumption time, total capacity of users, total number of users, online electricity service rate of the unit in the current month, electricity consumption per household in medical-related industries in each village in the unit, electricity consumption per household in communication base stations in each village in the unit in the current month, and electricity consumption in each village in the current month by the unit The basic data such as the electricity consumption of the charging piles, a total of 118343 lines × 40 dimensions are obtained.

3.2.1.2 Data preprocessing

This part mainly describes the basic data quality, including found data quality problems, verification rules, processing principles, processing results, etc. After eliminating the completely repeated fields, it is found that the main problem is the average fault repair time of each village of the unit. The reason is that there are input errors when the repair personnel enter the system data, as follows:

(1) The completion time of emergency repair is greater than the current time of the system, resulting in excessive repair time. The processing method is to remove this part of the data, as shown in Table 3

Table 3. Abnormal data of fault repair time (excerpt).

VILLAGE_CODE	Cos_no	Minute
00039658	'0002561514'	'8833.55'
00086560	'0002561530'	'8841.38'
00053442	'0002581659'	'8906.53'
00063569	'0002581952'	'9035.72'
00045390	'0002582102'	'9041.25'
…	…	…

(2) When entering data, since the completion time of emergency repair is less than the current time of the system, the emergency repair time is negative, and the processing method is to exclude this part of the data, as shown in Table 4.

Table 4. Abnormal data of fault repair time (excerpt).

VILLAGE_CODE	Cos_no	Minute
00054243	'8730149097'	'-26568455.87'
00039658	'8730149098'	'-44459.67'
00086560	'8730149100'	'-44625.02'
00053442	'8730149101'	'-460.07'
00206446	'8730149102'	'-5.07'
…	…	…

(3) Perform data conversion processing on the basic data exported by the system to form secondary indicators. The specific results are shown in Table 5:

Table 5. Conversion results of secondary indicators of rural power supply security index (excerpt).

Number	Date	VILLAGE_CODE	Village_Name	Average household capacity	Fault repair and repair time level	Rural Online electricity handling Index
1	202104	00146906	Xiachen	187.3	145.2	187.9
2	202104	00039841	Wushidu	120.78	174.3	150
3	202104	00147287	Yanxi	119.71	134.6	150
4	202104	00146981	Fantianzhu	104.81	0	66.67
5	202104	00039588	Anren	158.16	0	82.83
6	202104	00042597	Zhouxiang	146.5	143.2	173.2
7	202104	00042622	Jiulong	116.67	137.5	145.2
…	…	…	…	…	…	…

In the same way, the conversion results of secondary rating indicators of indicators such as rural livelihood power index, rural green energy index, and rural affluent power index can be obtained through conversion.

In order to maximize the extraction of features from the raw data for use by algorithms and models, this section transforms the raw data as follows:

In order to determine the relative importance (weight) of a single index, make the rural revitalization electric power index universal and comparable, and keep the change information of the index as much as possible, it is necessary to normalize the results of the index data, so that the results of the index processing are decimal between 0 and 1.

For indicators such as household average capacity level, rural online power supply index and rural power supply convenience index, the larger the better, the pretreatment formula is as follows:

$$r^i = (x^i - x_{\min}) / (x_{\max} - x_{\min}) \tag{5}$$

where, for index X, r^i represents the pretreatment result of the ith rural scoring index value index, x^i represents the ith rural scoring index value, $x_{\max}$ is the maximum value of the provincial rural scoring index, $x_{\min}$ is the minimum value of the provincial rural scoring index.

For indicators such as the smaller the time level of emergency repair, the better, the preprocessing formula is:

$$r^i = (x^i_{\max} - x) / (x_{\max} - x_{\min}) \tag{6}$$

Finally, with the village number (VILLAGE_CODE) in the system as the data primary key, In turn worth capacity level, fault repair repair time online do electric index, rural, rural medical power index such as multi-source data according to rural power supply security, rural people's livelihood power index, village green energy, rural rich power index level 2 rating of indicators such as association, finally obtain 112843 x 15 dimension sample data sets, For subsequent analysis.

3.2.2 Weight calculation based on principal component analysis

The analysis results of principal component analysis are used as the weights of the four second-level indicators under the rural power supply guarantee index. The specific results are shown in Table 6:

Table 6. Abnormal data of fault repair time (excerpt).

First-level indicator	Second-level indicator	Indicator weight
Rural Power Supply Guarantee Index	Average household capacity	19.2%
	Fault repair and repair time level	37.3%
	Rural Online electricity handling Index	28.1%
	Rural Electricity Convenience Index	15.4%

Similarly, the weights of other first- and second-level evaluation indicators of the rural revitalization power index can be calculated as shown in Table 7.

