Research on Smart City Construction Management Evaluation System Based on Ternary Subject Theory

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Abstract—In this paper, the existing problems and optimization principles of the current smart city construction management evaluation indicator system in China are analyzed. The evaluation indicator system is selected for two rounds based on the membership and utility and constructed systematically. The distribution of weight of smart city construction management evaluation indicators in China is obtained based on empirical investigation of the government officials, experts, scholars and the public participating in the evaluation from different typical regions in eastern, central, and western China by means of surveys and questionnaire investigations. Finally, the existing problems of the evaluation indicator system are analyzed and the optimization path is proposed.

1. Introduction
In recent years, more than 30 cities in China have been engaged in the smart city construction. The assignments have been signed for most cities, and the acceptance of some projects has been started [1]. As of 2018, the construction has actually been started in less than 40% pilot cities. Although the concept of smart city is put forward in a large number of cities in China, the smart city construction is carried out only in the first- and second-tier cities. The smart city construction is closely related to the economy, environment and resources. Despite of vigorous construction that appears, hardware investment is still emphasized, the expected goals of rectifying the soft environment of urban development, optimizing the functions of cities and towns, and cultivating smart industries are not reached, and there are common disadvantages such as insufficient innovation driving force [2]. This shows deficiencies to a certain extent in the evaluation of smart city construction management in China, and the evaluation indicators need to be optimized in order to provide more reasonable measures for the improvement of smart city construction management capability.

2. Current Condition of Smart City Construction Management Evaluation Indicator System and Optimization Principles
2.1. Analysis of Defects of Existing Evaluation Indicators
Differentiation of evaluation indicator systems. Up to now, no unified standard has been established for the documents concerning the evaluation indicator system for smart city construction management in China from the local governments to relevant ministries and commissions. The indicators that make up the evaluation indicator system are quite different in nature and quantity. For example, the pilot smart
city construction management evaluation indicator system established by the Ministry of Housing and Urban-Rural Development of China consists of 4 primary indicators, 11 secondary indicators and 57 tertiary indicators. The smart city evaluation indicator system established by the National Information Center consists of 6 primary indicators, 32 secondary indicators and 76 tertiary indicators. It is worth noting that the two systems focus on different indicators [3]. The difference brings difficulties to the overall evaluation of the smart city construction management in China, and the evaluation conclusions drawn are not convincing enough.

The evaluation indicator system fails to play an obvious guiding role. The existing evaluation indicator system for smart cities in China fails to provide guidance on the whole. The existing evaluation systems emphasize the promotion of the construction of smart industries without exception. The unbalanced development will lead to repeated investment in regional construction projects. Hence, the evaluation indicators that fail to provide guidance will lead to the failure to make the expected achievements by the future development goals of smart city construction [4].

2.2. Optimization Principles for Smart City Construction Management Evaluation Indicator System

Comprehensiveness of evaluation indicators. The smart city covers a wide range, including the development and application of modern information and smart technology, economic and social development, environmental resources, innovation, and government functions [6]. Accordingly, the smart city construction management evaluation indicator system should comprehensively reflect the evaluation objects from different aspects, and integrate all aspects for identification. In view of the importance of different indicators, the rationality and objectivity of the indicators should also be considered. On the basis of comprehensive consideration of the evaluation objects, the key content reflected by the indicator system should be representative and distinct.

Operability of evaluation indicators. On the basis of fully reflecting the level of construction management, the number of evaluation indicators should be, as far as possible, those that can show the actual situation with large amounts of information as practical as possible so as to make the evaluation indicator system comprehensive and operable. In order to facilitate the calculation, the source and expression of data and information are required to be as simple and intuitive as possible.

3. Selection of Evaluation Indicators for Smart City Construction Management

Based on literature review and field surveys of representative cities in eastern, central, and western China, cities such as Shanghai, Chengdu, Tibet, Shenzhen, and Beijing were selected. According to the aforesaid evaluation indicator system construction dimensions, 35 evaluation indicators were selected preliminarily, as shown in the fourth column in Table 1. The memberships of the preliminarily selected indicators [8] were selected using \( R_i = \frac{M_i}{M_{total}} \) (where \( M_i \) was the total number of selections after consulting experts, and \( M_{total} \) was the total number of experts). Based on investigation of the membership involved in the smart city construction management evaluation indicator system, the importance was classified into five levels: very important, important, general, unimportant and very unimportant. The questionnaires for survey were provided for 50 experts and 47 valid ones were recovered, with an effective rate of 94%. The questionnaires with the results of important and very important were selected. With 0.3 as the critical value, 6 indicators were deleted, and the evaluation indicators for smart city construction management were preliminarily determined, as shown in the fifth column of Table 1.

