*The Journal of Industrial Technology : Suan Sunandha Rajabhat University*
*Volume 12 / Number 2 / July – December 2024*

# Quantifying Innovation Potential: An Index System and Model for China's High-Tech Industry Development Zone

**Chenqing Su[1], Choat Inthawongse[2], Noppadol Amdee[3*]**
[1, 2, 3]Faculty of Industrial Technology, Muban Chom Bueng Rajabhat University
E-mail: 64a951003@mcru.ac.th[3]

Received: Apr 23, 2024
Revised: Jun 10, 2024
Accepted: Jul 04, 2024

## Abstract

The aim of this study is to investigate the innovative capacity of high-tech zones in China. To this end, we have developed an evaluation index system and established a solid theoretical basis for it. Our evaluation system includes four first-level indicators, eight second-level indicators and 28 third-level indicators, whose weights were determined using the entropy weight method. In addition, we applied the catastrophe progression method to comprehensively assess the innovative capacity of high-tech zones, capture innovation dynamics and identify areas for improvement. The novelty of this study lies in the construction of a multi-level index system based on the framework of cybernetics and information theory. By combining the entropy weighting method and the catastrophe progression method, we provide for the first time a scientific and comprehensive method for assessing innovation capability. Our research not only reveals the strengths and weaknesses of the innovation capability of high-tech zones, but also provides practical assessment tools and theoretical support for their further development. The results show that the systematic index system and scientific assessment methods can effectively evaluate the innovation capability of high-tech zones and provide deep insights and suggestions for improvement. Overall, our study provides valuable insights and practical guidance for the continuous innovation and development of high-tech zones in China.

**Keywords :** Evaluation index system, Evaluation model, Innovation capability, High-tech zone Industry

## Introduction

The National High-tech Industrial Development Zone (hereinafter referred to as the "High-tech Zone" leads China's innovation-driven development in each region, and its innovation capability directly determines the innovation level of the region. In addition to implementing the strategy of "innovative country", building a regional innovation system with local characteristics and advantages is the focus and core of local governments' development strategy in the new period. The high-tech industry is an emerging pillar industry with excellent development potential. The level and scale of the high-tech industry reflect a country's comprehensive national power, development potential and core competitiveness. The importance of high-tech enterprises as pioneers for the development of strategic emerging and high-tech industries in China is obvious.

The scholars Bruno and Tyebjee (1982)[1] were the first to start researching the valuation index system of science and technology parks and constructed the corresponding valuation index system with 12 factors that significantly influence the companies. Makecki (1987, 1988)[2, 3] evaluated the innovation ability of high and new technology zones from eight aspects: the strength of government support, the speed of capital flow, and the degree of personnel mobility — innovation in high technology zones. Chung (2004)[4] used the AHP method to evaluate the companies in Taiwan's science and technology parks. He concluded that seven factors, such as consumption effect, industry relevance, and government, are closely related to the high-tech industry. Zeng (2010)[5] argued that the innovation capability of high-tech zones can be evaluated based on three aspects: Innovation environment, innovation promotion and innovation organization.

The Chinese Ministry of Science and Technology has improved the National Indicator System for the Evaluation of High-tech Zones four times since 1993, and these four versions have integrated different innovation directions in the high-tech zones in different periods[6]. On this basis, Xu Guanhua (2006)[7] believed that six factors such as innovation environment, technological innovation and risk investment are closely related to the innovation ability of high-tech zones. Zhao Daping (2007) [8] developed an index system to evaluate the innovation ability of high-tech zones to analyze the impact of specialized division of labor on independent innovation ability in high-tech zones. Wang Feng (2010) [9] interpreted the development path of PIH innovation capability based on the study of the driving and development mode of independent innovation in high-tech zones. Hu Shuhua (2010)[10] proposed a three-level index system to evaluate the autonomous innovation capability based on the study of the concept, construction basis and characteristics of the autonomous innovation capability of high-tech zones. Fang Yumei et al. (2014)[11] designed a four-dimensional theoretical model of environmental support, innovation output, organizational process and innovation input based on theoretical analysis and practical research. In addition, Zhang Jixin (2022)[12] used the entropy value and disaster progression method to measure the ability of national high-tech zones to cultivate innovative industrial clusters. Zhang Lin (2022)[13] used the effectiveness coefficient method to measure the innovation ability of national high-tech zones in Shandong Province. Guo Yanqing (2022)[14] used the factor analysis method to measure 44 national high-tech zones in six central regions of China. Ren Fei (2020)[15] empirically investigated the innovation evaluation ability of 25 enterprises in Zhengzhou high-tech zone using DEMATEL-ANP analysis, Ding Qingqing (2019)[16] applied the DEA Malquist index method to dynamically measure the innovation efficiency of China's 54 national high-tech zones, and Su Chenqing (2018)[17] used the disaster progression method to measure the innovation efficiency of the 14 national high-tech zones in the city cluster on the middle reaches of the Yangtze River and conducted an empirical study.

