For office use only		Team Control Number	For office use only	
T1	_____	**58424**	F1	_____
T2	_____		F2	_____
T3	_____	Problem Chosen	F3	_____
T4	_____	**E**	F4	_____

2017

MCM/ICM

Summary Sheet

Our goal is to study the indicators of Smart Growth and further evaluate the success of smart growth of two cities with a population between 100,000 and 500,000 persons. We conduct models to analyze the statics from two cities' statistical bureau database.

Firstly, we polish Galster and Hanson's Urban Sprawl Index and set up the influencing factors of smart growth, including urban land output, urban employment, urban land revenue, Gini coefficient, corruption perception index, density, urban population expansion index, urban economic expansion index and air quality index. Then we employ a modified AHP model to get the weight value of each indicator. We set New York as benchmark to evaluate the two selected cities and New York, Philadelphia, Los Angeles, San Francisco, Denver, Miami. We testify the feasibility and reliability by comparing the results with Galster and Hanson's ranking for six cities. We also testify it with Sensitive Analysis.

Secondly, we select Jiayuguan City in China and Salt Lake City to do case study. Along with the Smart Growth Index, we measure the success of two cites' current plans. Then we adopt Grey Prediction Model to forecast future value of each indicator, which we associate with the background of the city including geography, the expected growth rate and economic opportunities to form our specific Smart Plans for two cities. Then we rank the initiatives of the smart growth plans with Principal Components Analysis.

Finally, we assume that there are additional 50% population in 2040, and our smart plan can perfectly support this kind of growth in the way of density, land use, economic growth, social equity and environment initiatives.

In summary, our paper considers multiple factors, our model is reliable and practical for handling smart growth in reality

Keywords: Smart Growth AHP Entropy Methods Grey Prediction

Contents

Introduction

Due to the rapid urban expansion, many countries are implementing smart growth initiatives in an effort to control urban sprawl. Smart Growth America promoted ten principles for smart growth. Specific objectives include four aspects: the protection of agricultural land; protection of the environment, including the natural ecological environment and cultural environment; the prosperity of the urban economy; improvement of the residents' life quality. Therefore, the smart growth is an efficient, intensive, compact urban development model.

Restatement of the Problems

We tackle three main subproblems:

- Build smart growth evaluation index which reflects economic prosperity, social equity, and environmental sustainability with optimal weight coefficient.
- Develop a growth plan for both cities over the next few decades according to smart growth principles by grey-prediction method.
- Analyze the individual initiatives within our redesigned smart growth plan as the most potential to the least potential by modelling and ranking.

TASK 1: The Smart Growth Metric

Literature Review

At present, the smart growth of the evaluation method has not yet formed a unified standard, different research organizations for different research purposes put forward their own urban growth evaluation method. However, the most representative one is the eight distinct dimensions of land use patterns: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity(Galster, et al,2001) [1]. Continuity, mixed uses and proximity are indexes of the urban land use structure, while the remaining five elements are related to the general meaning of urban land resource utilization. However, to evaluate a city's smart growth, we should also put emphasis on the improvement of productive efficiency in urban growth and human settlement. Thus, We optimize the eight dimensions and propose a metric with three-level evaluation system. And also taking the different indicators of interest between developing and developed countries into account, we have selected the indicators that two different types of countries both count to compose the metric.

Assumptions and Justifications

1. The data we extracted from the internet is all converted to the same metric.

2. we assume in our research period(2016-2030), there will not be any great climate change and political turmoil.
3. Some data was counted in metropolitan level, so it might not well reflect the situation of the urban area.

The Smart Growth Evaluation Index

Table 1.

The Smart Growth Evaluation Index

Goal	Criteria	Sub-criteria
Smart growth	Economic Prosperity	Urban Land Output
		Urban Employment
	Social Equity	Gini Coefficient
		Corruption Perception Index
		Health Insurance Coverage
	Environmental Sustainability	Urban Population Expansion Coefficient
		Urban economic expansion Coefficient
		density
		Air Quality Index

AHP Model

In this section, we applicate analytic hierarchy procession(AHP) as our main model to evaluate the smart growth plan of our chosen city. Meanwhile, we modify the AHP model by introducing entropy method to determine the significance of each indexes.

Entropy method and data preprocessing

Entropy is a measurement of disorder or randomness in the system. It can be used as a degree to determine the weight of each indexes. The application of this method incorporates three steps.

• Step 1. Normalize the row data.

Given m indexes and n evaluate objectives, we present it as matrix $A = [a_{ij}]_{m\times n}$.

After normalization, it comes out as matrix $R = [r_{ij}]_{m\times n}$. For index whose excellence is in positive correlation with its value, its normalization formula is

$$r_{ij} = \frac{a_{ij} - \min\limits_{j}\{a_{ij}\}}{\max\limits_{j}\{a_{ij}\} - \min\limits_{j}\{a_{ij}\}},$$

otherwise its normalization formula is $r_{ij} = \dfrac{\max\limits_{j}\{a_{ij}\} - a_{ij}}{\max\limits_{j}\{a_{ij}\} - \min\limits_{j}\{a_{ij}\}}$

• Step 2. Determine the entropy value of the index

In evaluation problems include m indexes and n evaluate objectives, the entropy value of the i[th] index $h_i = -k\sum_{j=1}^{n} f_{ij} \ln f_{ij}$, meanwhile $f_{ij} = r_{ij} / \sum_{j=1}^{n} r_{ij}$.

