"Smart Village" Method in Rural Development Research:
Three States in U.S. as an Example

Yaoxun Tang[1,*]

[1] *Ferguson College of Agriculture, Oklahoma State University, Stillwater, 74078, United States of America.*
[*] *Corresponding author. Email: yatang@okstate.edu*

ABSTRACT
Innovation has gradually become a focus of attention in modern times, and plays an important role in the development of the world economy. At the same time, rural development needs attention while urbanization is developing rapidly. Under the theory of sustainable development and innovation, the assessment and analysis of different innovation methods or models of the rural development is a topic worthy of discussion. This paper aims to explore the use of the concept of "Smart Village" mentioned in the guidance literature to measure the innovation potential of rural areas. Meanwhile, by integrating innovation into the rural development, this article analyses relevant variables of different dimensions under the implementation of "Smart Village" in three states in U.S. Finally, this paper discusses the expectation on "Smart Village" in the future's rural economic development, and the importance of this concept and topic under the development background of today's world.

Keywords: *Innovation, Rural development, Sustainability, Smart Village.*

1. INTRODUCTION

In order to cope with many changes brought about by modern economic development, many countries begin to focus on sustainable development. Based on this situation, the concept of innovation is often mentioned in economic development within sustainability theory, which includes not only the innovation of technology and production, but also the proposal of new theories and methods.

After industrial revolutions, the development of cities becomes very rapid. Today, 60% of the world's population lives in cities [1]. The process of urbanization is still taking place in most parts of the world, and urban development is the focus of many regions. The implementation of sustainable development strategy is an important guide for the coordinated development of urban areas. At the same time, colleges, universities and many other research institutions are densely distributed in the city, which provides a good foundation for scientific and technological innovation. Instead, rural areas have always been dominated by agricultural industry. Compared with urban areas, the development degree is backward, the population density is low, and there is a large amount of undeveloped land. However, in the sustainable development, the development of rural areas occupies an important position. According to the statistics of the World Bank, the global rural land area exceeds 110 million square kilometres, almost 30 times the urban land area [2]. It shows that rural areas have great development potential and rich resources that can be developed and utilized.

Innovation in rural areas is a meaningful topic to discuss in rural development. However, the innovation potential of these rural areas has not been paid attention, and its connection and function with sustainable development are unclear.

2. LITERATURE REVIEW

Rural development could be inseparable from the introduction of the theory of sustainable development. The concept of Sustainable Development could date back to last century. According to the United Nations report Our Common Future, sustainable development was defined as development that met the needs of the present without compromising the ability of future generations to meet their own needs. It contained two key concepts, the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be

given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs [3]. Also, there existed a direct relation between rural development and United Nations development agenda nowadays. The United Nations Commission on Sustainable Development (CSD) stated that Rural Development was included as one of the thematic areas along with Agriculture, Land, Drought, Desertification and Africa in the third implementation cycle CSD-16/CSD-17 [4].

Apart from the concept of sustainable development, the proposal and development of innovation economics theories in the past century could be very important in economic development. In the 1942, the economist Joseph Schumpeter firstly introduced and explained innovation economy. According to his theory, the entrepreneur was "the agent of innovation", which introduced new technological processes or products and brings change to the economy [5]. After that, many theories on introducing innovation economics emerged, which greatly developed this field.

With the theory of sustainable development and innovation, many scholars have done some researches and studies. They created relationships among innovation, sustainability theory and rural development, and made contributions to the proposal and development of innovative models or methods in the field of rural development.

Moseley used four specific and typical cases in Britain and Western Europe, and concluded some lessons that others could learn from them, including recognizing and choosing innovations in rural development, factors that swift diffusion and early adoption of innovation, some typical consequences of innovation for development, and the best way for the spread of innovation. Combined with the development status of modern European developed countries, this article discussed the problems related to urban and rural development. In the analysis and research of several cases, it summarized the application of innovation in the development of these areas, and obtained several rules and practices learned from these cases [6]. This provided some possible guidance and suggestions for the development and construction of rural areas in many developed countries, and a reference for the rural development in some developing countries.