To summarize, research on high-tech zones initially focused on system structure and functional mechanisms. As research deepened, attention gradually shifted to the development of index systems and evaluation methods. Despite the extensive literature on high-tech zones, several problems remain: First, there is no consensus on a valuation index system for high-tech zones, and research on unique indices is limited. Second, most existing comprehensive valuation methods are based on linear models, which are unsuitable for analyzing empirical objects with nonlinear relationships. Therefore, this study aims to develop a novel evaluation index system to evaluate the innovation ability of high-tech zones and select a suitable evaluation model to solve these problems.

The novelty of this study lies in the integration of cybernetic and information theory approaches with the entropy weight method and the catastrophe progression method to develop a multilevel index system for assessing innovation capability. This comprehensive and scientific approach not only reveals the strengths and weaknesses of the innovation capability of high-tech zones, but also provides practical assessment tools and theoretical support for their further development. The main research tasks include designing a multi-level index system, determining the indicator weights, applying the catastrophe progression method for comprehensive assessment, and finally providing a thorough assessment of the innovation capability of high-tech zones.

## Principles of indicator system construction

When assessing the innovative capacity of high-tech zones, it is crucial that the indicators are scientific, complete, and practicable. Therefore, the development of a set of scientific and practical index systems for assessing innovation capability is an essential part of the research in this paper. The design of an index system to evaluate the innovation capability of high-tech zones should follow the principles of the available data source, and indicators at all levels can be considered. The system can be operated, but it must also follow the principles of expediency, objectivity, systematic principle, and the combination of qualitative and quantitative principles.

## Theoretical basis for the construction of indicator system

Cybernetics assumes that in the regional innovation system, the innovation system is connected to the outside world through the control of inputs and outputs and that there is a black box in this process that does not allow the internal operation to be recognized intuitively. Information theory states that there are processes of identification, processing, transformation, transmission, storage and display in the information flow of the system. There are positive and negative feedback effects in the whole process of information flow transmission. In the regional innovation system, the source of information flow transmission is talent, capital and technology entering the black box from the innovation subsystem. It carries out innovation activities through the innovation subject in the black box and the outputs from the innovation subsystem. The output is fed back into the innovation input subsystem. The whole process is the structure of the regional innovation system under the guidance of cybernetic theory and information technology theory, as shown in Figure 1 below.

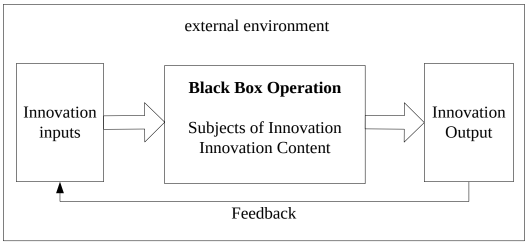



**Fig. 1** The structure of regional innovation systems in consideration of cybernetic information theory[17]

## Indicator design and screening

Based on the structure of the regional innovation system within the framework of cybernetic information theory, combined with the high-tech zone's own characteristics of innovation system, focusing on the goal of evaluating the innovation capability of the high-tech zone and drawing on the successful experience of previous similar index systems, the high-tech zone should improve its innovation capability from the four aspects of increasing innovation input, optimizing the organizational and operational level, increasing innovation output, and appropriately allocating resources and environment. Therefore, this paper is based on the four organizational aspects of innovation capability. Therefore, this paper develops an indicator system for the innovation capability of high-tech zones, which is composed of four dimensions: Innovation input capability, organizational operational capability, innovation output capability and environmental support, as shown in Figure 2.

