Problem Chosen	2022	Team Control Number
B	MCM/ICM Summary Sheet	220XXXX

The secret to win “war for talent”

Summary

Talent is a vital resource for a city’s development. Generally, a healthy, sustainable talent flow pattern plays an important role in a city’s talent eco-health. In this article, we develop a series of models to evaluate the eco-health status of talent in a city, provide rational solutions for establishing a healthy and sustainable talent introduction pattern, and improve it to make a reasonable prediction.For question 1, five aspects: economy, science and innovation, social culture, life, and natural environment are taken as standards and 11 inferior indicators are used to assess the talent health status of the city. Using Entropy-based TOPSIS method, we build **Model I: Talent Eco-health Grading Model,** and obtain weights of each indicators and scores of the 36 selected cities. Cities are divided into three grades according to their scores. Among them, Xi’an scores 0.0367 with B grade, which indicates much room for improvement.

For questions 2 & 3, based on model I, we divide the 36 cities into 7 different regions according to their grades and geographical locations, introduce sustainability indicators to reflect the strength of the city’s sustainable development ability, and establish **Model II: Talent Eco-health and Sustainability Evaluation Model.** A comprehensive evaluation matrix of talent eco-health and sustainability indicators is made to help give our 6 reasonable suggestions for the development of Xi’an from five aspects in terms of health and sustainability.

For questions 4, 5 & 6, based on models I & II and the Logistic Equation, talent eco-health growth factor, talent growth resistance factor, and city competitiveness factor are introduced to build the **Model III: City Talent Competition Model.** Hoping that Xi’an’s score to be raised from current 0.0367 to 0.06, the lower limit of A-class city, we frame measures based on the Model II, which will be taken in years 5, 10, and 15, respectively. Results of the Model III show significant improvements of eco-health in Xi’an, where reach the level of an A-class in the 17^{th} year after measures taken. With realistic factors considered, the growth rate of Xi’an’s talent eco-health score slows down in the short term, but it still reaches the level of A-class cities in the 19^{th} year.

For question 7, we select five new first-tier cities, Zhengzhou, Changsha, Shenyang, Qingdao, and Foshan, to assess the applicability of the model we develop. The scores obtained from Model I are 0.0336, 0.0319, 0.0276, 0.0297, and 0.0241, all of which are B grades, suggesting the city eco-health level needs to be improved. Reasonable suggestions are provided based on Model II. Using Model III to make predictions, we find that if the same policies as Xi’an are used, Zhengzhou and Changsha can reach the level of A-class cities in the next twenty years. For Shenyang and Qingdao, we suggest extending the targeted plan to 30 years. For Foshan, we provide a new strategy due to its weaker initial conditions compared to the other cities. In the end, with the policy adjustments, all five new Tier 1 cities can reach talent eco-health of A-class city.

Keywords: Talent eco-health, Entropy-based TOPSIS, City competition model, GE matrix.

Contents

1 Introduction

1.1 Problem Background

"Development is the first priority, talent is the first resource, and innovation is the first driving force." In recent years, the "War for Talents" launched by Wuhan, Xi'an, Zhengzhou and other cities has continued to attract social attention. Several cities have introduced preferential policies in terms of household registration, housing, education and subsidies to attract quality talents. Among them, not only Chengdu, Chongqing and other cities respond to it, first-tier cities like Guangzhou, Shenzhen also get involved. A new policy from Shanghai, regarding significant reduction in the restrictions on fresh graduates from prestigious universities, pushed the social discussion to new highs.

One of the reasons for the hunger for talents is that the severely aging household population can no longer afford to dominate competitions between cities, where have to rely on the foreign population to invigorate innovation in the future. On the other hand, this phenomenon also reflects the rising demand for highly skilled and innovative talents, under the guidance of national innovation-driven development strategy. Whether it is a city with traditional industry or a new one, absorbing quality human resources is the one and only way to enhance the competitiveness of the city.

However, ever-increasing monetary subsidies are not the best way for cities to attract talent. It is necessary for city managers to establish long-term, sustainable and healthy talent strategies, and avoid the short-sighted effects of policy incentives.

1.2 Restatement of the Problem

Considering the background information and restricted conditions identified in the problem statement, we simplify our team's 3 tasks below:

- **Task 1**

  Develop and validate a model to assess the the current health status of talent situation in Xi'an to solve Problem 1.

- **Task 2**

  Propose an available and reasonable vision for a healthy and sustainable talent introduction policy system in Xi'an, and use our model to measure it. In this task, Problem 2 & 3 will be solved.

- **Task 3**

  Propose a healthy and sustainable system .Give targeted policies and implementation timelines to support change from the current state to the state we pro-posed.Using the model in Task 1 to shape and evaluate the effectiveness of our policies.Discuss the impact of implementing our plans on realistic urban talent pattern in the transitional state and in the end state respectively. This task covers Problem 4,5 & 6.

- **Task 4**

  Apply our model to at least 5 of the 15 new first-tier cities (Chengdu, Chongqing, Hangzhou, Wuhan, Xi'an, Tianjin, Suzhou, Nanjing, Zhengzhou, Changsha, Dongguan, Shenyang, Qingdao, Hefei, Foshan) and analyze its applicability. We will solve Problem 7 in this task.

1.3 Literature Review

Nowadays, the competition for talent has been a worldwide trend, and governments are competing for talent by implementing different measures. By comparing the talent scramble policies implemented by cities, Shari Chen et al. suggested that these policies are an important reason for the variability of city development[1].In other words, there may be both positive and negative effects of the implementation of talent policies.As for the reasons for the implementation of talent scramble policies, the studies point out that the direct motive of talent scramble is the decay of talent dividend, the indirect push is the pressure of local real estate, the macro orientation is the demand of China's economic restructuring, and the deeper main reasons are that talent is the first resource for development. Meanwhile, some scholars also analyzed the obstacles and problems in the implementation of talent policy and explored the effective path of talent incentive[2]. Based on the theory of economic double cycle and talent flow, Ke Jianglin and Sun Renbin put forward the concept of talent flow double cycle, which is a new pattern of talent flow with "the domestic talent flow cycle as the main one and the domestic and international talent flow cycles promoting each other[3]". They proposed that we should draw on the domestic and international practical experiences in policy system, platform, mobility model and incentive mechanism to build a more open, inclusive and sustainable talent flow dual cycle ecosystem.

1.4 Our work

For Task 1, we select five aspects: economy, science and innovation, society and culture, life, and natural environment - to measure the health status of a city's talent. For each aspect, 2 3 inferior evaluation indicators are selected to construct our evaluation system. Based on the TOPSIS method, the entropy weighting method is used to obtain the weight of each indicator and scores of the 36 selected cities. Then the cities are divided into 3 grades according to their scores. Finally, the model is used to evaluate the talent health status of Xi'an.