• Step 3. Determine weight of the index

The weight of the i[th] index $w_i = \dfrac{1-h_i}{m - \sum_{i=1}^{m} h_i} \left(0 \le w_i \le 1, \sum_{1}^{m} w_i = 1\right)$

(1) Economic Prosperity Index

a. Urban Land Output = Urban GDP / Urban construction land area Urban land output is the main criterion to evaluate the efficiency of urban growth. The higher the total economic output of unit land, the better the urban growth efficiency, and vice versa.

b. Urban Employment = Employment population / Urban construction land area Employment is an important factor in measuring the quality of urban growth.

The coefficient matrix $A_{ep} = \begin{pmatrix} 1 & 1.47 \\ 0.6803 & 1 \end{pmatrix}$

The weight vector $U_{ep} = [0.5951, 0.4049]^T$

Check the consistency $CR = 0.0000$

c. Urban Land Revenue = Urban Fiscal Revenue / Urban Construction Land area

(2) Social Equity Index

a. Gini Coefficient

Gini Coefficient represents the wealth distribution of a nation's residents, and is the most commonly used measure of inequality

b. Corruption Perceptions Index

c. Health Insurance Coverage

the coefficient matrix $A_{se} = \begin{pmatrix} 1 & 15.0400 & 3.6200 \\ 0.0665 & 1 & 0.2400 \\ 0.2762 & 4.1667 & 1 \end{pmatrix}$

The weight vector $U_{se} = [0.7446, 0.0495, 0.2059]^T$

Check the consistency $CR = 0.0000$

(3) Environmental sustainability Index

a. Urban Population Expansion Coefficient= Urban land use growth rate / Urban population growth rate the international standard is 1.12

From the perspective of land resource utilization, measuring the total change of urban growth mainly involves the urban land use, and controlling the total urban growth that is to occupy the land as little as possible.

b. Urban Economic Expansion Coefficient = Urban land use growth rate / Urban economic growth rate

It is a comprehensive measurement and of a city's urban land expansion motivation. At present, many urban construction land increased rapidly with lack in economic growth, which reflects the economic value of urban land is not fully reflected. And it is helpful to reflect the growth of urban construction land brought by economic growth, which makes the evaluation of urban growth intensity more comprehensive.

c. Density = Total Urban Population / Total land area

This index can better express the intensity of urban construction land exploitation.

The coefficient matrix $A_{se} = \begin{pmatrix} 1 & 15.0400 & 3.6200 \\ 0.0665 & 1 & 0.2400 \\ 0.2762 & 4.1667 & 1 \end{pmatrix}$

The weight vector $U_{es} = [0.3866, 0.2797, 0.3337]^T$

Check the consistency $CR = 0.0000$

d. Air Quality Index

This index includes pm2.5, SO_2 emissions, COD emissions, and etc. It is an optimal criterion to evaluate environmental sustainability.

Results

We view the eight chosen city (New York, Philadelphia, Los Angeles, San Francisco, Denver, Miami, Salt Lake City, Jiayuguan) as the alternatives of AHP model. The results come as its weight value factor

$$U = [0.3394, 0.1248, 0.0956, 0.1077, 0.0852, 0.0805, 0.0527, 0.1141]^T.$$

In this model, we set New York City as benchmark, we view the smart growth plan's weight percentage against New York 's weight. The eight chosen cities' smart growth index presented as **Table 2**.

And we compare it to Galster and Hanson's results[1] (see as **Table 3**), the ranking is almost the same.

Table 2.

Smart Growth Index of 8 Cities

City	Smart Growth Index	Rank
New York	1	1
Philadelphia	0.3677	2
San Francisco	0.3173	**3**
Los Angeles	0.2817	**4**
Denver	0.2510	5
Miami	0.2372	6
Salt Lake City	0.1553	7
Jiayuguan City	0.1420	8

Table 3.

Galster and Hanson's Ranking of Urban Sprawl Index

City	Rank
New York	1
Philadelphia	2
Los Angeles	**3**
San Francisco	**4**
Denver	5
Miami	6

Sensitive Analysis

To analyze the robustness of our model, we perform a sensitivity analysis. We conduct this process by the method of factor perturbation. The figure presented below unveil the results of our analysis.

Figure 1.

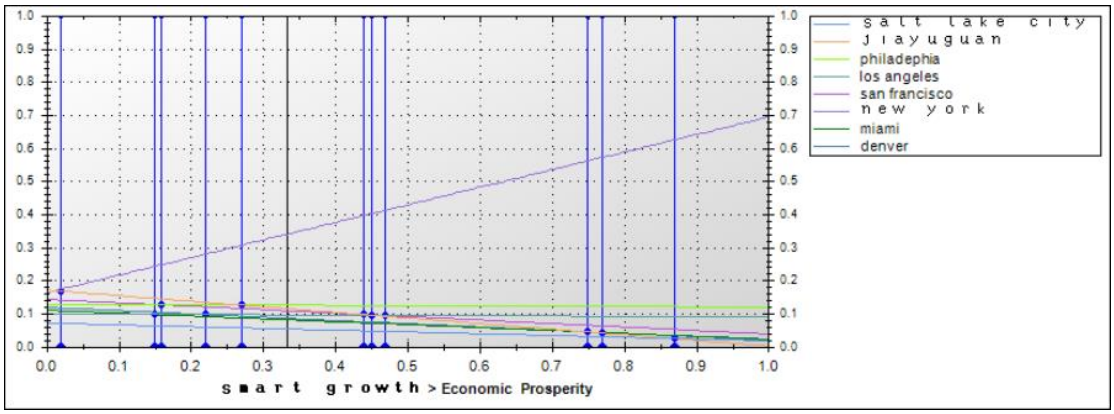


Figure 2.