Referring to the framework of high-tech zone innovation capability indicator system, according to the high-frequency principle of classical literature indicators of authoritative institutions and based on the principles of expediency, objectivity and systematic, this paper selects four first-level indexes, eight second-level indexes and 28 third-level indexes to establish the national high-tech zone innovation capability assessment index system, as shown in Table 1.

The innovation input index is used to measure the strength of resource input for innovation in high-tech zones. It mainly includes two aspects: intellectual input and financial input, and four indicators are selected for intellectual input, such as R&D personnel, personnel for scientific and technological activities, the full-time equivalent of R&D personnel and the density of personnel with middle and higher titles, etc. In contrast, the financial input for financing scientific and technological activities, R&D funding, intensity of financing scientific and technological activities and R&D funding intensity are selected. R&D expenditure intensity of S&T activities, R&D expenditure intensity of S&T activities and R&D expenditure intensity of S&T activities.

The innovation output capability indicator measures the output capability of high-tech zones according to the use of resources, including output scale and efficiency. Three indicators are selected for output scale: the scale of technology income, the annual growth of high-tech enterprises, the scale of export foreign exchange, etc. Output efficiency specifies three indicators: profitability, return on R&D investment and technological income per unit of R&D personnel.

The environment support capability indicator measures the supportive effect of a high-tech zone's environment on innovation capability, including the soft environment and the complicated environment. Four indicators are selected for the difficult environment: Company size, number of employees, capital investment status and the total number of science and technology incubators, etc. In comparison, the soft environment selects four indicators: the strength of policy support, the innovation of institutional mechanisms, the essential supporting environment and financial support.

The organizational and operational capability indicators are used to measure the comprehensive capability of high-tech zones to transform resource inputs into outputs, including the capability of the innovation unit and the organizational coordination capability. Three indicators were selected for innovation capability, such as the number of high- tech enterprises, the number of universities and R&D institutes, the number of innovation service facilities, etc. , and three indicators were selected for organizational coordination capability, such as the number of national college science and technology parks, the number of innovative industry clusters, the number of productivity promotion centers, etc. Three indicators.

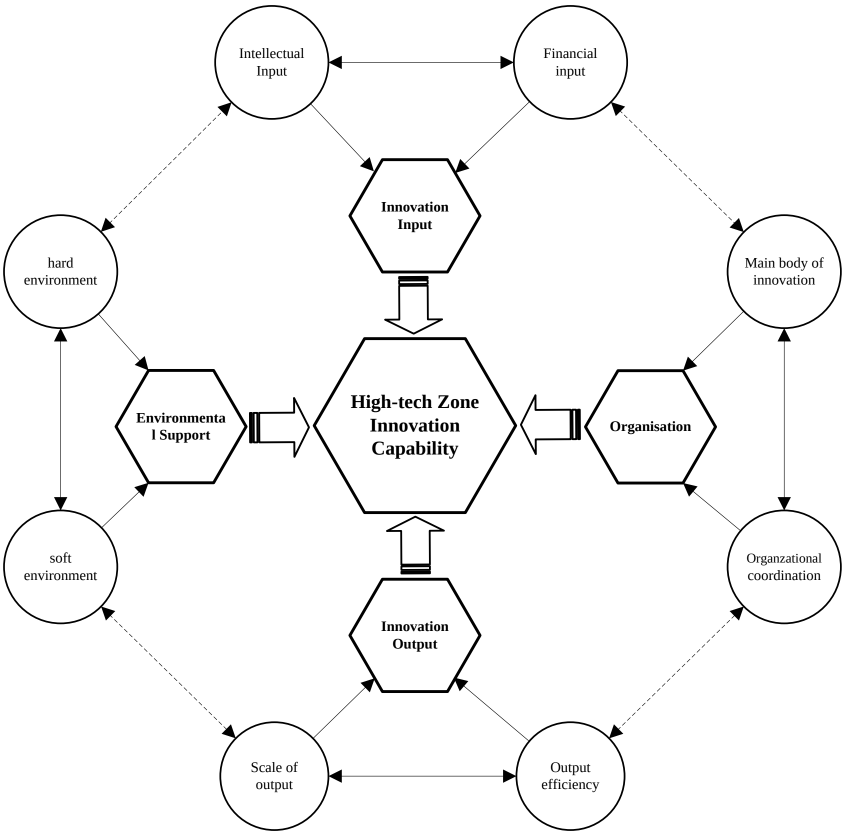


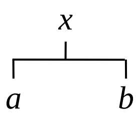
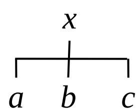
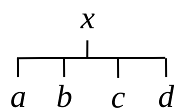