For task 2, on the basis of model one, we build a talent eco-health and sustainability evaluation model. The 36 cities are divided into different regions according to their grades and geographical locations, and sustainability indicators are introduced to reflect the strength of the cities' sustainability. Then, a comprehensive evaluation matrix of health and sustainability indicators is made. Finally, reasonable suggestions are given for the future development of Xi'an from these two dimensions.

For task 3, we establish a talent competition model based on models 1 & 2 as well as Logistic Equation. And we propose targeted policies with corresponding timetables. The talent eco-health growth factor γ, talent growth resistance factor α, and city competitiveness factor σ are introduced to establish differential equations for prediction. The measures given in Model II are expected to be taken to improve the talent eco-health level of the city in years 5, 10, and 15, respectively. We use the model to analyze the changes in the short-term and long-term, which involves realistic factors like epidemic and other unexpected events.

For task 4, we select five new first-tier cities, Zhengzhou, Changsha, Shenyang, Qingdao, and Foshan, to evaluate the applicability of our model. And we make predictions on the future changes of these five cities.

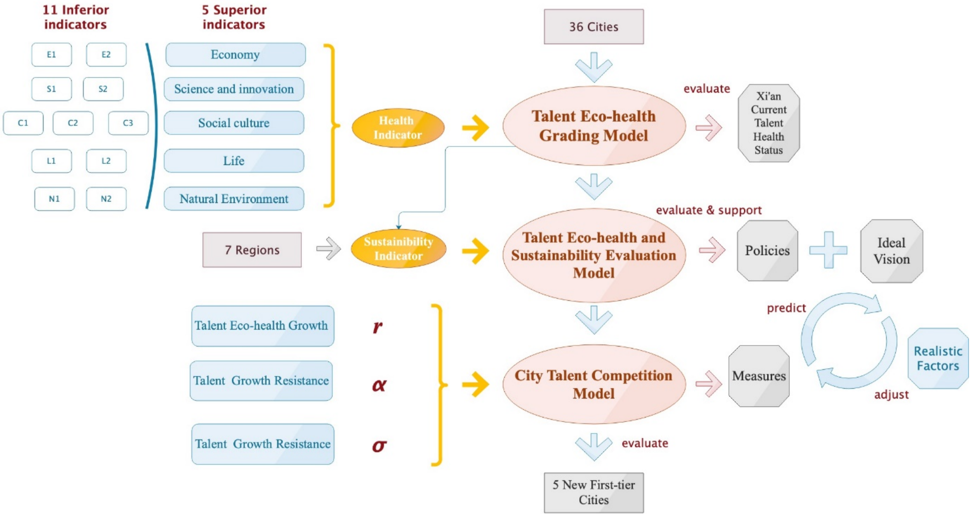


Figure 1: Our work

2 Assumptions and Justifications

To simplify the given problems and modify it more appropriate for simulating real life conditions, we make the following basic hypotheses.

1. **The indicators selected for the evaluation model are robust and do not fluctuate drastically over time.** The selected features do not produce sudden changes in quantity in a short period of time. That is, they do not increase or decrease suddenly, but are at a relatively stable level.

2. **Cities that belong to the same administrative region have the same regional advantages.** For the convenience of our study, differences in regional advantages between cities are ignored and a city is supposed to have the same geographical advantage as the other cities in its administrative region.

3. **The talent resource of the society is stable in the short term.** In a period of time, the number of talents in the society is stable. No unexpected events affecting social talent resources is considered and thus no large-scale change of talent will happen.

4. **Policies proposed in this article have no side-effects.** When measures taken, the city will grow in a healthy and sustainable direction as expected, without side effects or negative effects complicating the situations.

3 Notations

The key mathematical notations used in this paper are listed in Table 1.

Table 1: Notations

Symbol	Definition
e_j	Information entropy for the j-th indicator
P_{ij}	Proportion of i class cities in j region
α	Talent growth resistance factor
σ	City competitiveness factor
γ	Talent eco-health growth factor

4 Model I: Talent Eco-health Grading Model

4.1 Evaluation Indicators Description

Assessing the current talent state of a city and its health needs consideration from several aspects. By referring to information and thinking, we select five indicators to measure the health of a city's talent: economy, science and innovation, society and culture, life, as well as natural ecology. Our data comes from *the China City Statistical Yearbook 2020, and the Statistical Communique of the People's Republic of China on the National Economic and Social Development* of each city.

Here we will introduce the inferior indicators we select. After that, weights of each superior and inferior indicators will be calculated using entropy-based TOPSIS in the next section.

Our model will be construct based on 5 superior indicators, which are determined by 11 specific inferior indicators. We are going to discuss about them in detail.

• **Economy**

The economy reflects the development level of the city. This indicator reflects whether the city can satisfy the demand of talent's salary and life quality in financial aspects. Accordingly, we choose: GDP per capital(E1) reflecting city development quality, number of A-share companies(E2) reflecting the economic vitality of the city.

• **Science and innovation**

Science and innovation reflects whether there is a strong academic or science and innovation atmosphere, and whether there is a suitable research environment provided, including incentives, equipment,etc. A health status of talent should be full of science and innovation vitality. Accordingly, we choose: number of R&D personnel(S1), number of pa-tent applications(S2).

• **Social culture**

Talents need social security in infrastructure which is related to livelihood issue. Health care and education are indispensable parts when measuring health status of talent in a city. Accordingly, we choose: number of hospitals(C1), number of higher education institutions(C2) , number of vocational education colleges(C3), reflecting a city's investment in these aspects.

• **Life**

As part of the social group, daily life quality in a city also shows its health status of talent. Accordingly, we choose: total retail sales of consumer goods(L1) reflecting the sup-ply of consumer goods and shopping conditions in the city, the saleable area of commercial housing(L2) reflecting the adequacy of habitable area.

• **Natural environment**

Many people care about the natural environment ecology, whose good or bad reflects the quality of life in a city. The area of green space examines the size of the area available for talents to relax and unwind. Industrial wastewater discharge reflects whether the city's industrial pollution is serious. Accordingly, we choose: green area(N1), industrial wastewater discharge(N2).

4.2 Construction of Model I

We consider using AHP (Analytic Hierarchy Process) or TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) to evaluate ecological health of talent. However, the judgment matrix in AHP relies on experts, whose subjectivity can have a great impact on the results. Therefore, TOPSIS is used to build our model. In order to avoid the shortcoming of TOPSIS that it cannot weight the indicators, we combine the entropy weight method to improve it, and then determine the weights of the indicators.

The entropy-based TOPSIS is divided into the following steps:

Step1: Unify the indicator types

In general, the indicators are classified into two types: benefit and cost. The benefit indicators means that a higher value is better while for the cost criterion is valid the opposite.