Moreover, some new theories or models on rural innovation have been proposed. Yin et al. compared and contrasted the difference between rural and urban development, and then built a new theoretical rural innovation system under innovation and sustainability theories, showing a three-dimensional structural model of the system combined with typical cases. This model, with three aspects of agriculture science & technology innovation, institutional & management innovation, and network & intermediary organization innovation, explained three main directions of innovation in rural development [7]. This contribution did give a new idea and latest theoretical support of how innovation worked in rural sustainable development, providing reference and guiding significance to global rural development. Besides, Knickel et al. discussed in the article the gap between current social needs, relevant farm level adjustments, and innovation institutions and consulting service capabilities, and tried to build a conceptual framework to understand the innovation process as the result of the collaborative network of information exchange and learning process. They also discussed the relevant social and institutional factors and influences across and within sectors, emphasizing that innovation was a process in which the knowledge, motivation and values of farmers and rural entrepreneurs all played an important role. Thus, this article explained a more systematic and comprehensive knowledge and innovation model, which provided better support for innovation in the field of agriculture and rural development [8]. On the whole, these researches and studies gave us some experience of rural development and relevant innovation methodology, providing the evolution of leading innovation of rural sustainable development.

In addition to these new theories or models, there were some problems and threats in rural innovation and sustainable development which were mentioned by some researchers and scholars. Moschitz and Home stated that there was a challenge of up-scaling from local learning and innovation networks to a regional, avoiding support framework under innovation of sustainable agriculture development in Europe [9]. Besides, Yin et al. said that scholars and policy makers have realized the importance of the innovation system to improve the competitiveness of cities and promote economic growth, but they usually lacked attention to how to release the potential of the innovation system for rural revitalization [7].

Combined with the new theories and models mentioned above, as well as some problems existing in the development of rural areas, a suitable method should be applied to the rural sustainable development and to explore and develop the innovation ability of rural areas through this way. A method called "Smart Village" mentioned in the previous research could be an appropriate answer. According to Adamowicz and Zwolińska-Ligaj, the "Smart Village" concept could be explained as "rural areas and rural communities that have built their development strategy on their existing assets and strengths, as well as by pursuing some new opportunities related to new digital technologies, networks and services that support better use of knowledge and innovative solutions for citizens, business and society". They took rural areas throughout Poland as a study case, detected and estimated the index of the potential of smart growth, and stated that the "Smart

Village" concept could be a useful means to "achieve the sustainability and resilience of rural areas" [10].

As a result, this paper explores the use of the concept of "Smart Village" mentioned in the guidance literature to measure the innovation potential of rural areas. Then, some relevant variables of different dimensions are considered under the implementation of "Smart Village" in the given example, providing some possible analysis of different aspects on this method and rural economic development.

3. METHODOLOGY

3.1. Research Design

Applying "Smart Village" method in a different condition, this article takes United States as an example. Due to its various advantages, United States is one of the world's leading agricultural producers and suppliers. In 2019, there were more than 960,000 agricultural employees in the United States [11]. In 2020, the total number of farms in US exceeded 2 million, and there were nearly 896 million acres of farmland in the country [11]. The United States is also a major player in global agricultural trade. In 2020, the national export of agricultural products was about 164 billion US dollars [11]. In the same year, agricultural imports worth about $130.2 billion entered the United States [11].

Therefore, three states in US are selected for measurement. These places should be agriculture-based, or contain large rural areas, which show typical characteristics related to the study. In the United States, agricultural production is particularly concentrated in the central Great Plains and the Great Lakes region in the northeast. Thus, this paper chooses Kansas (KS), Oklahoma (OK) and Texas (TX) states as the research objects.

Then, quantitative method is used in the research, since the need for collecting a set of data and conducting data processing and analysis with statistical and mathematical tools. After that, different kinds of data should be compared and contrasted, and get the result and give conclusion.

3.2. Participants

According to the method in the guide literature, the analysis of innovation potential is the key of this method. Therefore, the innovation potential of each selected place needs to be divided into six dimensions: management, life quality, economy, society, natural environment and mobility. Each dimension has a corresponding weight, and the sum of the weights should be 100.

On this basis, a set of variables also need to be established to describe the situation of rural areas under each dimension. Similarly, several variables below each dimension have corresponding weights, and the sum of these weights should be 100 as well.

Different variables, X_{ij}, under 6 dimensions of the "Smart Village" idea are shown in Table 1, which are numbered with the order of dimensions and the order of one set of variables.

Compared to the previous paper, some adjustments have been made on it. And some variables showed in the table do not reflect the rural data directly due to data collection reasons. However, the dimensions remain the same in order to collect and analyse data, and show results through one way, which helps to compare the results and give conclusion.