**Fig. 2** Framework of the indicator system for the innovative capacity of the high-tech zone

**Table 1** Evaluation Indicators System of Innovation Capability of Hi-tech Zone [18-27]

| Evaluation objectives | Level 1 Indicators | Level 2 Indicators | Level 3 Indicators | Indicator Description | Unit |
|---|---|---|---|---|---|
| High-tech Zone Innovation Capability | Innovation Input Capability | Intellectual input | R&D personnel | Number of R&D Personnel | Persons |
| | | | Scientific and technological activity personnel | Number of technologically active personnel | Persons |
| | | | R&D Personnel Full-time Equivalent | Full-time equivalent of R&D personnel | Persons/year |
| | | | The density of middle and senior title personnel | Number of middle and senior title personnel/number of employees at the end of the year | % |
| | | Financial input | Funds for scientific and technological activities | Internal Expenditure on S&T Activities | Thousands of Yuan |
| | | | R&D Expend | Internal Expenditure on R&D | Thousands of Yuan |
| | | | The intensity of Expenditure on Scientific and Technological Activities | Internal Expenditure on S&T Activities/Total Income | % |
| | | | R&D Expenditure Intensity | Internal Expenditure of R&D Funds/Total Income | % |
| | Innovation Output Capability | Scale of output | The scale of technology income | Amount of technology income | Thousands of Yuan |
| | | | Annual Increase of High-tech Enterprises | Growth of high-tech enterprises | per unit |
| | | | The scale of export earnings | Export earnings amount | Thousands of Yuan |
| | | Output efficiency | Profitability | Enterprise net profit ratio | % |
| | | | Return rate of R&D investment | Technology Income/R&D Expenditure | % |
| | | | Technology Income Creation per Unit of R&D Personnel | Technology Income/R&D Personnel | Thousand Yuan/person |
| | Environmental Support Capability | Hard environment | Enterprise size | Total revenue/number of enterprises | Thousand Yuan/Each |
| | | | Employee Size | Number of employees at the end of the year | persons |
| | | | Capital Operation Status | Year-end assets/year-end liabilities | % |
| | | | Total number of technology business incubators | Number of incubators | per unit |
| | | Soft environment | Policy Support | Measured according to the policy introduction of each high-tech zone | Level |
| | | | Institutional Mechanism Innovation | Measured according to the operation and management of each high-tech zone | Level |
| | | | Basic Supporting Environment | Measured by the infrastructure of each high-tech zone | Level |
| | | | Financial Support | Measured by financial services of each hi-tech zone | Level |

| Evaluation objectives | Level 1 Indicators | Level 2 Indicators | Level 3 Indicators | Indicator Description | Unit |
|---|---|---|---|---|---|
| | Organization Operation Capability | Innovation main body capability | The scale of high-tech enterprises | Number of high-tech enterprises | per unit |
| | | | Number of Universities and R&D Institutions | Number of universities and R&D institutions | per unit |
| | | | Number of Innovation Service Organizations | Number of Innovation Service Organizations | per unit |
| | | Organization and coordination capability | Number of National University Science Parks | Number of National University Science Parks | per unit |
| | | | Number of Innovative Industrial Clusters | Number of Innovative Industrial Clusters | per unit |
| | | | Number of Productivity Promotion Centers | Number of Productivity Promotion Centers | per unit |