Cost indicators are all converted into benefit types. Then, we get positive-index matrix D.

$$X = \begin{array}{c c} & \begin{array}{cccc} A_1 & \cdots & \cdots & A_m \end{array} \\ \begin{array}{c} C_1 \\ \vdots \\ \vdots \\ C_n \end{array} & \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{pmatrix} \end{array}$$

Step2: Normalize the matrix X

The data of the decision matrix D come from different sources, so it is necessary to normalize it in order to transform it into a dimensionless matrix, which allow the comparison of the various criteria. In this work, we use the normalized decision matrix $\tilde{z} = \left[z_{ij}\right]_{m\times n}$ with i=1,..,n, and j=1,...,m. The normalized value is calculated as:

$$\tilde{z}_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{n} x_{ij}^2} \tag{1}$$

Step3: Calculate probability matrix P

$\tilde{P} = \left[p_{ij}\right]_{m\times n}$ with i=1,..,n, and j=1,...,n. The value p_{ij} is calculated as:

$$p_{ij} = \tilde{z}_{ij} / \sum_{i=1}^{n} \tilde{z}_{ij} \tag{2}$$

Step4: Calculate the entropy weight of each indicator

For the j-th indicator, the information entropy is defined as:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) (j = 1, 2, \cdots, m) \tag{3}$$

Utility value is defined as:

$$d_j = 1 - e_j \tag{4}$$

Normalize it and we can obtain entropy weight:

$$W_j = d_j / \sum_{j=1}^{n} d_j \, (j = 1, 2, \cdots, m) \tag{5}$$

Step5: Score using TOPSIS

Identify the maximal value Z^+ and minimal value Z^- as follows:

$$Z^+ = \left(Z_1^+, Z_2^+, \cdots, Z_m^+\right) = (\max\{z_{11}, z_{21}, \cdots z_{n1}\}, \max\{z_{12}, z_{22}, \cdots z_{n2}\}, \cdots, \max\{z_{1m}, z_{2m}, \cdots z_{nm}\})$$

$$Z^- = \left(Z_1^-, Z_2^-, \cdots, Z_m^-\right) = (\min\{z_{11}, z_{21}, \cdots z_{n1}\}, \min\{z_{12}, z_{22}, \cdots z_{n2}\}, \cdots, \min\{z_{1m}, z_{2m}, \cdots z_{nm}\})$$

Calculate the Euclidean distances from the maximal value Z^+ and minimal value Z^- of each evaluation object Ai , respectively as follows:

$$\begin{aligned} D_i^+ &= \sqrt{\sum_{j=1}^{m} W_j \left(Z_j^+ - z_{ij}\right)^2} \\ D_i^- &= \sqrt{\sum_{j=1}^{m} W_j \left(Z_j^- - z_{ij}\right)^2} \end{aligned} \tag{6}$$

Finally, we can calculate the score of evaluation object Ai as given by:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{7}$$

And normalize it as follows:

$$\tilde{S}_i = S_i / \sum_{i=1}^{n} S_i \tag{8}$$

4.3 Result and Analysis

Figure 2: Distribution of 36 cities selected (Deeper color means more selected cities in the area)

36 major cities in China are selected for evaluation and 11 indicators are used to measure these cities' ecological health of talent. We fill the missing data with mean value. To present it clearly, we divide the scores into 3 interval bands using hierarchical clustering. In descending order, the three grads of ecological health of talent are excellent(A), good(B), and improvable(C). The intervals of the scores are listed in the following table:

Table 2: Talent Ecological Health Scale

Grades	A	B	C
Value	> 0.06	$0.02 \sim 0.06$	< 0.02

Among these 36 cities, top 12 cities with higher scores are made into bar charts as below:

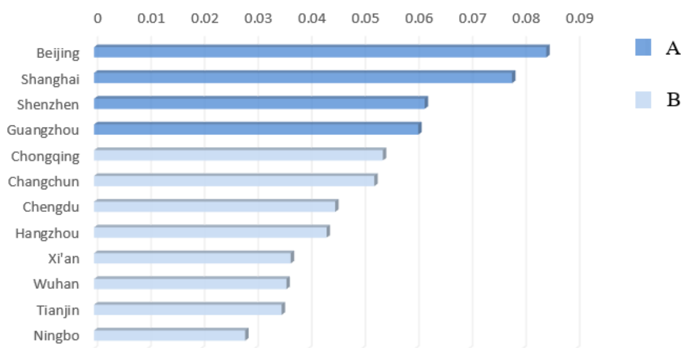


Figure 3: Score of Talent Ecological Health for top 12 cities

From the figure above, Shanghai, Beijing, Guangzhou and Shenzhen rank A, Chongqing, Changchun, Chengdu, Hangzhou and Xi'an rank B, and Xianyang, Urumqi, Lanzhou and Hohhot rank C. Among them, Beijing and Shanghai have the best talent ecological health with scores of 0.0844 and 0.0780 respectively.

We can derive the weight of each indicator in the 11 indicators with entropy weighting method, and the results are shown as follows:

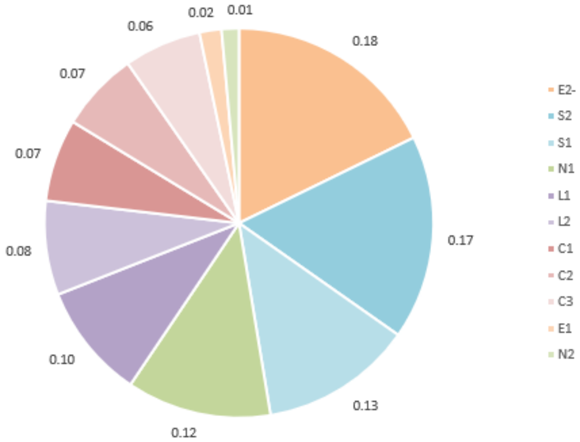


Figure 4: Weights for11 talent ecological indicators

The weight of each indicator shows that among the 11 indicators, A-share listed companies, number of patent applications(S2), number of R&D personnel(S1) and green area(N1) have the weight greater than 10%, so they are considered the most important factors for ecological health of talent. As for five superior indicator, science and innovation ranks top with weight of 29.6%. Next comes the social culture and economy, with the weight of 19.9% and 19.6% respectively. To sum up, the enhancements of these three aspects: Science and innovation, social culture, and economy, is most helpful for a city to improve ecological health of talent and its attraction.

Comprehensive evaluation model of talent ecological health level and sustainability

5 Model II: Talent Eco-health and Sustainability Evaluation Model

5.1 Construction of Model II

The regional advantage of a city means that the city is located in a good geographical location, often with city partners around who can cooperate to form urban clusters. A strong urban cluster has a great attraction to talents. The formation of urban clusters makes the city basically meet the conditions of sustainable development in natural, social and economic aspects. So we use this indicator to evaluate the strength of sustainability of a city.

According to the results of the talent ecological health model (Model I), the regional characteristics are presented as follows:

- **High in the south and low in the north, with the eastern regional center leading**

The difference between the South and North China is relatively significant, but the difference between cities within their respective South and North regions is more consistent.