Table 7. Analysis results of the index weight of rural revitalization power index

Name	Primary indicator	Primary weight	Secondary indicator	Secondary weight
Rural Revitalization Power Index	Rural power supply guarantee index Rural Industrial Power Index Rural livelihood electricity index Rural Green Energy Index	17.2%	Average capacity level of household	19.2%
			Level of emergency repair duration	37.3%
			Rural line power index	28.1%
			Index of convenience of running electricity in rural areas	15.4%
	Rural Affluent Electricity Index	18.1%	Industrial power index of primary production, tertiary production and low-voltage non-residential	100%
	Rural power supply guarantee index Rural Industrial Power Index Rural livelihood electricity index Rural Green Energy Index	22.3%	Rural medical Power Index	31.2%
			Rural Communication and Electricity Index	16.6%
			Rural Governance Power Index	41.8%
			Rural culture and Education Power index	10.4%
	Rural Affluent Electricity Index Rural power supply guarantee index Rural Industrial Power Index	15.8%	Photovoltaic power generation level	44.6%
			Hydropower generation level	32.7%
			Charging pile service index	22.7%
	Rural livelihood electricity index	26.6%	Power consumption level	42.1%
			Residential electricity intensity	33.6%
			Index of residents staying in villages	24.3%

Specific calculation results are as follows:

Rural Vitalization Power index =17.2%* Rural power supply guarantee index +18.1%* Rural industrial power index +22.3%* Rural livelihood power index +15.8%* Rural green energy index +26.6%* Rural affluent power Index.

Rural power supply guarantee index =19.2%* average household capacity level +37.3%* emergency repair and repair time level +28.1%* Rural online power supply index +15.4%* Rural power supply convenience index.

Rural industrial Power index =100%* (Industrial power index for primary, tertiary and low-voltage non-residential industries).

Rural livelihood power index =31.2%* Rural medical power index +16.6%* Rural communication power index +41.8%* Rural governance power index +10.4%* rural culture and education power index.

Rural green energy index =44.6%* photovoltaic power generation level +32.7%* rural livelihood power index +22.7%* Charging pile service index.

Rural affluent power index =42.1%* Electricity consumption level +33.6%* Residential electricity intensity +24.3%* residential stay in village index.

4 The application practice

Based on the evaluation model of rural revitalization electric power index obtained in the study, a monitoring platform for rural revitalization electric power index was designed and developed, the comprehensive effect of rural revitalization electric power index was displayed and analyzed, and the development trend of rural revitalization was depicted from the perspective of provinces and cities. At present, the rural revitalization power index has covered all 31,864 administrative villages and 16,565,200 rural electricity users in the province, realizing the evaluation and application of five administrative dimensions from province to village, as well as five directions of industry, prosperity, people's livelihood, power supply and low carbon. At the same time, a good atmosphere for rural revitalization construction has been formed through horizontal comparison with model villages

4.1 Construction of real-time monitoring platform for rural revitalization power index

Figure 2. Rural revitalization power index real-time monitoring platform.

As shown in Figure 2, is the real-time monitoring platform of rural revitalization power index. The platform to give full play to power large data full coverage, high penetrability and high image advantage, through data analysis, to realize rural residents active perception, rural industry business activities all penetrate completely, comprehensive refraction depicting rural revitalization of the development, reflect the country revitalization of the running effect, boost rural areas to repair short, strong industry, promoting development, It will provide powerful quantitative suggestions for the government to carry out precise policy implementation, and support the high-quality development and construction of common prosperity demonstration zone in Zhejiang.

4.2 Comprehensive results have been achieved in the electricity index for rural revitalization

The Rural Revitalization Power index platform can display the level of rural revitalization from five levels, namely, provinces, counties, towns and villages, monitor the current situation of rural revitalization in real time, display the typical features of Zhejiang villages and data such as real-time daily electricity consumption, number of emergency repair of faults, number of online power offices, photovoltaic power generation and cumulative charging pile installation. The results are shown in Figure 2. At present, the calculated rural revitalization power index has been pushed to government departments through the government data big data platform, enriching the application of energy big data services to the government,

providing theoretical basis for power supply enterprises to carry out power construction, operation and maintenance, and providing quantitative suggestions for the government to implement precise policies.

As shown in Figure 3, from the perspective of the whole province, the electric power index of Zhejiang Rural Revitalization increased rapidly from 109.6 in 2018 to 134.3 in 2021. The overall development of Zhejiang rural revitalization has made steady progress, and the rural electricity of the whole province has increased from 79.43 billion KWH to 96.11 billion KWH, an increase of 21%. Among the five sub-indexes, the rural power supply guarantee index rose to 138 in 2020, an increase of 25 points compared with 2018, reflecting a stronger rural power grid in recent years, more convenient power services, and strong power supply guarantee for high-quality rural development. The rural green energy consumption index rose rapidly, reaching 116.4 in 2020, up 11.2 points compared with 2018, reflecting the accelerated transformation of rural energy production and energy consumption to clean, efficient and low-carbon development.