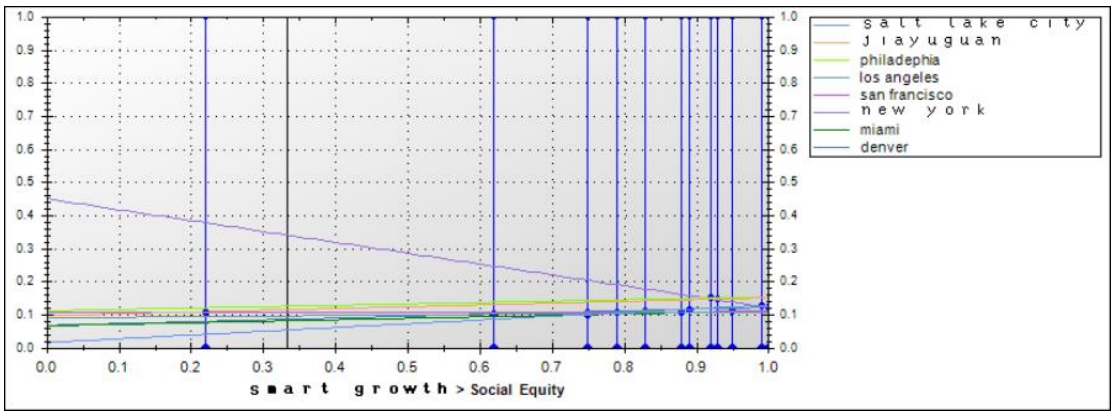
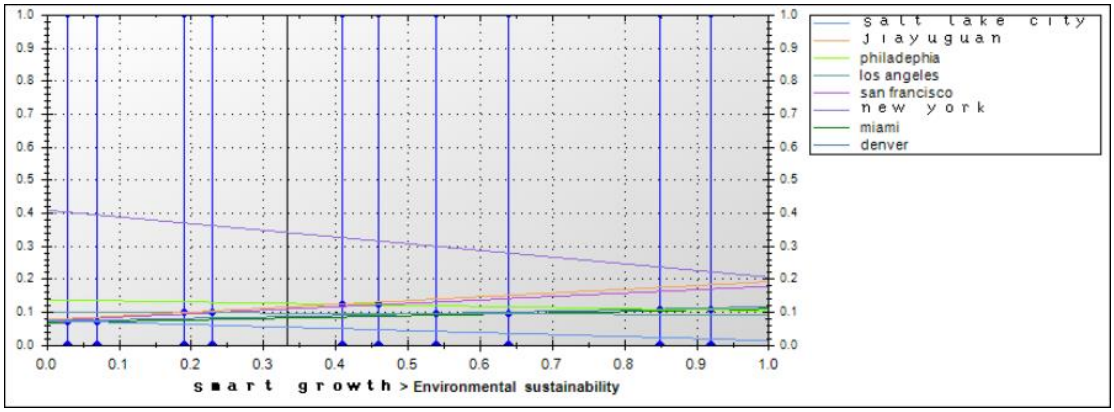


Figure 3.



The results show that in a certain range, the smart growth index changes slowly with a change in the weight of criteria. Consequently, our model has high stability.

TASK 2: Case Study

As being required, We Select two mid-sized cities with a population of between 100,000 and 500,000 persons, on two different continents. One is **Jiayuguan City** (China) and another is **Salt Lake City** (America). We tend to compare two cities with different geography, development level, and policy circumstance. Jiayuguan City is located in the west of China and it is a representative of mid-sized city in developing country. In contrast, Salt Lake City is the representative of mid-sized city in developed country.

Based on **TASK 1**'s result, we successfully determine the weight of the sub-criteria which effect the smart growth data. Aiming to evaluate the growth plan, we introduce the improving index. Under this conception, the sub-criteria's increase contributes to the improving index by its weight. The current growth plan presented as follows. Also the weight vector

$$U = [0.1984, 0.1350, 0.2482, 0.0165, 0.0686, 0.1289, 0.0932, 0.1112]^T$$

It is arrayed as the sequence: Urban land output, Urban employment, Gini

Coefficient, Corruption Perceptions Index, Health Insurance Coverage, Urban population expansion coefficient, Urban economic expansion coefficient, density.

Current Growth Plans of Two Cities

Jiayuguan City (2015)[2]

- **Economic Prosperity**

1. The average annual GDP growth rate is 25%. The city's total economic output reached 54.5 billion yuan, an average annual increase of 16%.
2. Municipal fiscal revenue is anticipated to reach 2.7 billion yuan, an average annual increase of 25%.
3. Urban registered unemployment rate is below 3%.

- **Social Equity**

1. Per capita disposable income of urban residents reaches 35,000 yuan, with an average annual growth of 16%; farmers per capita net income reached 17,900 yuan, with an average annual increase of 18%; Engel coefficient decline to 30%.
2. Social security system is further improved, the comprehensive social insurance coverage rate is predicted to reach 60%.