- **Slight city-level differences between the central and western regions**

The difference in talent ecology scores between the central and western region is not significant. However, the degree of differentiation among cities within the same region gradually decreases from east to west: the cities in the east have the largest differences in index levels, followed by the central region, and the smallest differences in the west.

The major cities of three economic regions: Beijing-Tianjin-Hebei Region, Yangtze River Delta and Pearl River Delta constitute the first echelon. These three regions are the pioneer areas of China's economic development, with higher levels of economic and social development, more complete industrial systems, and industrial structures that are more attractive to talents.

It can be seen that the eastern high-level talent eco-belt is nearly completed, and the coastal regions have definite advantages. With developed economic base and superior location, the eastern cities occupy absolute advantages in the sustainability of development.

As a result, we suspect the regional advantages, also the sustainability indicator, of cities have a very important influence on the attraction of talents. We now divide the selected cities based on seven different Chinese administrative divisions, namely, East China, Northwest China, North China, South China, Southwest China, Northeast China, and Central China.

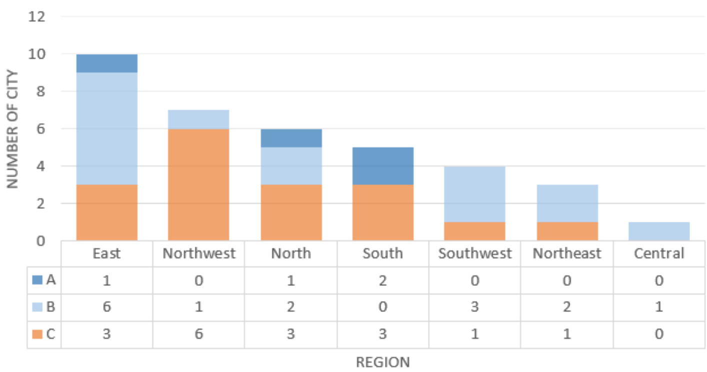


Figure 5: Distribute of Different Health level cities in Regions

Regional grades are calculated as follows:

$$G_j = \sum_{i=A,B,C} S_i P_{ij} \tag{9}$$

Where S_A, S_B, S_C refers to normalized weights for average scores of health status of A,B,C-class cities, and P_{ij} is the proportion of the number of i-class cities in the j-th region.

5.2 Solution of Problem 2

Undoubtedly, in order to support better support a healthy and sustainable talent introduction policy system, it is necessary to go further in the performance of economy, science and innovation, life, social culture and natural environment.

In the City Talent Ecological Health Assessment Model, Xi'an scores 0.0367, and gets a B health grade.

5.2.1 Vision of Talent System in Xi'an

The following describes our vision of Xi'an in each of the five aspects:

- **Economy**

After accelerating the upgrade and transformation of the industrial structure, the service industry is more promising. At the same time, high-end enterprises of Xi'an in the Internet and finance fields play a leading role. With the introduction of a large number of foreign companies, economic vitality increase significantly. As a result, Xi'an's urban GNP is greatly improved, and both GDP per capita and the number of A-share companies are expected to reach the average level of the current four A-class cities.

• **Science and innovation**

Xi'an increase the number of research institutes, create a stronger research atmosphere, and pay its researchers higher, which attracts talents from all over the country. The number of R&D personnel and the number of patent applications reach the same as Chengdu, an-other B-class and also first-tier city in western region in China.

• **Social culture**

Xi'an stress medical research and development. After the COVID-19 epidemic, Xi'an improve the medical system and strictly examines hospitals, ensuring the medical care for the citizens and alleviating the "difficult to see a doctor". Hospitals are reasonably distributed in the city, with the number of it reaching 400. Meanwhile, the number of higher education institutions rise to 80, and the middle vocational and technical schools are upgraded and its number rise to 180, due to the emphasis of the training of vocational and technical talents in Xi'an.

• **Life**

The income of Xi'an residents increase, prices are stable and the living standard has improved. Total sales of consumer goods are expected to match the consumption level of Chengdu, a first-tier city in the west. Xi'an develop the real estate industry, secure that talents settle down, and raise the sales area of commercial houses to 35 million square meters.

• **Natural environment**

Xi'an highlights ecological construction and sustainable development. It supervises the emissions of industrial enterprises and reduces industrial wastewater emissions to 20 mil-lion tons. Xi'an reasonably protects wetlands and forest resources, and increases the proportion of artificial green areas, which is expected to reach the average of the A-class cities. Specific values are listed in the following table8:

Table 3: Indicator-based Vision of Talent Eco-health in Xi'an

Superior indicator	Inferior indicator	Current	Ideal
Economy	GDP per capital (million yuan)	931.7742	1690.31
	Number of A-share companies (piece)	47	325
Science and innovation	Number of R&D personnel (piece)	107385	145950
	Number of patent applications (piece)	72377	80819
Social culture	Number of hospitals (piece)	359	400
	Number of higher education institutions (piece)	63	80
	Number of vocational education colleges (piece)	157	180
Life	Total retail sales of consumer goods (million yuan)	514092.8	831340.2
	Saleable area of commercial housing (million square meter)	2713	3500

Natural environment	Green area (hectare)	31994	122980
	Industrial wastewater discharge (million tons)	39.14	20.00

Taking Beijing's 11 indicators as a benchmark, we plot the radar map of Xi'an's current status and vision. As it can be seen, the shape remains largely unchanged, which reflects the feasibility of our vision. The shortcomings of Xi'an talent ecosystems, such as the green area(N1) and the number of A-share companies(E1) are greatly improved, while other indicators still maintain their relative strengths.

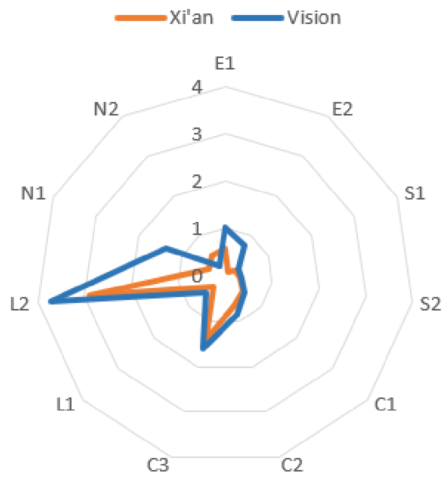


Figure 6: Xi'an rader map of current talent ecosystem and vision(Beijing as benchmark)

5.2.2 Talent Introduction Decision System

The GE Matrix is a portfolio approach developed by General Electric (GE) in the 1970s, which is vital for companies to make business selection and positioning. Based on this matrix, we construct a talent introduction decision matrix. With a broad and flexible definition of sustainability and talent eco-health, the GE matrix can serve as a basis for strategic planning.