**Table 2** Mutation level system model and diagrams[24]

| Type | Spike mutation system | Swallowtail mutation system | Butterfly mutation system |
|---|---|---|---|
| System model | $f(x)=x^4+ax^2+bx$ | $f(x)=\frac{1}{5}x^5+\frac{1}{3}ax^3+\frac{1}{2}bx^2+cx$ | $f(x)=\frac{1}{6}x^6+\frac{1}{4}ax^4+\frac{1}{3}bx^3+\frac{1}{2}cx^2+dx$ |
| Control variable | *a, b* | *a, b, c* | *a, b, c, d* |
| Divergence point equation | $a=-6x^2$, $b=8x^3$ | $a=-6x^2$, $b=8x^3$, $c=-3x^4$ | $a=-10x^2$, $b=20x^3$, $c=-15x^4$, $d=5x^5$ |
| Normalization formula | $x_a=\sqrt{a}, x_b=\sqrt[3]{b}$ | $x_a=\sqrt{a}, x_b=\sqrt[3]{b}, x_c=\sqrt[4]{c}$ | $x_a=\sqrt{a}, x_b=\sqrt[3]{b}, x_c=\sqrt[4]{c}, x_d=\sqrt[5]{d}$ |
| Diagram |  |  |  |

**Remark:** Using the diagrams, we can determine the type of each mutation, i.e. "one change two" for the spike mutation, "one change three" for the swallowtail mutation and "one change four" for the butterfly mutation.

### Evaluation Model

**1. Indicator weighting: Entropy weight method**

The Entropy Weight Method (EWM) is a widely used multi-criteria decision-making technique that helps to determine the weighting or importance of different criteria in decision-making. It was first proposed by J.W. Doyle in 1978 and has since been applied in various fields such as engineering, management, and economics.

The EWM is based on the concept of information entropy from information theory. It aims to measure the degree of uncertainty or variability in a set of criteria and assign a weighting to each criterion based on its relative importance in reducing overall uncertainty. The basic idea is that criteria with higher entropy (i.e. higher variability) are considered more critical and receive a higher weighting [28,29].

The steps of the entropy- weight method usually include:

**Step 1:** To determine the valuation matrix to be used. Assuming that the number of evaluation indicators and objects corresponds to i and j in this order, the following specific matrix formula results.

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1j} \\ x_{21} & x_{22} & \cdots & x_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} \end{pmatrix} \quad (1)$$

**Step 2:** Data- based dimensionless processing is performed. The formula for processing positive indicators is as follows.

$$x'_{ij} = \frac{x(i,j)-x_{min}(i,j)}{x_{max}(i,j)-x_{min}(i,j)} + 1 \quad (2)$$

The formula for the reverse indicator is also referenced as follows.

$$x'_{ij} = \frac{x_{max}(i,j)-x(i,j)}{x_{max}(i,j)-x_{min}(i,j)} + 1 \quad (3)$$

The dimensionless processed judgment matrix is then derived as follows.

$$x' = \begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1j} \\ x'_{21} & x'_{22} & \cdots & x'_{2j} \\ \vdots & \cdots & \cdots & \cdots \\ x'_{i1} & x'_{2} & \cdots & x'_{ij} \end{bmatrix} \quad (4)$$

where: i = 1,2,3···, m; j = 1,2,3···,n, and H represents the panning magnitude.

**Step 3:** The weighting of the indicators is carried out.

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \quad (5)$$

**Step 4:** Calculate the specific first value of the indicator.

$$e_j = -\frac{1}{n}\sum_{\ln m}^{m} y_{ij} \ln y_{ij} \quad (6)$$

Where: i = 1,2,3···, m; j = 1,2,3···, n, $e_j$ is the first value of the j indicator match.

**Step 5:** Complete the derivation of the coefficient of variation.

$$g_i = 1 - e_i \quad (7)$$

Where: i = 1,2,3···, m

**Step 6:** The indicators at each level are fully weighted.

$$f_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \quad (8)$$

Where: j = 1,2,3···, n

The Entropy Weight Method provides a systematic approach for dealing with multiple criteria and their relative importance in decision problems. It helps decision makers to identify the most important criteria and make more informed and objective decisions.