Table 1. Variables describing each of the 6 dimensions

Dimensions of the "Smart Village" Concept and Their Weights	Variable Number	Name and Time of Variables	Weight of the Variable in the Dimension
Management (10)	X_{11}	Net farm income per capita (2020)	33.33
	X_{12}	Number of all types of farm organizations (2017)	33.33
	X_{13}	The number of farms whose economic sales class ranges from $10,000 to $99,999 (2020)	33.33
Life quality (10)	X_{21}	Total amount of housing loans and grants of USDA rural development programs (2009-2014)	20

	X_{22}	Average percentage of food secure households in rural areas (2018-2020)	20
	X_{23}	Percentage of households with internet access (2018)	30
	X_{24}	Number of physicians in patient care per 100,000 resident population (2018)	30
Economy (30)	X_{31}	Indices of total factor productivity (2004)	20
	X_{32}	Per-capita income in rural areas (2020)	30
	X_{33}	Employment rate in rural areas (2020)	20
	X_{34}	Amount of rural economic development loans and grants of USDA programs (2009-2014)	30
Society (20)	X_{41}	Percentage of rural population completing college level of education (2015-2019)	35
	X_{42}	Number of public libraries (2019)	10
	X_{43}	Amount of rural business enterprise and rural business opportunity grants of USDA programs (2009-2014)	20
	X_{44}	Average operator age of principal farm operators (2012)	10
	X_{45}	Proportion of rural population (2020)	10
	X_{46}	Percentage of nonmetro counties which is adjacent to a metro area among all nonmetro counties in state (2013)	15
Natural environment (10)	X_{51}	Total amount of water and waste disposal loans and grants of USDA rural development programs (2009-2014)	33.33
	X_{52}	Proportion of farmland in total land areas (2017)	33.33
	X_{53}	Percentage of farmland in conservation or wetland reserve program in total land area (2017)	33.33
Mobility (20)	X_{61}	Percentage of nonmetro counties whose net migration rate are greater than 2% among all nonmetro counties in state (2010)	40
	X_{62}	Length of total lane-miles in rural areas (2020)	30
	X_{63}	Intercity air coverage for rural residents in service area (2010)	20
	X_{64}	Average daily person miles (2017)	10

i) Sum of dimensions is 100, and sum of variables X should be equal to 100.

ii) USDA: United States Department of Agriculture.

iii) Data sources: https://www.ers.usda.gov/, https://www.nass.usda.gov/, https://www.rd.usda.gov/, https://www.cdc.gov/, https://nces.ed.gov/, https://www.bts.gov/, https://www.fhwa.dot.gov/, https://www.imls.gov/, https://data.census.gov/.

3.3. Procedures

After collecting the different sets of data, normalization method is used on the them with the quotient transformation formula, then the stimulant variables can be normalized [10][12]:

$$Z_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \quad (1)$$

And the destimulant, variable X_{44}, can be normalized with the formula [10][12]:

$$Z_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}} \quad (2)$$

And the outcome, Z_{ij}, should satisfy the range:

$$Z_{ij} \in [0, 1] \quad (3)$$

After normalization, zero unitarization method need to be used, which helps to create the ranking of all dimensions. This ranking shows the level of innovation potential in different places. With the use of the values of matrix Z elements and weights on each variable and dimension, the values of synthetic variables are obtained [10][12]:

$$Q_i = \frac{1}{m} \sum_{j=1}^{m} Z_{ij} \ (i = 1, 2, \ldots, r) \quad (4)$$

Then, unlike the previous study, the 6 dimensions are classified into 3 groups with the value of Q_i, showing smart development potential level, including high, average and low level. The range of the synthetic variable can be obtained by the formula [10][12]:

$$R(Q_i) = \max (Q_i) - \min (Q_i) \quad (5)$$

And the designated k parameter of division can be obtained by [10][12]:

$$k = \frac{1}{3} R(Q_i) \quad (6)$$

Thus, 3 groups of different innovative potential levels are extracted [10][12]:

i) The group with a high level of smart development potential:

$$Q_i \in [\max Q_i - k, \max Q_i] \quad (7)$$

ii) The group with an average level of smart development potential:

$$Q_i \in [\max Q_i - 2k, \max Q_i - k] \quad (8)$$

iii) The group with a low level of smart development potential:

$$Q_i \in [\max Q_i - 3k, \max Q_i - 2k] \quad (9)$$

4. RESULTS

4.1. Data Analysis

According to the results, in general, among the three selected states, Kansas has the highest innovation potential in rural areas. The table 2 in the following shows synthetic variables of 6 dimensions of three states, and which potential group each one lies. In this table, rural Kansas has the highest smart development potential level in 4 dimensions, which means that it has highest innovative potentials in these aspects. Also, Texas's rural potential level of innovation can be highest when considering management, life quality and mobility. However, rural Oklahoma shows lowest smart development potential level in the most of dimensions, implying that it lacks ability of innovation compared to the other two states.