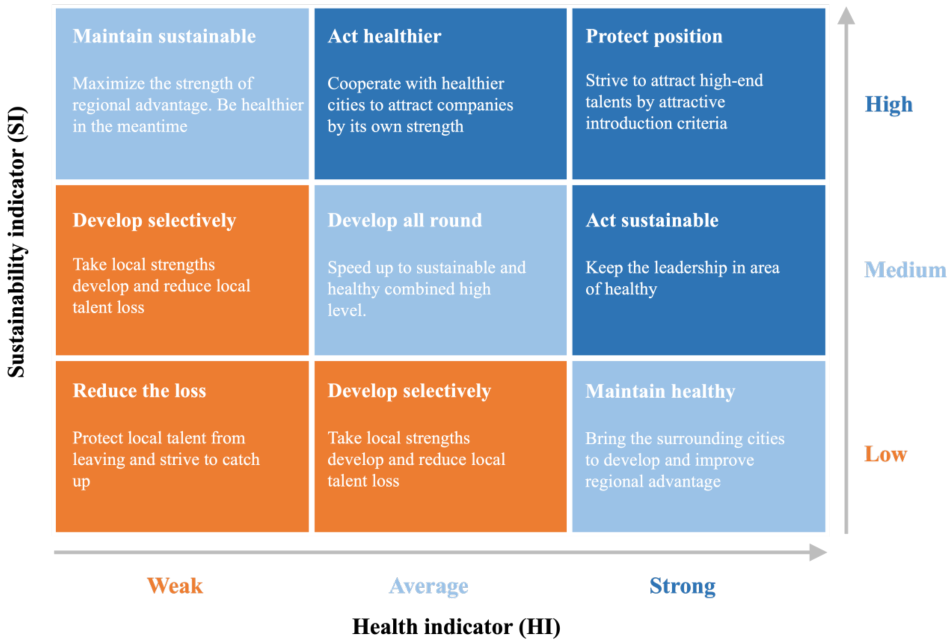


Figure 7: Talent introduction matrix

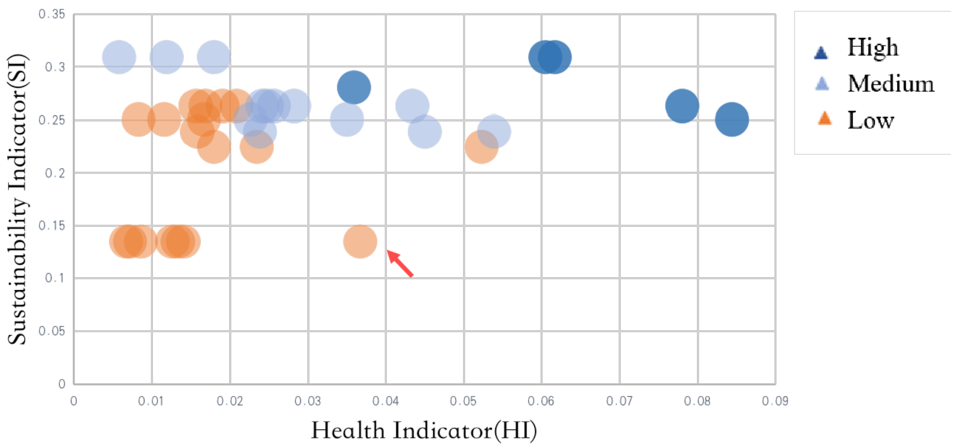


Figure 8: SI and HI scores of 36 cities

Given an orthogonal coordinate, it can be seen from the figure that the closer to the upper right corner, the better the city performs in terms of health and sustainability. We assume that the optimal point is (HI_{opt}, SI_{opt}). Then we define the shortest distance from a city to the optimal point d as follows:

$$|\vec{d}| = \sqrt{(HI - HI_{opt})^2 + (SI - SI_{opt})^2} \tag{10}$$

We optimize along this path, and the smaller fluctuation, the faster the city progresses in attracting talent.

5.3 Solution of Problem 3

5.3.1 Current talent health status of Xi'an Analysis

According to the results in model I, we can see that Xi'an get B grade in talent ecological health status. Among them, A-share listed companies, number of patent applications, number of R&D personnel and green area have extremely important effects on score. However, among the 36 cities we select, Xi'an ranks 16, 10, 8 and 11 in these four indicators, respectively. It can be seen that Xi'an is near the front rank of talent health status among 36 cities, but it still has some room for improvement to be the top.

Based on the results of model 1, we calculate S_A,S_B,S_C, with values of 0.07115, 0.03303, 0.01292, respectively. Now using model II, we can calculate the score of seven regions and the outcomes are as shown in the table below:

Table 4: Regional Grades of Talent Eco-health and Sustainability

Region(China)	**Score(SI)**	**Grade**
South	0.31	High
Central	0.28	High
East	0.26	Medium
North	0.25	Medium
Southwest	0.24	Medium
Northeast	0.22	Low
Northwest	0.13	Low

Table 5: City Location Attractiveness Scale

Grade	High	Medium	Low
Value	> 0.27	$0.23 \sim 0.27$	< 0.23

From the results above, it can be seen that Northwest Region, where Xi'an belongs to, scores lowest with "Low" Grade. It reflects that Xi'an has little regional advantages in talent eco-health and sustainability over other cities.

5.3.2 Sustainable Policies in Xi'an

Xi'an ranks first in the talent ecological health evaluation among cities in the northwest region. How could Xi'an use its regional advantages to attract talent is the key points of our following research.

- **Integration into city cluster construction**

A city cluster is a large, multi-core, multi-level urban grouping of several geographically concentrated mega-cities and large cities, and is a combination of metropolitan areas. The performance of a city in or near a city cluster can better reflect the locational attractiveness of this city.

Some of our selected cities belong to the Pearl River Delta Cluster, Guanzhong City Cluster, Yangtze River Delta City Cluster, etc. It can be seen that the city clusters present a state of aggregation. For the city cluster development benefits, the Guanzhong Plain City Cluster Development Plan was approved by the State Council in 2017, which clearly set a goal of turning

Xi'an into a national central city. in 2019, the population of Xi'an exceeds 10 million. Xi'an has already set Yanliang, Zhouzhi and Lantian as administrative areas in the past few years, and cooperate with neighboring Xianyang to speed up the construction and development of Xi Xian New Area. These actions are effective, adding jobs and stabilizing tax revenues in the development of the Guanzhong city cluster. In addition, it rapidly making use of rich industrial land in Xi'an and drive the development of the service industry in surrounding areas.

- **Regional advantages of the center of the Silk Road Economic Belt**

The new Silk Road Economic Belt holds the Asia-Pacific economic circle in the east and ties the European economic circle in the west. As starting point of the road, Xi'an should play its regional advantages effectively, promote the interconnection of western cities, and create new growth points to accelerate the development of the northwest region.

- **Protection of Cultural Heritage**

Cultural heritage is an intrinsic motivation for a city's sustainable development. The rich historical and cultural heritage of Northwest China such as the Qin, Han and Tang sites needs to be preserved, and Xi'an should make efforts to create city-card of a historic city.