- **Environmental Sustainability**

1. The natural population growth rate is 6.5 ‰ or less.
2. Unit GDP energy consumption, SO_2 emissions, COD emissions are limited within the national requirements. Green ratio in build-up area is up to 38%. The rate between total days that Air pollution index is less than or equal to 100 and 365 days is greater than 90%.

Evaluation of Jiayuguan City growth plan in 2015

- **Merits**

1. It is significant that governors take strong measures and set specific goals to promote economy prosperity, which is accord with the principles of economically prosperous.
2. There is no doubt that the fiscal bureau and the municipal government keep a dynamic balance on income and expenditure.
3. As the economy has been booming in Jiayuguan City in few decades, the air quality has been deteriorated. Thanks to applying the national requirements to curb this phenomenon, the emission of toxic gas and consumption of energy which produce a large quantity of carbon dioxide has decreased regularly.
4. Income growth and Economic development, labor remuneration growth and labor productivity increased simultaneously, the middle-income groups continue to expand, people's quality of life is continuously improved.

- **Demerits**

1. Policy makers may ignore the efficiency of land use, which is an indispensable index to measure smart growth. In some extent, it is correlated with the principle of environmentally sustainable.

2. They may oversimplify the principle of socially equitable. In fact, they are supposed to give certain inclination in policy to help those vulnerable groups, such as offering a range of housing opportunities and choices. For example, providing indemnificatory houses or housing loans is a moderate decision.
3. They should create motivation in community and stakeholder collaboration in development decisions, which may make decisions fair, practical and effective.

Salt Lake City (2015) [3]

- **Economic prosperity**

1. Address existing barriers to economic development within the organization to support a culture of customer service.
2. Support business through effective and efficient use of economic development tools. The Economic Development Loan Fund re-launched in November 2014. *2.74* million dollars in loans has been approved to support 17 local independent businesses.

- **Social Equity**

1. Develop 30–40 new affordable rental housing units.
2. Provide equitable access to open space by completing trail network, proving for multiple users, and offering local open space. It is estimated that the local government complete 5 new or updated recreational opportunities.

- **Environmental sustainability**

1. Reduce by 10% the amount of waste landfilled for refuse accounts, from the 2012 average of 2,260 pounds.
2. Increase annual collection and disposal of unused prescription drugs to 1,800 pounds.
3. Reduce greenhouse gas emissions from City operations by 13%, to 72,400 tons annually.
4. Complete 50–100 units of multifamily rental housing rehabilitation projects through work with public and private developers.
5. Reduce by 10% the amount of waste landfilled for refuse accounts, from the 2012 average of 2,260 pounds.

Evaluation of Salt Lake City plan in 2015

- **Merits**

1. The municipal government apply effective and efficient measures to boost local economy.
2. They provide affordable housing and homeownership opportunity for residents and support development of a variety of affordable housing types with moderate access to public transit, which fit with one of the ten principles that create a range of housing opportunities and choices
3. It is a creative and attractive ways to engage residents and businesses in waste reduce on and recycling. Meanwhile, it strengthens the collaboration of the community and stakeholders.

4. Using conservation tools to protect and expand the city's open space inventory neatly fits with the principle of fostering distinctive, attractive communities with a strong sense of place.

- **Demerits**

5. The target aims to continue to exceed national target ratio of 6.5 acres of parks, natural lands may lead to the contradiction of smart growth and continued urban sprawl.
6. Policy makers may simplify the principle of socially equitable excessively.

Evaluation Results

We use our metric to evaluate the successfulness of the current plans of two cities and compare the results to the real values in 2014 then come to the improving ratio for the Smart Growth Evaluation Index. See as **Table 4**.

Table 4.

Evaluation of the Current Plans

City	EP Index	SE index	ES index	Improving ratio
JYGC	16.000%	5.743%	13.080%	11.61%
SLC	4.000%	6.987%	8.125%	6.371%

TASK 3: Model for Predicting Development

Background of Jiayuguan City

- **Geography:**

Jiayuguan City is located in the northwest of Gansu Province. The territory is flat terrain, and most land in the Midwest is Gobi where the urban and industrial areas are located. Oasis are scattered in the southeast and northeast, and only take up 19% of the total land area. Jiayuguan City is also known as a city with diverse mineral resources, especially iron.

- **Economics (expected growth rate)**

From 1990, its per capita GDP, per capita income and per capita disposable income of urban residents for ranked first in Gansu Province. Jiayuguan City is an important national steel production base, and industrial economy is the lifeline of its survival. Its expected economic growth rate for five years is always above 25% and the growth rate of Urban Fiscal Revnue is 3% annually.

- **Development opportunities**[4]

The establishment of the new Silk Road has created a good opportunity for the development of Jiayuguan City for instance providing a large number of jobs and improving infrastructure construction.

Government have attached Jiayuguan City's development to circular economy and smart growth, and create a good atmosphere for development.

Background of Salt Lake City

- **Geography**

Salt Lake City is located in northern Utah and it is the capital of the state. The city is located in the northeast corner of the Salt Lake Valley surrounded by the Great Salt Lake to the northwest and the steep Wasatch and Oquirrh mountain ranges on the eastern and southwestern borders.

- **Economics (expected growth rate)**

The mining industry and the construction of the first crossroads brought economic prosperity to the city. The City has seen a steady growth rate in all economic indicators including employment, wages, and development.

- **Development opportunities[5]**

Utah led the nation in job growth in 2015, a signal that economic opportunity may be better in Utah than in any state. And it has already adopted the Smart Growth Plan to better develop its economic, environment, transportation and land use.