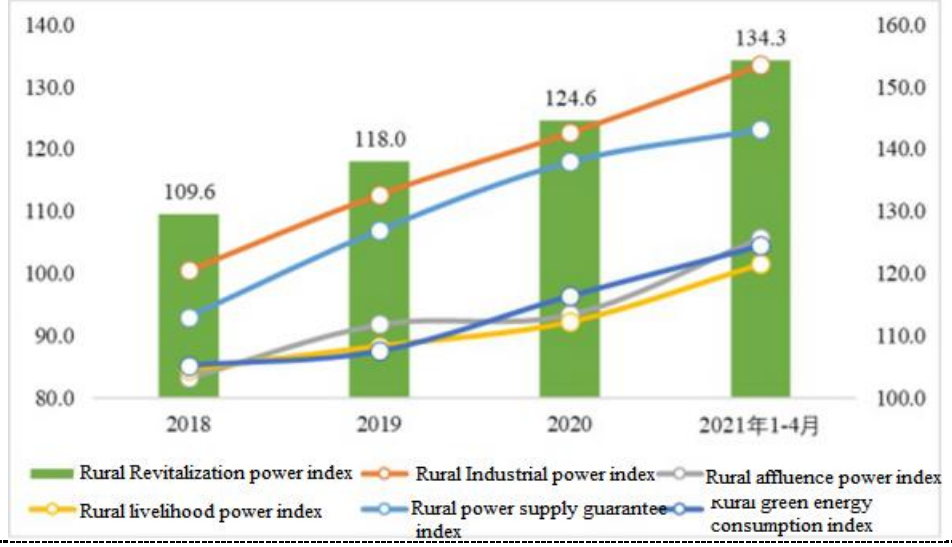

Figure 3. Trend chart of Rural Revitalization Power index in recent three years

5 Conclusion

This paper puts forward the evaluation system of rural revitalization from the perspective of electricity, and designs and researches the rural revitalization platform covering the whole province. The platform objectively reflects the evaluation and application of five aspects: industry, affluence, people's livelihood, power supply and low carbon, and measures the level of rural revitalization from multiple dimensions such as time and region, so as to provide decision-making basis for the government to implement precise policies. Subsequently, by continuously improving the relevant indicator system, increasing data empowerment, deepening the research on rural development trend prediction and poverty return warning, and

constantly upgrading and enriching the rural revitalization electricity index index system. In the future, we will take the electricity data of rural revitalization as the strong support, take the application scenarios of electricity support, electricity environmental protection, electricity rural tourism and other application scenarios as the main construction line, strengthen the cooperation with the government hutong, and assist the government to do a good job in the dynamic assessment and monitoring of rural development.

References

[1] Shanghai Rural Revitalization Index Research Group. (2020) Construction and Evaluation of Shanghai's Rural Revitalization Index System. Scientific development. 2020(09): 56–63.

[2] Guo, X. (2019) Taking the pulse of rural revitalization and development: Theoretical deconstruction, index evaluation and planning strategies——Comment on the Blue Book of China's Rural Revitalization and Development Index (2018). Rural Economy. 2019(08): 143–144.

[3] Wu, J. (2020) The measurement and spatial disparity pattern of provincial rural revitalization index. Journal of Henan University of Technology. 2020, v.36 No.118(01):7-14.

[4] Shen, J., Wang, Y. Zhu, M. et al. (2020) Evaluation index system and empirical analysis of rural revitalization level. Transactions of the Chinese Society of Agricultural Engineering. 36(3): 236–243.

[5] Xu, L. Ma, S. Li, L. (2018) Measurement and spatial correlation pattern of rural development level in China——Based on the perspective of the rural vitalization. Guangdong Agricultural Sciences. 45(09):148-156+179.

[6] Jia, J. Li, X. Shen, Y. (2018) Indicator System Construction and Empirical Analysis for the Strategy of Rural Vitalization. Finance & Economics. No.368(11):76-88.

[7] Tang, D. (2019) Research on Statistical Monitoring System and Evaluation Method of Rural Revitalization Strategy. Urban construction theory research. 000(006): P.185-185.

[8] Wang, L. Zhang, J. Wang, M. et al. (2021) A Case Study of Rural Industry Development in Baoding Against the Background of Rural Revitalization: Current Situation and Suggestions. Journal of Hebei Agricultural University. 23(1): 7.

[9] Wang, K. Zhu, M. (2018) Analysis on the driving forces of upgrading rural infrastructure in Qingdao based on rural revitalization strategy. Chinese Journal of Agricultural Resources and Regional Planning. 039(008):49-53.

[10] Nie, H. Nie, C. Qiao, Y. et al. (2010) Comprehensive Decision-Making of Alternative Transmission Network Planning Based on Principal Component Analysis. Power System Technology. 2010(06): 134–138.

[11] Yin, S. Jin, X. Zhou, Y. (2007) Allocation of Newly-added Quota of Regional Construction Land Based on Principal Components Analysis and AHP-GEM Model —A Case Study of Jiangsu Province. Journal of Natural Resources. 22(003):372-379.

[12] Century Business Herald. (2018) The CPC Central Committee and The State Council issued the Strategic Plan for Rural Revitalization (2018-2022). Urban Planning International. 2018(6):150-150.

[13] Editorial office of this journal. (2019) Serving the strategy of rural revitalization and vigorously promoting rural electrification. Rural Electrification. 2019(5): 1