In addition, the decision matrix shows that Xi'an is at the stage of managing for earnings, so policies can be made to protect existing programs and concentrate investments in augments where profitability is good and risks are relatively low.

- **Encouragement of entrepreneurship**

Aimed at the problem of few listed companies, Xi'an can appropriately lowered.

the threshold of entrepreneurship by reducing registered capital or allowing registered capital installments. In this way, healthy competition among enterprises is encouraged, and the healthy development of small and medium-size companies is guaranteed, thus making the city's economy burst with vitality.

- **"green mountains are gold mountains"**

To address the problem of little green areas, Xi'an should improve the ecological environment, strictly control pollution emissions from heavy industries, build urban greenways and urban parks to enhance the living environment. It carries out river treatment, soil con-trol and forest protection on a regular basis, and vigorously implements projects such as mine restoration, and ecological restoration of wetlands and riverfront zones.

- **Reward for scientific and technological achievements transformation**

Outstanding scientific research teams could be encouraged with bonuses and honorary title of municipal level. Meanwhile, Xi'an can improve the title system as well as the treatment of professional scientific researchers to retain scientific talents. Appropriately improvements of the housing benefits for high-end talents, such as granting housing subsi-dies and settlement fees for those who meet the conditions, can also help increase the vi-tality of science and technology innovation in the city.

6 Model III: City Competitiveness Models

6.1 Construction of Model III

In 1789, the English priest Malthus proposed the Malthus model after analyzing demographic data over more than 100 years. Based on the Malthus model, mathematical biologist Pierre-Francois Verhulst proposed the Logistic Equation to better describe the population growth pattern. After that, Logistic Equation was widely used in the fields of economics, physics and so on.

The Logistic Equation is:

$$\begin{cases} \dfrac{dx}{dt} = \gamma\left(1 - \dfrac{x}{x_m}\right)x \\ x(t_0) = x_0 \end{cases} \tag{11}$$

where x_m is the maximum population that can be accommodated by natural resources and the environment.

However, if there are two or more populations in one natural environment, their relationships include competition, predation, and mutualism. We can use the Logistic Equation to build a talent growth model. However, considering the competition between cities and local talent cultivation as well as its outflow, we improve the talent growth model and pro-pose the Talent Competition Model.

In order to reflect the level of talent ecological health of a city and the degree of policies influence on it, we construct a talent competition model to visually describe it. In model I, we calculate the weights of economy, science and innovation, life, social culture and natural environment for evaluation of health status of talent. Their values are 0.20, 0.30, 0.17, 0.20 and 0.13, respectively, which can be classified into two major categories. One category is the city's own ability to cultivate talents, which is related to the level of science and innovation and the number of schools. The other category is the city's ability to attract foreign talents, including the level of economic development, quality and cost of living, and natural ecological environment.

Here we use two coefficients α and σ to express the quantitative influence level of these two types of factors. Among them is the talent growth resistance factor, which is re-sulted from the low quality of education, lack of scientific and creative ability and other factors caused by the city itself on the its talent growth. The greater the α ,the stronger the obstacle to the city talent growth. σ is the city competitiveness factor, which is positively associated with the city competitiveness. Additionally, γ_i is the talent eco-health growth factor, which reflects the growth rate of the city's health status of talent evaluation indicators due to policy and geographical location, etc.

We are going to research the competition between the selected city and other cities. We use α_i, σ_i, γ_i (i=1,2) and to represent the talent growth resistance factor, the city competitiveness factor, and the talent eco-health growth factor, respectively. When i =1,the factors refer to the selected city, while i =2 referring to the other cities. Then, we es-tablish the differential equation as follows:

$$\begin{cases} \dfrac{dx_1}{dt} = \gamma_1 x_1 (1 - \alpha_1 x_1 - \sigma_2 x_2) \\ \dfrac{dx_2}{dt} = \gamma_2 x_2 (1 - \alpha_2 x_2 - \sigma_1 x_1) \end{cases} \tag{12}$$

6.2 Solution of Problem 4 & 5

We construct a talent competition model between Xi'an and other cities, and the value of γ, α, σ in Xi'an and other cities are as follows:

Table 6: Values of factors (no measures taken)

Factor	γ	α	σ
Xi'an	0.02	0.8	0.2
Other cities	0.03	0.6	5

It can be seen that there is a gap between Xi'an and other A-class cities in terms of talent cultivation and attraction. In this regard, to help Xi'an improve its talent ecological health, we formulated a 20-year development plan. Measures will be taken in years 5, 10, and 15, respectively, so that its talent ecological health score would be higher than 0.06 in 20 years and reach the standard of an A-class city.

Based on the results of Model 2, we can raise the talent eco-health grow factor γ_1 of Xi'an to 0.05 by building city clusters and exploring the potential of regional advantages. Also, we can reduce the talent growth resistance factor α_1 of Xi'an to 0.3 by encouraging the transformation of technological achievements. Finally, through building a livable city image, improving ecology and building a national green city, the city competitiveness of Xi'an σ_1 can be enhanced to 5, while σ_2 changes into 0.2.

Table 7: Values of factors (measures taken)

Factor	γ	α	σ
Xi'an	0.05	0.3	5
Other cities	0.03	0.6	0.2

From Model 1, Xi'an's initial score is 0.0367 and we set the initial score of other cities to 0.5. If no measures are taken, Xi'an's score over the next 20 years is shown as following :

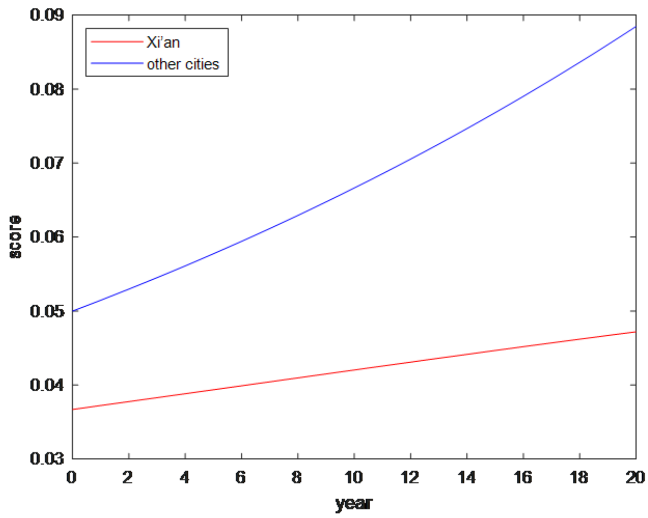


Figure 9: Xi'an's score over the next 20 years(no measures taken)

The figure shows that it will be difficult for Xi'an to reach the standard of an A-class within 20 years if we take no measures. city in the next twenty years From the figure, we can get that Xi'an's talent ecological health cannot reach the standard of an A-class city in the next twenty years when no measures are taken. Therefore, it is necessary to take actions stated above so as to improve the talent ecological health.