In order to specifically express this difference, various factors of 6 dimensions need to be integrated. Combining the weights added on each dimension and the corresponding synthetic variable values, the results can be obtained in Figure 1. From the figure, Kansas has the largest value, which is not far from Texas, but Oklahoma, the lowest, is much smaller than the first two ones.

Table 2. Comparative results

Dimensions	Synthetic variable (Q_i)			Smart development potential level		
	KS	OK	TX	High	Average	Low
Management	0.3333	0.0805	0.7318	TX	KS	OK
Life quality	0.7760	0.0291	0.7093	KS, TX		OK
Economy	1.0000	0.1106	0.2375	KS		OK, TX

Society	0.5898	0.6013	0.4500	KS, OK		TX
Natural environment	0.6990	0.0522	0.3608	KS	TX	OK
Mobility	0.0750	0.2956	0.9589	TX		KS, OK

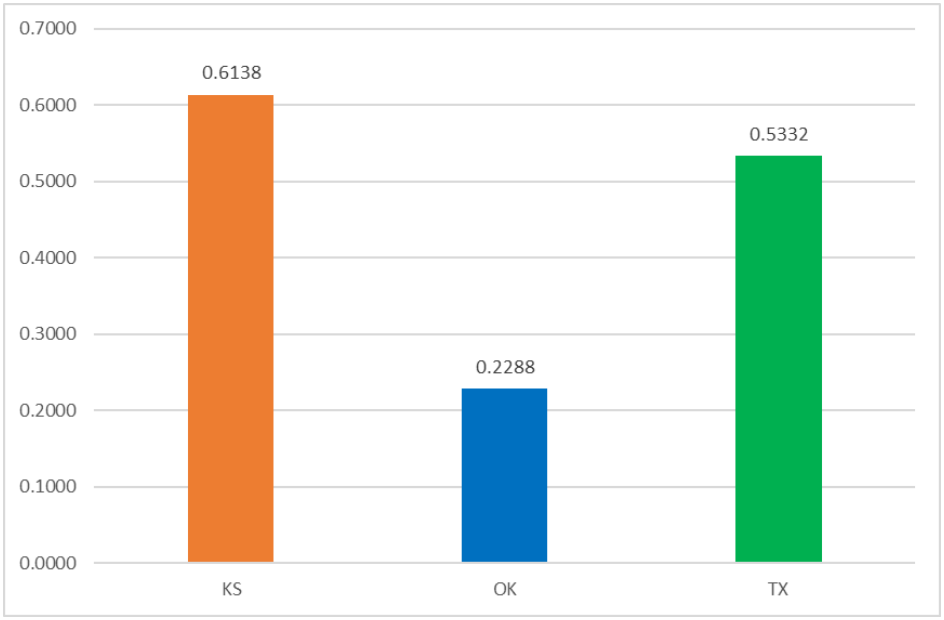

Figure 1 Overall Q_i for three selected states considering 6 dimensions

For further analyse results from each dimension and its variables, Figure 2 and 3 are given to assist in the analysis with collected data. The results of 6 dimensions reflects influence factors of innovation potentials and explains the content of sustainable development.

For the aspect of management, rural Texas seems to be most innovative according to the three variables selected. As the biggest state of the three ones, Texas has the largest number of farms, and the number of all types of farm organizations is the largest correspondingly. This has provided a lot of guidance and assistance for farm management, and promoted farmers' exchange and cooperation. In this case, potential innovation is possible. In addition, the number of farms whose economic sales class ranges from $10,000 to $99,999 in Texas is much larger than that in the other two places. Farms of this economic scale account for the largest proportion of farms of all sizes, and these farms have developed to a certain scale and want to continue to grow, so they are the largest part with smart growth potential. This is also the advantage of Texas's wide territory and large number of farms. Next, the variable, net farm income per capita, measures the income base that may be required for innovation. This can be also a good index of farm management. Kansas has the highest number, so considering with other factors it ranks behind Texas and before Oklahoma in this dimension.