**2. Evaluation of Innovation Capacity: Catastrophe progression method**

The theoretical basis of the Catastrophe Progression Method (CPM) is one of the three new theories of the system, the mutation theory (catastrophe theory). Catastrophe theory was founded in 1972 by the French mathematician Rene Thom mainly through the development of structurally stable topological concepts, and built on the basis of topological dynamics, singularity theory and other theories, which can be used for state evaluation and change trend analysis, and is known as " calculus after a revolution in mathematics" The CPM derived from the mutation model of mutation theory is often used in multi-criteria decision problems. Its comprehensive evaluation of the objective is first to decompose the overall objective of the system evaluation at multiple levels, and then use the mutation fuzzy membership function generated by the combination of mutation theory and fuzzy mathematics, and then perform the comprehensive quantitative operation through the normalization formula, and finally normalize it to one parameter, that is, seek the overall membership function to arrive at the comprehensive evaluation results —the complete evaluation results[30].

**Step 1:** Determine the index system for mutation evaluation.

When determining the mutation evaluation indexes based on the evaluation purpose, guided by the intrinsic mechanism of the mutation level, starting from the evaluation of the overall index, each level of the index is decomposed step by step, that is, one index is decomposed into two or two or more indexes, with the aim of obtaining the subdivided indexes that can better express the actual evaluation object. Since the mutation system does not contain more than four control variables under normal circumstances, the corresponding decomposition of indicators at each level is also no more than four. At most, each indicator is decomposed into the next level of indicators, which can only deteriorate from four.

**Step 2:** Determine the weights of the indicators --EWM.

Catastrophe progression method in the calculation process: although the weight of each indicator does not need to be used, in the construction of the mutation level indicator system needs to be the weight of each indicator, the use of weight to determine the relative importance of each indicator, the weight of the larger is ranked in the front, the weight of the smaller is classified in the back, the role of the indicator before and after the order of the different formulas used to reflect the operation is other. To overcome the subjective factors in index sorting, this paper adopts the entropy weight method to calculate the weight of each index when assigning weights to the indexes. The entropy weight method is a relatively objective method of assignment. The original data need to be standardized before starting the entropy weight method to calculate the weight. $Y_{ij}$ Indicates which indicates the $j$ sample of the $i$ indicator. All of them are standardized data.

Firstly, the weight of the $j$ sample of the $i$ indicator is $p_{ij} = y_{ij} \big/ \sum_{j=1}^{n} y_{ij}$ $(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$ ;

Secondly, the entropy value of the $i$ indicator $e_i = -1 \big/ \ln n \sum_{j=1}^{n} (p_{ij} \ln p_{ij})$ ;

Finally, according to the utility value of the indicator $d_i = 1 - e_i$, the weight of the $i$ indicator is obtained $\omega_i = d_i \big/ \sum_{i=1}^{m} d_i$.

If the evaluation index system is a multi-layer structure, then according to the additivity of entropy, the utility value of the indicators of the lower structure can be summed up to get the utility value of each type of indicator in the upper layer $D_k$. Thus, the weight of the corresponding upper indicator can be obtained $W_k = D_k \big/ \sum_{k=1}^{s} D_k$ $(k = 1, 2, \cdots, s)$.

**Step 3:** Determine the type of mutation.

In general, the mutation system will have no more than four control variables, so there will be at most seven forms of mutation, namely the seven types of cusp mutation, dovetail mutation, butterfly mutation, fold mutation, hyperbolic umbilical point mutation, elliptical umbilical point mutation, and parabolic umbilical point mutation. When using the catastrophe progression method, only three types are generally expected, as shown in Table 2.

Table 2 models the potential function of a state variable x of the mutation system. The coefficients of x, a, b, c and d denote the control variables of the state variable. The state variable and the control variable of the potential function of the system are two opposing aspects. If an indicator is decomposed into two sub- indicators, the system can be regarded as a hump mutation system; if an indicator is decomposed into three sub- indicators, the system can be regarded as a dovetail mutation system; if an indicator is decomposed into four sub-indicators, the system can be regarded as a butterfly mutation system.

**Step 4:** Derive the normalization formula from the divergence equation.

According to the mutation theory, divergence point set equations cannot be directly analyzed and evaluated because the range of values of the state and control variables is not uniform, nor can it be consistent with the range of values of fuzzy affiliation numbers 0 to 1. Thus, limiting the range of state and control variable values in each mutation model to 0 to 1, i.e., normalization is necessary. The divergence point equations are obtained by taking the potential function's first-order derivatives, and the mutation system's set of singularities is obtained by taking the second-order derivatives $f''(x)=0$. By $f'(x)=0$ $f''(x)=0$ eliminating x, the divergence point set equation of the mutation system is obtained, i.e., the equilibrium surface formed by the set of all critical points. The divergence point set equation indicates that the system mutates when each control variable satisfies this equation. The normalization formula can be derived by decomposing the form of the divergence point set equation. The normalization formula indicates $x_i(i=a,b,c,d)$ the number of mutation levels corresponding to the control variable i. The normalization formula is a multidimensional fuzzy affiliation function in the mutation-level system.