The adopted policies and targeted measures is illustrated in the following table:

Table 8: Timetable for measures

Time	**Measures**	**Goal**
5^{th} year	1.Play the role of the starting city to promote and advance the construction of the Silk Road Economic Belt. 2.Accelerate the construction of modern urban infrastructure and narrow the gap between urban and rural areas. 3.Lower the standards to set up factories as well as propose a series of preferences for foreign high-tech enterprises to attract investments. 4.Play a leading role as the center of Guanzhong city cluster, and cooperate with Xianyang, Baoji and other surrounding cities to form a mutually beneficial situation.	Increase γ_1
10^{th} year	1.Value higher education and provide subsidies for teachers in special situations. 2.Supervise and guarantee the quality of vocational education and speed up the upgrade of secondary vocational and technical colleges that meet the conditions into universities. 3.Encourage universities and research institutes to actively undertake the National Natural Science Foundation of China projects, etc. and improve the research environment.	Reduce α_1
15^{th} year	1.Secure city's talent housing, and plan urban land reasonably. 2.Protect urban green areas, actively build urban parks, relocate some industries and rehabilitate industrial land. 3.Promote the development of water conservancy projects and create a national sponge city. 4.Accelerate industrial upgrade and transformation: transit to service industry, protect historical relics and develop tourism.	Increase σ_1

After adopting and implementing targeted policies, Xi'an' score is shown below:

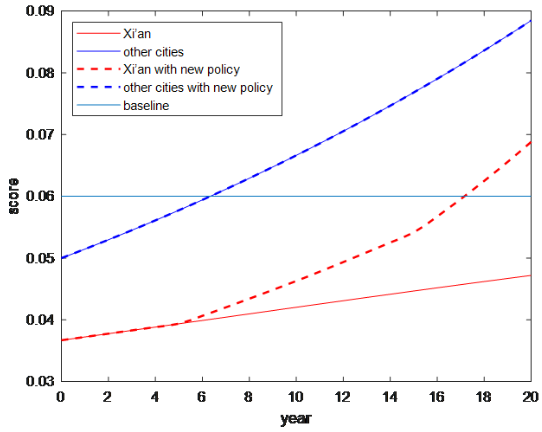


Figure 10: Xi'an's score over the next 20 years(measures taken)

From the figure, we can see that Xi'an's talent ecological health improve significantly in the next 20 years. In the 17_{th} year, Xi'an reach the talent eco-health level of A class. Be-cause other cities do not take measures, the change of the score curve is not obvious. How-ever, due to historical foundations and geographical reasons, Xi'an is not able to exceed them in a short term.

6.3 Solution of Problem 6

Considering that the implementation of the policy may be affected by realistic factors like epidemics, unexpected events, natural disasters, etc., measures cannot make a significant positive difference in a short term, so we lower the changes in the value of factors (Table 9) and get new score curves (Figure 11):

Table 9: Values of factors (realistic factors considered)

Factor	γ	α	σ
Xi'an(0)	0.02	0.3	0.2
Xi'an(5-8)	0.025	0.3	0.2
Xi'an(10-13)	0.025	0.6	0.2
Xi'an(15-17)	0.25	0.6	1
Other cities	0.03	0.6	5

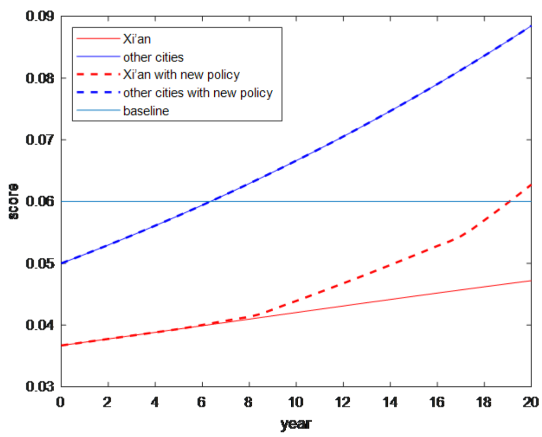


Figure 11: Xi'an's score over the next 20 years (realistic factors considered)

As can be seen from the figure, before the 8^{th} year, there is little difference between the original score and the new one. After the 15^{th} year of implementation of the polices, the score of talent eco-health level drastically increases and reaches the level of A-class cities in the 19^{th} year.

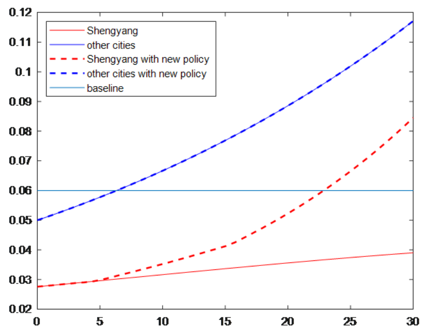
Although realistic factors have an impact on the effectiveness of the measures in the short term, increasing the time required for Xi'an to achieve the goal of becoming A-class city of talent health status. However, the desired target can still be reached eventually in the longer term.

7 Model Applicability Analysis

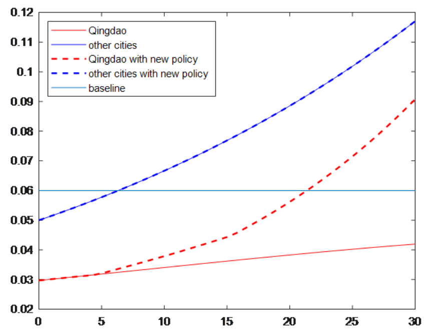
We apply our model to 15 new first-tier cities in China, including, Zhengzhou, Chang-sha, Shenyang, Qingdao, and Foshan, and score them using the entropy-based TOPSIS. Scores of these five cities are 0.0336, 0.0319, 0.0276, 0.0297, and 0.0241, respectively, and are dived into B-class of talent eco-health. Among them, Foshan is close to the Improvable (C) grade.

Based on the model III and the 20-year measures, we obtain curves for the scores of these five cities. Results shows that Zhengzhou and Changsha can reach the level of A(score>0.6) in the next 20 years of development if they adopt targeted measures. Shenyang, Qingdao and Foshan fail to reach the same results due to their weaker infrastructural capabilities. In this regard, we can extend our plan to 30 years or use new strategies, such as accelerating the construction of modern urban infrastructure, introducing foreign high-tech enterprises, protecting urban green areas, emphasizing higher education, and improving the research environment, to increase the growth factor of the city's talent eco-health γ, reduce the talent growth resistance factor α of the city, and improve the city competitiveness factor σ.