A validity test was conducted on the indicators after the first selection. As the measurement of the evaluation indicator system was regarded as the content validation, the analysis was made by the empirical judgment method during this research, and the degree of relationship between the contents was measured by the experts using \( CVR = \frac{2ne}{n} - 1 \) (where \( n_e \) was the number of evaluation experts who believed that an indicator better shows the measured content, and \( n \) was the number of evaluation experts) [9]. \( CVR \in [-1, 1] \) and the larger it is, the better the validity of the indicator system will be. The validity test was conducted by a questionnaire survey. A total of 50 questionnaires were distributed and 42 valid ones were recovered, with the effective rate of 84%. With 0.6 as the critical value, 7 indicators with a
value below 0.6 were deleted, and the smart city construction management evaluation indicators were obtained for the second time, as shown in the seventh column in Table 1. After selection of the indicators as shown above, it is finally determined that the smart city construction management evaluation indicator system consists of three levels. The first level is the overall evaluation indicator, i.e., the level of smart city construction; the second level is the criterion which defines four dimensions of the indicator system; the third level is the indicators, including the final 22 specific indicators.

Table 1 Smart City Construction Management Evaluation Indicator System Determined After Selection

| Objective                  | Criterion                     | Membership | Site Selection (Membership) | Membership | Validity | Selected or not |
|----------------------------|-------------------------------|------------|----------------------------|------------|----------|-----------------|
| Smart city construction management | Smart economy                | 0.897      | 0.874                      | 1.000      | √        |                 |
|                            | Information industry investment level |            | 0.502                      | 0.870      | √        |                 |
|                            | E-commerce level              |            | 0.471                      | 0.643      | √        |                 |
|                            | Innovation and entrepreneurship level |            |                            |            |          |                 |
|                            | Talent market mobility level   |            |                            |            |          |                 |
|                            | Internationalization level    |            |                            |            |          |                 |
|                            | Brand building                |            |                            |            |          |                 |
|                            | Economic development level    |            |                            |            |          |                 |
| Smart city governance      | Smart technology              | 0.874      | 0.763                      | 1.000      | √        |                 |
|                            | Broadband fiber access level   |            | 0.801                      | 1.000      | √        |                 |
|                            | Coverage of wireless network in public places | |                            |            |          |                 |
|                            | Coverage of basic data        |            |                            |            |          |                 |
|                            | Average internet speed        |            |                            |            |          |                 |
|                            | Application of Internet of Things |          |                            |            |          |                 |
|                            | Home computer usage rate      |            |                            |            |          |                 |
|                            | Application of cloud computing technology | |                            |            |          |                 |
|                            |                               |            |                            |            |          |                 |
|                            |                               |            |                            |            |          |                 |
|                            |                               |            |                            |            |          |                 |
|                            |                               |            |                            |            |          |                 |
|                            |                               |            |                            |            |          |                 |
| Smart environment | Natural environment | 0.245 | - | × |
| | Energy management | 0.513 | 0.701 | √ |
| | Low carbon and environmental protection | 0.437 | 0.824 | √ |
| | Ecological wisdom | 0.367 | - | × |
| | Pollution indicator | 0.540 | 0.903 | √ |
| Smart citizen | Educational level and cultural literacy | 0.615 | 1.000 | √ |
| | Information industry and talent introduction | 0.510 | 1.000 | √ |
| | Degree of civic participation in political affairs | 0.141 | - | × |
| | Internationalization level of citizens | 0.371 | 0.690 | × |
| | Level of digital usage | 0.445 | 0.847 | √ |
| Smart life | Cultural systems and facilities | 0.679 | 0.317 | × |
| | Smart transportation system | 0.814 | 1.000 | √ |
| | Smart education | 0.873 | 1.000 | √ |
| | Social security and management | 0.619 | 0.319 | × |
| | Smart health care | 0.704 | 1.000 | √ |
| | Smart safety | 0.663 | 1.000 | √ |
| | Income level of citizens | 0.092 | - | × |

4. Analysis of Evaluation Indicator System Based on Ternary Subject Theory

4.1. Research idea
Firstly, the distribution areas and investigation methods for the ternary subjects (i.e., government officials, experts, scholars, and the public) were determined. For government officials, online survey was made, supplemented by mail questionnaires. 70 mail questionnaires were finally distributed and 59 valid ones were recovered. 140 online questionnaires were recovered, of which 128 were valid. The valid questionnaires totaled up to 187, with the effective rate of 89.05%. The experts and scholars were surveyed in the same way as government officials. 70 mail questionnaires were finally distributed, and 64 valid ones were recovered. 158 online questionnaires were recovered, of which 142 were valid. The effective rate was 90.35% as a whole. For the public, a questionnaire survey was made during this research. A total of 100 questionnaires were distributed and 79 valid ones were recovered.