**Step 5:** Comprehensive evaluation using the normalization formula

The normalization formula transforms the different qualitative states of each control variable in the system into the same qualitative state, i.e., the control variables are unified into the qualitative state expressed by the state variables. Control variables in the use of the normalization formula to calculate the value of each state variable, if there is no apparent correlation between the control variables of the system, the object of the control scalar for the "non-complementary," following the principle of "taking the smallest out of the big," let $\min\{x_a,x_b,x_c,x_d\}$ to be the x value of the entire system; If there is evident interrelatedness between the control variables of the system, then the control variables of the object are called "complementary," and let $\frac{1}{m}\sum_{i=1}^{m}x_i$ to be the x value of the entire system; which is the only way to meet the requirement of qualitative change of the divergence equation. Finally, the evaluation objects are ranked according to their total evaluation index scores regarding their advantages and disadvantages.

## Conclusion

This study summarizes the national and international research on the evaluation indexes of innovation capability in high-tech zones and constructs an evaluation index system for high-tech zones. The entropy weight method is used to determine the weights of each index level, and the total value is calculated by the catastrophe progression.

The practical significance of this research lies in providing a rigorous and comprehensive framework for assessing the innovation capability of high-tech zones. Using a scientifically grounded and multidimensional assessment system, this study identifies the strengths and weaknesses of innovation capability, thus providing valuable insights for policy makers and stakeholders to improve the innovation ecosystem in high-tech zones. This comprehensive approach not only contributes to a deeper understanding of innovation dynamics, but also serves as a guide for strategic decisions that promote sustainable development and enhance the competitive advantages of high-tech industries.

## References

[1] A. V. Bruno and T. T. Tyebjee, "The environment for entrepreneurship, "*Prentice-Hall, Englewood Cliffs,* 1982.

[2] E. J. Malecki, "The R&D location decision of the firm and creative regions: A survey," Technovation, 1987, vol. 6, no. 3, pp. 205-222.

[3] E. J. Malecki and P. Nijkamp, "Technology and regional development: Some thoughts on policy," *Environment and Planning C: Government and Policy,* 1988, vol. 6, pp. 383-399.

[4] J. C. Chung and C. H. Chin, "A multiple criteria evaluation of high-tech industries for the science-based industrial park in Taiwan," *Information & Management*, 2004, vol. 41, pp. 839-851.

[5] S. X. Zeng, X. M. Xie, and C. Tam, "Evaluating innovation capabilities for science parks: A system model," *Technological and Economic Development of Economy,* 2010, vol. 16, no. 3, pp. 397-413.

[6] J. Song, Z. Li, and L. Wu, "Establishing a scientific evaluation system to guide the transformation and upgrading of industrial parks: An analysis of the evaluation index system for national high-tech zones (Revised edition 2013)," *China High-Tech Zones,* 2013, vol. 8, pp. 136-141.

[7] G. Xu, "Enhancing independent innovation capability and accelerating the construction and development of national high-tech zones," *China Soft Science,* 2006, vol. 8, pp. 1-8.

[8] D. Zhao and X. Li, "The impact of specialization in China's national high-tech zones on independent innovation capability," *Science Studies,* 2007, vol. 25, no. 12, pp. 500-505.

[9] F. Wang, "Research on cultivating and measuring independent innovation capability of China's national high-tech zones," 2010, *Doctoral dissertation, Jilin University,* pp. 112-150.

[10] S. Hu, J. Yang, and J. Zuo, "Indicator system and evaluation model of independent innovation capability of high-tech zones," *Journal of Wuhan University of Technology (Information & Management Engineering Edition),* 2010. vol. 32, no. 6, pp. 974-977.