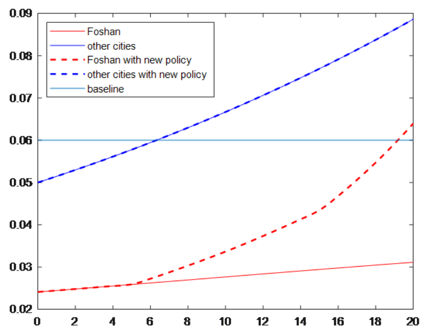
For of Shenyang and Qingdao, we extend the original strategy plan to 30 years. For Foshan, because its initial conditions are weaker than other cities, we adopt a new strategy. We increase its talent ecol-health growth rate by building city clusters and exploiting regional advantages, and raise γ to 0.08 in the 5^{th} year; we reduce its talent growth resistance by securing education quality, promoting higher education, and improving the research environment, and lower α to 0.15 in the 10th years. The latest score curves of these three cities are as follows:



(a) Shenyang



(b) Qingdao



(c) Foshan

Figure 12: Scores in next 20 years of Shengyang, Qingdao, Foshan

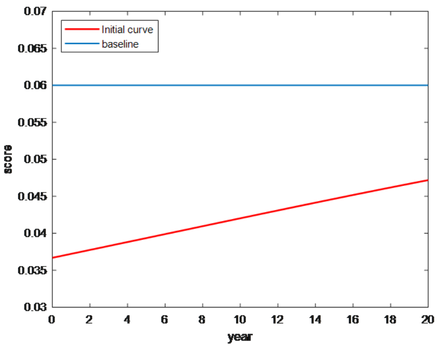
From the figure, it can be seen that Shenyang and Qingdao reach the A-class city level in the 22^{nd} year, while Foshan make it in the 19^{th} year after new measures taken.

Based on the results above, our model not play an important part in the development and policy-making for the talent eco-health in Xi'an, but also is applicable to other cities, indicating an excellent applicability.

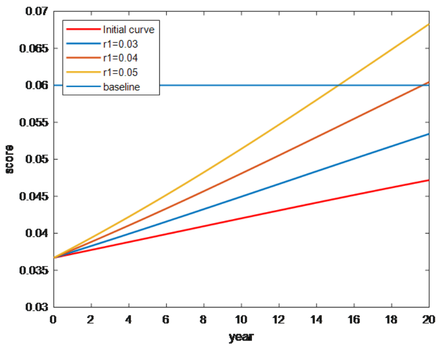
8 Sensitivity Analysis

In the previous section, we introduce talent eco-health growth factor, talent growth resistance factor, and city competitiveness factor to build model III: City Talent Competition Model. In this part, we will conduct selectivity analysis on this model.

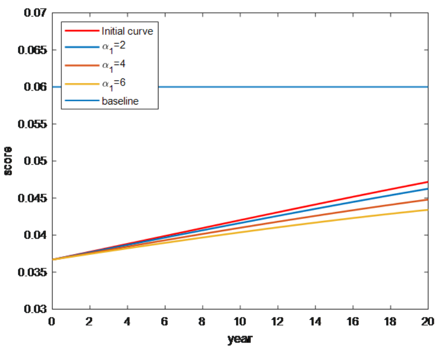
Taking Xi'an city as an example, with other parameters fixed, we gradually change γ, α, σ, respectively and observe the change of score in the next 20 years. For the initial value, γ_1=0.02, γ_2=0.03, α_1=0.8, α_2=0.6, σ_1=0.2, σ_2=5.



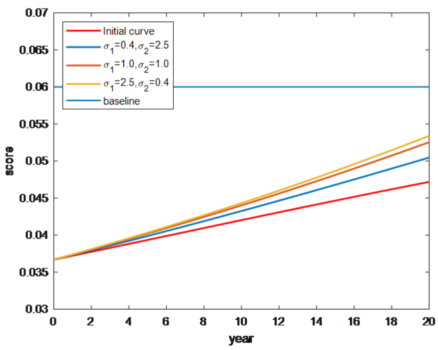
(a) Original



(b) change in γ



(c) change in α



(d) change in σ

Figure 13: Sensitivity Analysis(original, changes in γ,α,σ,from left to right, top to bottom)

As it can be seen, higher and lead to higher score in the 20^{th} year while higher results in lower score. Among the three factors, the model is the most sensitive to and comes second, the last. Therefore, measures such as accelerating the construction of modern ur-ban infrastructure, developing high-tech enterprises, and promoting economic construction are most important for the improvement of the city's talent health level.

However, changes in the each of the three factors alone have limited impact on the tal-ent eco-health. So comprehensive measures from all three aspects are proposed in the model II to facilitate the development for talent eco-health in Xi'an.

9 Model Evaluation and Further Discussion

9.1 Strengths

1. Using a two-layer evaluation system with 5 superior indicators and 11 inferior ones, we are able to gain a comprehensive and multidimensional insight into the talent eco-health evaluation.

2. We creatively combine the entropy method with TOPSIS, which can avoid personal biases and lead to more objective results.

3. By dividing cities according to geographical location, the model is simplified while cleverly integrates with Chinese current conditions of existing city clusters as well as the policies of the construction of new city clusters.

4. The talent introduction decision matrix can concisely and intuitively reflect the decision orientation of cities in different positions of the GE matrix.

5. The talent competition model is highly flexible, which can reflect changes in the talent eco-health level under unexpected factors at any point of time, merely through simple adjustments of its factors.

9.2 Weaknesses

1. Inferior indicators in model I are not adequate, and the may be easily influenced by a extreme value.

2. In model II, the changes in three factors are discrete and abrupt, which cannot accurately reflect the impacts of proposed measures and may lead to lager error.

9.3 Further Discussion

1. In the subsequent research, after gathering more data, more indicators like compensation level for talent can be taken into consideration. The model can also generalize to evaluate the growth pattern of talent between nations.

2. Our model can be used for other evaluation issues by modifying the indicators. The talent competition model can be used to solve problems such as analyzing group competition and cooperation in management or population interactions in biology.

References

[1] Ke Jianglin, Sun Renbin. Research on the double circulation system of talent flow driving high-quality economic development [J]. *New Vision*, 2021(06): 27-35.

[2] Chen Shali, LI Minglu. Regional Comparison and Policy Structure Preference of Talent Policy [J]. *China Science and Technology Forum*, 2009 (9): 107-111

[3] Massimiliano T. Migration Policy and Immigrant' Labor Market Performance [J]. *International Migration Review*, 2020, 54(1): 35-37.

[4] Barigozzi F, Burani N. Competition for Talent when Firms' Mission Matters[J]. *Games and Economic Behavior*, 2019(4): 128-151.

[5] Ng.Tee P. The Global War for Talent: Responses and Challenges in the Singapore Higher Education System[J]. *Journal of Higher Education Policy and Management*, 2013(3): 280-292.

[6] Yu Xiuyuan, Wang Kaiwei. Returning city people: Problem generation, Pros and cons, and Solutions[J]. *Chinese Public Administration*, 2019(3): 88-92.

[7] Gu Ling-li, Wang Jian-ping, Yang Xiao-ling. Research on the construction and application of the evaluation index System of the implementation effect of science and technology talent Policy[J]. *China Human Resources Development*, 2019(4): 100-108.

[8] Scullion H, Collings D G. Global Talent Management[J]. *Journal of World Business*, 2009, 45(2): 105-108