Secondly, statistical analysis of the results of the investigation of the ternary subjects was made. The statistics were made based on the three subjects, and the average was used as the score for the weight matrix of the smart city evaluation indicator system. The weight was calculated by the square root method, the principle of analytic hierarchy process was introduced to determine the maximum value of the matrix, and the calculation during the consistency check was made using $CI=(λ_{max}-n)/(n-1)$ and consulting the RI table. The calculation results are shown in Table 2.
Table 2 Ternary Subject Weight and Consistency Check

| Indicator | Government Officials | Experts and Scholars | Public |
|-----------|----------------------|----------------------|--------|
| **Smart economy** | | | |
| Information industry investment level | $\lambda_{max} = 4.035$ | $\lambda_{max} = 4.039$ | $\lambda_{max} = 4.09$ |
| E-commerce level | CI=0.0116 | CI=0.015 | CI=0.030 |
| Innovation and entrepreneurship level | RI=0.89 | RI=0.89 | RI=0.89 |
| Economic development level | CR=0.013 | CR=0.014 | CR=0.034 |
| **Smart governance** | | | |
| Comprehensive government service level | $\lambda_{max} = 3.186$ | $\lambda_{max} = 3.018$ | $\lambda_{max} = 3.050$ |
| Government information disclosure level | CI=0.093 | CI=0.009 | CI=0.025 |
| Cultural and social management level | RI=0.58 | RI=0.58 | RI=0.58 |
| | CR=0.016 | CR=0.015 | CR=0.043 |
| **Smart technology** | | | |
| Broadband fiber access level | $\lambda_{max} = 5.108$ | $\lambda_{max} = 5.412$ | $\lambda_{max} = 5.116$ |
| Coverage of wireless network in public places | CI=0.0269 | CI=0.103 | CI=0.029 |
| Coverage of basic data | RI=1.12 | RI=1.12 | RI=1.12 |
| Application of Internet of Things | CR=0.024 | CR=0.092 | CR=0.026 |
| Application of cloud computing technology | <0.1 | <0.1 | <0.1 |
| **Smart environment** | | | |
| Energy management | $\lambda_{max} = 2.012$ | $\lambda_{max} = 3.028$ | $\lambda_{max} = 3.023$ |
| Low carbon and environmental protection | CI=0.006 | CI=0.014 | CI=0.016 |
| | RI=0.58 | RI=0.58 | RI=0.58 |
| Pollution indicator | CR=0.011 | CR=0.024 | CR=0.020 |
| | <0.1 | <0.1 | <0.1 |
| **Smart citizen** | | | |
| Educational level and cultural literacy | $\lambda_{max} = 3.038$ | $\lambda_{max} = 3.018$ | $\lambda_{max} = 3.036$ |
| Information industry and talent introduction | CI=0.0192 | CI=0.009 | CI=0.018 |
| | RI=0.58 | RI=0.58 | RI=0.58 |
| Internationalization level of citizens | CR=0.033 | CR=0.017 | CR=0.031 |
| | <0.1 | <0.1 | <0.1 |
| **Smart life** | | | |
| Smart transportation system | $\lambda_{max} = 4.067$ | $\lambda_{max} = 4.059$ | $\lambda_{max} = 4.088$ |
| Smart education | CI=0.0223 | CI=0.0196 | CI=0.0294 |
| | RI=0.89 | RI=0.89 | RI=0.89 |
| Smart health care | CR=0.025 | CR=0.022 | CR=0.033 |
| | <0.1 | <0.1 | <0.1 |
| **Overall consistency check** | $\lambda_{max} = 22.361$ | CI=0.0172 | RI=0.903 |
| | CR=0.019 | CR=0.019 | CR=0.019 |

4.2. Result analysis

Table 3 shows that the distribution of weight given by the experts and scholars is generally unbalanced. The main reasons are as follows: Firstly, there was a "polarization phenomenon" among the experts and scholars, which means that some experts believed that an indicator was very important in the evaluation process and gave it a weight ratio which was too high, which resulted in a smaller weight ratio for other indicators and widened the weight gap between indicators. Secondly, some experts and scholars proposed a forward-looking and predictive indicator weighting system based on in-depth systematic analysis of the smart city construction management evaluation indicator system, while the proposed system failed to combine the specific characteristics of the local reality and the evaluation object, resulting in an unbalanced distribution of weight.