The dimension of life quality shows that both Kansas and Texas are relative high-level compared to Oklahoma. For the total amount of housing loans and grants from USDA rural development programs, Texas receives the most loans because of its largest population. In terms of quantity, this loan can alleviate the housing pressure of the rural population and provide preconditions for innovative development. Besides, the three states are similar in both average percentage of food secure households in rural areas and percentage of households with internet access. Having enough food means that people have basic survival security, so on this basis, many people can start their own businesses, such as farming and pasturing. In the three regions, most of the rural population has food security, indicating that the social security measures are relatively complete in US. In addition, Internet penetration is a very important indicator. Most of the population in the three states can connect to the Internet, indicating that the United States has a high degree of modernization. Most people can receive a wide range of information from the Internet, which provides help for smart and innovative development. However, the number of physicians in patient care per 100,000 resident population is highest in Kansas, which is due to the perfection of the local medical system. With health protection, people can carry out all kinds of economic activities.

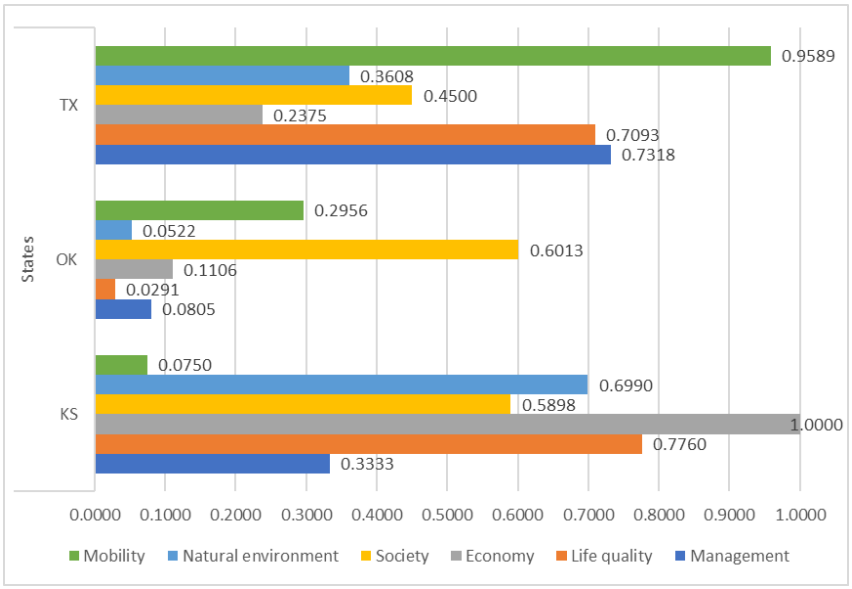

Figure 2 Synthetic values of 6 dimensions of the smart development potential of rural areas for three selected states

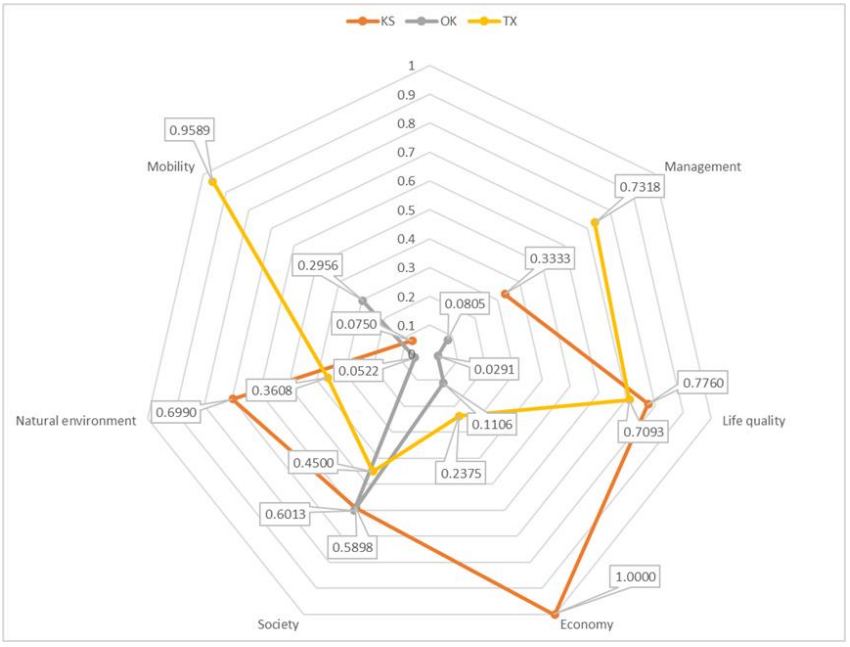

Figure 3 Profile characteristics of three selected states on the 6 dimensions of smart growth potential