Grey Prediction Model

This Section applies Grey Prediction model to estimating the eight factors including (1)Urban GDP, (2)Urban Construction Land Area, (3)Population, (4)Employment Population, (5)Urban Fiscal Revenue, (6)Gini Coefficient, (7)Corruption Perception Index, (8)Health Insurance Coverage over the few decades. The nature of Grey Prediction is discovering the characteristic of the system and the development. Then, it forecast the situation of future time. It also can estimate and calculate the time when the abnormal behavior occurs.

Therefore, we are able to make more specific policies of smart growth and set more accurate development goals of 2030.First, we use Grey Prediction Model to predict the development in **Jiayugua City**.

The Steps are Shown as Follow:

- **STEP 1**

In order to ensure the feasibility of the modeling method, it is necessary to test the known data columns. The data over the past years is defined as $x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n))$, the series ratio of this sequence can be calculated as follow:

$$\lambda(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, \qquad k = 2,3, \dots, n$$

If all the series ratio $\lambda(k)$ fall on the interval $\left(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+2}}\right)$, then the sequence

$x^{(0)}$ can be predicted by Grey-forecasting model. Otherwise, data should be transformed. Taking appropriate constant c, doing translation transformation as follow:

$$y^{(0)} = x^{(0)}(k) + c, \quad k = 1,2,\dots,n$$

After transformation, the series ratio $\lambda_y(k)$ of the sequence $y^{(0)}$ fall on the interval.

- **STEP 2**

By calculating and modeling, the one-accumulated sequence is shown as follow:

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}, \quad k = 1,2,\dots,n-1$$

Hence, the predicted value is $\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1,2,\dots n-1$

- **STEP 3 Test predicted value**

Residual test Suppose that residual is $\varepsilon(k)$, then

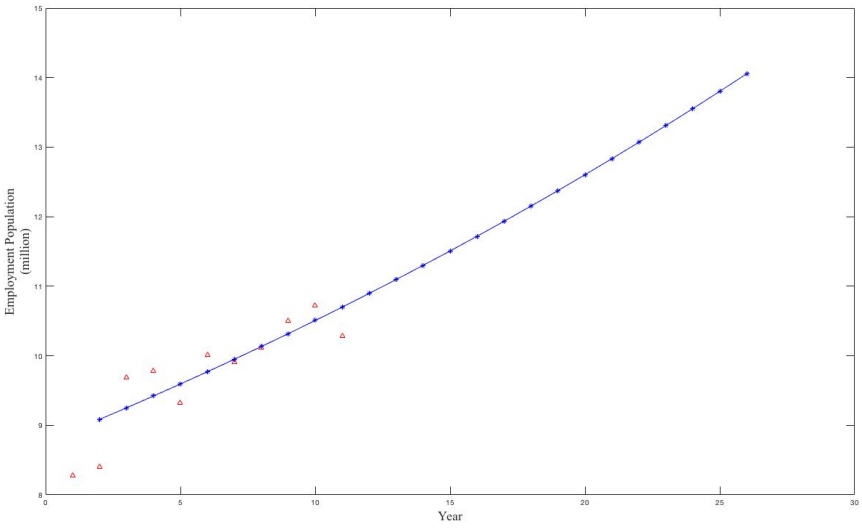
$$\varepsilon(k) = \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)}, \quad k = 1,2,\dots,n$$

If the prediction $\varepsilon(k)$<0.2, it can be considered to meet the general requirements. If the prediction $\varepsilon(k)$<0.1, it can be considered to achieve the high requirements.

Finally, we get predicted value of eight factors from 2016-2030. Set (4)Employment Population as an example (**Figure 4**), which is displayed as follow.

Figure 4.

Grey Prediction of Employment Population



Then we deal with all the indicators of Jiayuguan City and get the results as **Table 5**. We do the same procedure to predict the value of all Salt Lake City's

indicators and get the results as **Table 6.**

Table 5.

Grey Predition of Jiayuguan City's indicators

Index (Unit)	2016	2020	2025	2030	Residual
Urban GDP (million dollars)	414685	654731	973879	1435757	13.40%
Urban Construction Land Area (km^2)	70.20	74.22	87.40	96.62	4.47%
Population (ten thousand)	24.4500	24.5247	30.2436	34.4610	**0.97%**
Employment Population (ten thousand)	10.90	11.72	12.83	14.06	**0.29%**
Urban Fiscal Revenue(million dollars)	22638.3	29970.1	45425.9	83952.9	16%
Gini Coefficient	0.463	0.452	0.439	0.426	**0.0038%**
Corruption Perception Index	3.522	3.575	3.643	3.712	**0.09%**
Health Insurance Coverage	0.448	0.508	0.594	0.695	**0.02%**

Table 6.