Table 2 shows that the weight given by government officials is evenly distributed, and the difference in weight of an individual indicator is significantly smaller than the weight given by the experts and scholars. The main reasons are as follows: Firstly, from the perspective of the government, to ultimately achieve the goal of safeguarding public interests, the government officials are required to think about issues from the overall standpoint. Secondly, with high overall quality, the government officials can comprehensively weigh related issues and possible impacts and make reasonable judgments when dealing with problems. However, it should be noted that the position of government officials may involve the risk of the transfer of public interests and the indirect transformation of public interests with asymmetric information.
Table 3 shows that the public pays great attention to smart life and smart livelihood, and the distribution of weight is the most balanced. The main reasons are as follows: Firstly, with different groups of people and different value orientations, the public is featured by the complicated internal structure, and the differentiated value orientation is integrated with the decentralization of survey samples, resulting in the relatively balanced distribution of weight. Secondly, the public is easy to influence each other and pursue assimilation, which leads to the consistency of the public's understanding of smart city construction. Thirdly, without systematic knowledge and theoretical basis, the public is prone to dealing with problems based on what the problems look like, making the smart city construction management evaluation affected by the social hot spots and balanced distribution of weight.

5. Strategy for Optimizing the Smart City Construction Management Evaluation Indicator System

Firstly, coordinate the requirements of different groups of people for smart city construction. Extensively collect the subjective preferences of different subjects for the status of smart city construction, and determine the focus of evaluation indicators. Establish a scientific and operable evaluation indicator system based on the focus of smart city construction since the smart city construction involves all aspects.

Secondly, coordinate the relationship between the objective position and the subjective position of government officials. Reduce the subjective influence of government officials who, as the main subject of smart city construction management evaluation, have an important influence on the evaluation indicator system, and improve the scientific nature of the evaluation indicator system. First of all, establish an accountability system to set performance goals for government officials from a result-oriented perspective, avoid any irresponsible behavior in the construction process, and ensure the realization of construction goals. Second, improve the transparency of the smart city construction management evaluation indicator construction process. The evaluation indicator system determines the direction of urban development and the distribution and flow of construction resources to a certain extent, and it is the easiest to be operated by government officials and becomes a tool for individuals to seek personal gains.

Thirdly, optimize the reliability of the public participating in the evaluation of smart city construction management. The participation of the public in the establishment of the smart city construction management evaluation indicator system helps to truly reflect the public sentiment, public opinion, and people’s livelihood, and increases the enthusiasm of the public for participating in smart city construction. However, owing to the complicated internal structure and the imperfect knowledge system of the public, the reliability and validity of the evaluation results are widely questioned. Hence, to optimize the reliability of the public in the establishment of the evaluation indicator system, the followings should be ensured. Firstly, strengthen the promotion of smart cities, which is conducive to guiding the public to form a more correct understanding and judgment on smart city construction; second, systematically sort out the complicated internal values of the public to make clear the internal values of the public as a whole, and integrate different internal values through effective technical means to reflect the public opinions and public sentiments to the greatest extent and improve the reliability of the public in the evaluation of the indicator system.

6. Conclusion

This article comprehensively uses statistical analysis methods to study the smart city construction management evaluation system. The main conclusions can be summarized as follows: First, balance the needs of organizations and individuals for smart city construction, coordinate the relationship between organizations and individuals, and choose the "common indicators"; second, the establishment process of the evaluation indicator system should be made public, and the government should explain the evaluation indicator system if necessary; third, optimize the reliability of the public in the establishment of the evaluation indicator system, the followings should be ensured. The following two points should be paid attention to in the future work; Firstly, strengthen the promotion of smart cities, which is
conducive to guiding the public to form a more correct understanding and judgment on smart city construction; second, systematically sort out the complicated internal values of the public to make clear the internal values of the public as a whole, and integrate different internal values through effective technical means to reflect the public opinions and public sentiments to the greatest extent and improve the reliability of the public in the evaluation of the indicator system.

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