And the economy aspect also shows great difference among three states for different variables. The Indices of total factor productivity is highest in Kansas, which means that its agricultural production efficiency is highest. This is mainly due to the agricultural tradition of Kansas. The local agriculture has developed for many years and accepted innovative achievements. Also, per-capita income in rural areas is largest in Kansas. This is different from per-capita farm income, and includes many other forms of income. Rural people in Kansas have more disposable income, so the potential for innovation is relatively increased. In addition, rural employment rate in three states is relatively high, and employment can be said to be a basic condition for innovative development. This shows that people can produce economic output in their jobs. Most importantly, the amount of rural economic development loans and grants of USDA programs for Kansas is much larger than that of the other two states. Kansas has a great demand for agricultural development, and many people work in the field of agriculture in rural areas, so the government's support for the development of rural areas is also relatively large. Thus, under the influence of these factors, Kansas has the most obvious advantage in economic development for smart growth potential, and the economic factors show the possibility of regional sustainable development.

However, when looking at the society dimension, which is line with the goal of sustainable development, Oklahoma has the highest potential for innovative development among three states, followed with Kansas at the same time. One main reason for this is the population quality issue, which is related to two variables, percentage of rural population completing college level of education and the number of public libraries in the state. The education level of the population in the rural areas of the two states is high, and the number of public libraries is also considerable. The high-quality population often has higher innovation potential, and the library can enable the public to obtain free knowledge and provide development ideas. Besides, the proportion of rural population is highest in Oklahoma, and the second largest in Kansas. It cannot be ignored that the population base is also the basis for development, so the population remaining in rural areas in both states can be an important factor. In addition, Oklahoma has the largest percentage of nonmetro counties which is adjacent to a metro area among all nonmetro counties in state. This is related to the local administrative planning, and it is said that the straight-line distance between each county and the major cities in the state is basically not far. The closer rural areas are to cities, the more new ideas and scientific and technological development can be received, so thereby more smart development potential. However, the amount of rural business enterprise and rural business opportunity grants of USDA programs are largest in Texas, and the average operator age of principal farm operators, the destimulant, is highest in Oklahoma. People in rural Texas may prefer new economic activities in agricultural business to traditional planting and animal husbandry. Also, the older farm workers are, the more difficult it is for them to accept innovative ideas and methods.

Then, for the aspect of natural environment, Kansas also has highest value, considering inside variables. This dimension measures some indirect factors that affect the potential of smart development in rural areas, including the utilization of natural resources and the impact of human activities on the environment. The total amount of water and waste disposal loans and grants of USDA rural development programs is highest in Texas, which means that the local government pays great attention to the treatment of sewage and various wastes. This not only improves people's quality of life, but also protects the local natural environment and prevents pollution. At the same time, the proportion of farmland and the percentage of farmland in conservation or wetland reserve program in total land area can show the way of utilizing of natural resources. Kansas ranks first for these two, and this shows that the local government considers the use of land and tries to balance the relationship between economic development and environmental protection. Therefore, this provides an excellent prerequisite for green innovation and sustainable development.

Finally, the dimension of mobility shows that Texas has the highest value, which is much bigger than the other two states. Texas has the largest percentage of nonmetro counties whose net migration rate are greater than 2% among all nonmetro counties in state, which means that more people outside state would like to come to stay in rural Texas compared to the other two states. This population growth brought about by external migration is also an important factor, because the external population often brings new technologies and ideas and promotes local development. In addition, the construction of infrastructure and transportation also needs to be considered, including the length of total lane-miles in rural areas, the intercity air coverage for rural residents in service area and the average daily person miles. Since Texas has transportation advantages such as land transportation hub and aviation hub, its potential level is greater than the other two. Complete transportation facilities can promote exchanges and cooperation in different regions, and promote innovation and development to varying degrees.

4.2. Conclusion

In summary, the expected application of this method in the future is possible. It combines the concept of innovation and sustainable development and applies it to the development of rural areas. The dimensions and variables inside not only show the level of smart and innovative growth, but also reflects the social, environmental and economic ways of sustainable development. Under the background of urbanization and modernization, rural development is still an important issue in today's world. Different countries and regions have different actual situations, so the governors should formulate policies and provide solutions according to local conditions. Also, taking a series of development issues such as population and environment into account, they should balance various factors in this process. The “Smart Village” can be a way for many places, since considering the innovative development potential of each region in rural development is conducive to the relevant analysis and formulation of strategies for sustainable development. Besides, this can be used in comparative analysis and other relevant problems in rural development. The methods and concepts are renewing and improving, and the public should continue to pay close attention to this topic.

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