Grey Predition of Salt Lake City's indicators

Index (Unit)	2016	2020	2025	2030	Residual
Urban GDP (million dollars)	72661.55	79671.72	89393.02	100300.48	14.40%
Urban Construction Land Area (km^2)	195.52	202.19	210.85	219.87	**0.93%**
Population (ten thousand)	19.40	19.87	20.48	21.11	3.169%
Employment Population (ten thousnd)	6.42	11.72	12.83	14.06	12.19%
Gini Coefficient	0.410	0.208	0.406	0.403	**0.305%**
Corruption Perception Index	7.2505	7.1771	7.0864	7.0000	**0.09%**
Health Insurance Coverage	0.86851	0.85891	0.84706	0.83537	**0.01%**

We can see in **Table 5.** that the residual for Population, Employment population, Gini Coefficient, Corruption Perception Index and Health Insurance Coverage is under **1%**, so these prediction values can be accurate. In **Table 6.** the residual for

Urban Construction Land Area, Gini Coefficient, Corruption Perception Index and Health Insurance Coverage is under **1%.**

We combine the background of the Jiayuguan City and the expected growth rate (**3%** annually for Urban Fiscal Revenue, **1.2%** annually for Population and **8%** for Urban GDP) with the results of Grey Prediction of Jiayuguan City and design our smart growth plan. See as **Table 7.** And the same as Salt Lake City(3% growth rate annually for Urban GDP and Health Insurance Coverage up to 90%).See as **Table 8.**

Table 7.

Jiayuguan City's Smart Growth Plan

GUIDING PRINCIPLES	METRIC	2015 BASELINE	2030 GOAL	
ECONOMY				
Creat an effective and efficient economy that produces quality jobs and fosters an environment for business to thrive.	1. Urban Land Output (Million yuan. per km2)	39542	98882	Promote economy development with high val added and low energy-cosumption. Increase employment rate and household income constantly.
	2. Urban Employment (Pop. per km2)	1530	1650	
EQUITY				
Maitain fairness to access livelihood, education and full participation in the political and cultural life of the community. Meanwhile, A municipal authority is supposed to be collaborative, responsive and transparent.	1. Gini Coefficient	0.462	0.42	Narrow the gap between the rich and the poor
	2. Corruption Perceptions Index	3.5	3.7	Be committed to create a just, honest transparent government.
	3. Health Insurance Coverage	43.38%	70%	Ensure access to all citizens for medical security system.
ENVIRONMENT				
On the one hand, minimize our impact on the natural environment. On the other hand, buildan environment-friendly society to our residnets.	1. Urban Population Expansion Coefficient	2.56	2.97	Curb continued urban sprawl and reduce the l of farmland surrounding urban centers. Reduc
	2. Urban Economic Expansion Coefficient	0.34	0.88	emission of toxic gas and meet the requiremnt of national standard.
	3. Density (Pop. per km2)	8310	11741	
	4. Air Quality Index			

Table 8.

Salt Lake City's Smart Growth Plan

GUIDING PRINCIPLES	METRIC	2015 BASELINE	2030 GOAL	
ECONOMY				
Creat an effective and efficient economy that produces quality jobs and fosters an environment for business to thrive.	1. Urban Land Output (Million dollars. per km2)	367.135	503.195	Develop a sign program to support business development and encourage discovery throughout the mid-block network.
	2. Urban Employment (Pop. per km2)	631	740	
EQUITY				
Maitain fairness to access livelihood, education and full participation in the political and cultural life of the community. Meanwhile, A municipal authority is supposed to be collaborative, responsive and transparent.	1. Gini Coefficient	0.415	0.403	Narrow the gap between the rich and the poor
	2. Corruption Perceptions Index	7.6	8.0	Be committed to create a just, honest transparent government.
	3. Health Insurance Coverage	89.50%	91%	Ensure access to all citizens for medical security system
ENVIRONMENT				
On the one hand, minimize our impact on the natural environment. On the other hand, build environment-friendly society to our residents.	1. Urban Population Expansion Coefficient	0.56	1.4	Curb continued urban sprawl and make use of underutilized land. Increase the area of mix used land.Reduce emission of toxic gas and meet the requiremnt of national standard.
	2. Urban Economic Expansion Coefficient	0.15	0.4	
	3. Dnsity (Pop. per km^2)	996	1001	
	4. Air Quality Index			

Then, we evaluate the success of our smart growth plans and get the results as **Table 9**.

Table 9.
Evaluation of the Smart Growth Plans

City	EP Index	SE index	ES index	Improving ratio
JYGC	15.784%	7.347%	12.569%	11.9%
SLC	5.346%	6.126%	8.868%	6.78%

TASK 4: Rank the Individual Initiatives

Table 10.
Evaluation and Rank of the Smart Growth Plans for Two Cities

City	Plan	EP index	SE index	ES index	Improving rate	Rank
JYGC	Redesigned	16.341%	8.004%	12.645%	12.33	1
JYGC	Current	15.784%	7.347%	12.569%	11.9%	2
SLC	Redesigned	5.298%	6.329%	8.779%	6.80%	3
SLC	Current	5.346%	6.126%	8.868%	6.78%	4

Principal Component Analysis

As being required to rank the individual Initiatives, we apply PCA to get the principal component of the ten indictors including X1 Urban land output, X2 Urban employment, X3 Urban Land Revenue, X4 Gini Coefficient**,** X5 Corruption Perceptions Index, X6 Health Insurance Coverage, X7 Urban population expansion coefficient, X8 Urban economic expansion coefficient, X9 Density, X10 Air Quality index. Firstly, we rank the individual initiatives of the growth plan for Jiayuguan City. Considering that each index is possibly related, we need to take orthogonal linear transformation to remove redundant information.