[11] Y. Fang and F. Liu, "Research on the evaluation of innovation capability in China's national high-tech zones," *Journal of Dalian University of Technology (Social Sciences),* 2014, vol. 35, no. 4, pp. 26-32.

[12] J.-X. Zhang and Y. Chen, "Evaluation of innovative industrial clusters cultivation capacity in national high-tech zones," *Science and Technology Management Research,* 2022, vol. 20, pp. 57-64.

[13] L. Zhang, C. Guo, C. Wang, Y. Shang, and J. Jia, "Evaluation of innovation capacity of national high-tech zones in Shandong Province based on efficacy coefficient method," *Science and Management,* 2022, vol. 06, pp. 85-92.

[14] Y. Guo and X. Wang, "Research the indexes of innovation capacity evaluation systems of high-tech zones in Henan Province," *Henan Science and Technology,* 2022, vol. 05, pp. 154-157.

[15] F. Ren, "Research on constructing an evaluation index system of the innovation ability of high-tech zones," *Enterprise Technology and Development,* 2020, vol. 06, pp. 25-29.

[16] Q. Ding, "Evaluation of innovation capacity of national high-tech zones based on DEA-Malmquist index," *Modern Business Industry,* 2019, vol. 35, pp. 10-12.

[17] C. Su, J. Xie, and S. Hu, "Research on the evaluation of the innovation capacity of high-tech zones in the city cluster in the middle reaches of the Yangtze River based on the Catastrophe progression method," *Value Engineering,* 2018, vol. 12, pp. 234-237.

[18] L. A. Zadeh, "Fuzzy sets," *Information Control,* 1965, vol. 8, pp. 338-353.

[19] J. C. Bezdek, "Pattern recognition with fuzzy objective function algorithms." *New York: Plenum Press,* 1981.

[20] R. Krishnapuram and J. A. Keller, "Possibilistic approach to clustering," *IEEE Transactions on Fuzzy Systems,* 1993, vol. 1, no. 2, pp. 98-110.

[21] P. Kaur and A. A. Gosain, "Density-oriented fuzzy c-means clustering algorithm for recognizing original cluster shapes from noisy data," *International Journal of Innovative Computing and Applications*, 2011, vol. 3, no. 2, pp. 77-87.

[22] J. L. Xie and S. H. Hu, "Research on the 'double-four' structure of the national high-tech zone innovation network and its factor correlation," *Modernization of Management,* 2014, vol. 1, pp. 45-47.

[23] J. Xie and S. Hu, "Research on the structural framework and operation mechanism of the national high-tech zone innovation system," *Economic System Reform,* 2014, vol. 2, pp. 97-101.

[24] J. Xie, S. Hu, and Y. Y. Jiang, “A study on the spatial differentiation of competitiveness of national high-tech zones based on the Catastrophe progression method,” *Science and Technology Management,* 2011, vol. 12, pp. 101-108.

[25] L. Yang and D. Wang, “Research on enhancing e-commerce collaborative innovation capability in countries along the 'Belt and Road,” *Resource Development and Market,* 2019, vol. 04, pp. 533-542.

[26] J. Zhang and Y. Chen, “Evaluation of innovative industrial clusters cultivation capability in national high-tech zones,” *Science and Technology Management Research,* 2022, vol. 20, pp. 57-64.

[27] Y. W. Zhang and L. Wang, “Research on the evaluation index system of regional innovation capability in Gansu Province,” *Gansu Science and Technology,* 2022, vol. 11, pp. 47-52.

[28] W. Fu and L. Chu, “Research on the Evaluation of High-quality Development of the Manufacturing Industry under the Perspective of Yangtze River Delta Integration - TOPSIS Evaluation Model Based on Improved CRITIC-Entropy Weight Method Combined Weights,” *Industrial Technology and Economics,* 2020, vol. 09, pp. 145-152.

[29] S. Zhang, M. Zhang, and G. T. Chi, “Science and technology evaluation model based on entropy weight method and its empirical research,” *Journal of Management,* 2010, vol. 01, pp. 34-42.

[30] J. L. Xie, S. H. Hu, and Y. Y. Jiang, “Research on the spatial differentiation of national high-tech zone competitiveness based on the catastrophe progression method,” *Science of Science and Management of S & T,* 2011, vol. 32, no. 12, pp. 101-108.