- Assuming that there are n indicators, the value of the i^{th} indicator and the p^{th} element is defined as $x_{i1}, x_{i2}, x_{i3},..., x_{ip}$, so that observed values of i countries and p elements can be expressed as the following matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} \cdots & x_{np} \end{bmatrix}$$

- i>p, the sample array is constructed and normalized to the following sample elements:

$$\bar{x}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n}, \qquad s_j^2 = \frac{\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2}{n-1}$$

Here,

$$Z_{ij} = \frac{x_{ij} - \bar{x}_j}{s_j}, \qquad i = 1,2,\dots,n; j = 1,2,\dots,p$$

we can get normalized matrix Z.

- Then we can get the correlation coefficient matrix with the normalized matrix Z:

$$R = [r_{ij}]_P xp = \frac{Z^T Z}{n-1}$$

Here,

$$r_{ij} = \frac{\sum z_{kj} \cdot z_{kj}}{n-1}, i, j = 1,2,\dots,p$$

Table 11.

Correlation Matrix

		Urban Land Output (Million yuan. per km2)	Urban Employment (Pop. per km2)	Gini Coefficient	Corruption Perceptions Index	Health Insurance Coverage	Urban Population Expansion Coefficient	Urban Economic Expansion Coefficient	Dnsity (Pop. per km2)
Correlation	Urban Land Output (Million dollars. per km^2)	1.000	.887	-.629	-.568	-.765	.012	.149	.960
	Urban Employment (Pop. per km^2)	.887	1.000	-.731	-.433	-.730	.138	.318	.942
	Gini Coefficient	-.629	-.731	1.000	.492	.566	-.343	-.568	-.768
	Corruption Perceptions Index	-.568	-.433	.492	1.000	.581	-.284	-.587	-.529
	Health Insurance Coverage	-.765	-.730	.566	.581	1.000	-.082	-.253	-.834
	Urban Population Expansion Coefficient	.012	.138	-.343	-.284	-.082	1.000	.677	.097
	Urban Economic Expansion Coefficient	.149	.318	-.568	-.587	-.253	.677	1.000	.263
	Dnsity (Pop. per km^2)	.960	.942	-.768	-.529	-.834	.097	.263	1.000

- By corresponding the coefficient correlation matrix R, p non negative eigenvalue of characteristic equation $|R - \lambda I|$ can be represented as $\lambda_1, \lambda_2, \dots, \lambda_j$, determining the principal component. and feature vectors corresponding to eigenvalues can be written as

$$C_i = (c_{1i}, c_{2i}, \dots, c_{ni}), i = 1,2,\dots,p$$

Table 12.

Component Matrix[a]

	Component	
	1	2
Urban Land Output (Million dollars. per km^2)	.890	-.367
Urban Employment (Pop. per km^2)	.904	-.223
Gini Coefficient	-.838	-.168
Corruption Perceptions Index	-.711	-.267
Health Insurance Coverage	-.839	.230
Urban Population Expansion Coefficient	.301	.824
Urban Economic Expansion Coefficient	.523	.782
Dnsity (Pop. per km^2)	.949	-.281

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

- Converting the standardized indicator variables into principal components and evaluating the m principal components:

$$F_i = c_{1i}X_1 + c_{2i}X_2 + \cdots + c_{pi}X_p, i = 1,2, \ldots, m$$

Obtaining the weighted sum of m principal components, which is the final evaluation value, and the weight is the variance contribution rate of each principal component.

The Score Model:

$$Score = \frac{\sum_{i=1}^{j} F_i \lambda_i}{\sum_{m=1}^{p} \lambda_m}$$

- And also determining the value of m by $\frac{\sum_{j=1}^{m} \lambda_i}{\sum_{j=1}^{p} \lambda_j} \geq 0.85$,so that the utilization of information more than 85%.

Table 13.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.856
Bartlett's Test of Sphericity	Approx. Chi-Square	117.113
	df	28
	Sig.	.000

KMO equals to 0.856 indicates that the eight factors have a high correlation that fit to do the analysis.

Table 14.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared			Rotation Sums of Squared		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.786	59.820	59.820	4.786	59.820	59.820	4.328	54.102	54.102
2	1.706	21.329	86.149	1.706	21.329	81.149	2.164	27.047	81.149
3	.638	7.974	89.123						
4	.381	4.767	93.890						
5	.257	3.210	97.100						
6	.184	2.301	99.401						
7	.044	.556	99.957						
8	.003	.043	100.000						

Extraction Method: Principal Component Analysis.

The same steps to rank initiatives of the growth plan for Salt Lake City

Results

The rank individual initiatives within our redesigned smart growth plan as the most potential to the least potential is shown as follow:

Table 15.

Rank of Initiatives in Smart Growth Plan

Index	Urban Land Output	Urban Employment	Gini Coefficient	Corruption Perceptions Index	Health Insurance Coverage	Urban Population Expansion Coefficient	Urban Economic Expansion Coefficient	Density
Rank of Jiayuguan City	2	1	4	7	3	8	6	5
Rank of Salt Lake City	3	1	5	6	4	7	8	2

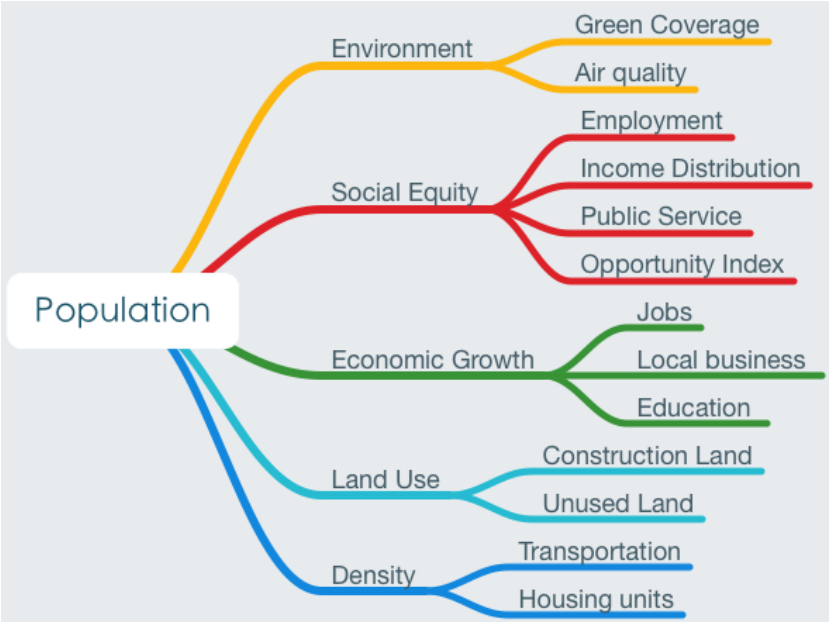
TASK 5: Population Growth

Suppose each city faces with an additional 50% growth in population by 2050. Firstly, we have already made the smart growth plan in **TASK 3** for **Jiayuguan City** and the growth rate for Population is annually 1.2%. With 1.2% Population growth rate, Jiayuguan City in 2050 will have an additional 50% growth in population, so that our plan supports this level of growth in every way.

As for Salt Lake City, if in 2050 there are extra 50% population in the city, the city is facing with potential urban sprawl. Our smart growth plan can perfect serve the purpose of curbing the urban sprawl.

Figure 5

The Indicators Affected by Population



- **Economic Prosperity**

1. **Density.**

The increase in population will lead to an increase in density (when the land area changes not as fast as population). And population density will contribute to increased housing tensions, traffic congestion, and urban pollution. Our plan calls for constant attention to population growth as well as population density. Tracking the growth in the number of housing units is critical to measure our housing supply. At the same time, we ask for building bike lanes, pedestrian streets and increasing public transport capacity to alleviate the traffic problems, which will greatly reduce carbon dioxide emissions, improve air quality index and be better for civics' health.

2. **Land use.**

We advocate improving the utilization of land, increasing the area of mixed land and unused land. In the terms of land use, we also require the maintenance of open places, farmland, nature reserves and cultural landscape area, and improvements of the city's green coverage, which can provide a good public environment for the city's development.

3. **Economic growth.**

In the terms of economic growth and prosperity, we are calling for more jobs and higher employment rates. The government is also being urged to provide good information for the job market. As the investment in both small and large businesses can grow economy, uniting established companies with new ideas and entrepreneurs with essential resources. Therefore, we call for devoting more resources to helping locally-grown businesses become established and thrive and ensuring a place for small businesses by developing. Moreover, Economic growth is supported by a strong relationship with higher education so that it is necessary to

grow and support creative industries and an educated workforce downtown by introducing more student housing and educational spaces.

We also require to vigorously develop the tourism industry, change the mode of economic development from the inherent resource-based development model to a sustainable development model. It can increase the capacity of sustainable development while increasing Urban GDP.

4. **Social Equity**

In the terms of social equity, apart from increasing employment, we call for close attention to income distribution and intergenerational mobility. We should address the economics issues are associated with the homeless and the jobless and their impact on local business. At the same time, we need to put emphasis on evaluating economic development programs for minority-owned business.

We advocate to ensure every civic has the access to all public services including health insurance and unemployment compensation.

5. **Environment**

Along with population growth, we should consider to build friendly, instinctive and attractive communities. We should set up places for recreation.

We are advocating to reduce polluted air emissions, preserve the green land and make the urban development more sustainable.

Strengths

• **Comprehensiveness**: From the perspective of 3E, we give numerous ratios to measure the smart growth indexes.
• **Objective:** Different from traditional AHP model, we introduce entropy method to distribute the weight of each indexes without relying on subjective opinions.
• **Adaptability and Practicability**: The model we build has good portability; it is suitable for analyzing various of cities.
• **Simplicity and Accuracy**: The programs of the model are easy to understand, and the calculations are precise.
• **Effectiveness**: We put forward our plan based on scientific prediction model, providing a solid ground for us to analyze and evaluate.

Weakness

1. Our metric is optimal to evaluate a city's growth or cities in different countries smart growth. However, it is lack of accuracy evaluating different cities in one country, as our Gini index and Corruption Perceptions Index are measured in the national perspective.
2. Factors of transportations may be over-simplified. As the difficulty existing in searching data of transportation variety in China, we exclude it from consideration.

Reference

[1] George Galster, et al. "Wrestling Sprawl to the Ground: Defining and measuring an elusive concept." *Housing Policy Debate* 12.4(2001):681-717.

[2] Jiayuguan City Economic Development Plan
http://www.gsjyg.cn/xxgk/zfxxgkml/ghjh/201609/t20160914_19205.html

[3] Salt Lake City Economic Development
http://www.slcgov.com/economic-development

[4] Jiayuguan City Economic Development Plan from 2015 to 2020
http://www.gsjyg.cn/xxgk/zfxxgkml/ghjh/201612/t20161215_130656.html

[5] Plan Salt Lake: Citywide Vision
http://www.slcdocs.com/Planning/Projects/PlanSaltLake/final.pdf