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Summary Sheet

Summary

With the increase of population, more and more people are pouring into cities. The world is rapidly urbanizing. Consequently, urban planning has become increasingly important and necessary to ensure that people have access to equitable and sustainable homes, resources and jobs.

Smart growth focuses on building cities that embraces the E's of sustainability—Economically prosperous, socially Equitable, and Environmentally Sustainable. To measure how successful the city meets the goal of smart growth, we propose a metric model to identify the degree of smart growth, and evaluate two cities' metric. Then we offer unique smart growth plans for each city, considering the geography, expected growth rates, and economic opportunities.

Firstly, we construct our metric, Smart Growth Metric (SGM) based on three aspect, Economically Prosperous, Socially Equitable and Environmentally Sustainable. The detailed factors are Per Capita Gross Domestic Product, Mean travel time to work, Per Capita Land, Primary Enrollment Rate (for Prosperous Metric) and Male/Female Income Ratio (for Socially Equitable Metric) and Urban Green Space Ratio (for Environmentally Sustainable).The weights of factors are determined by Grey Relational Analysis. In our case study, we choose Reykjavik and Ann Arbor to measure the degree of success of Smart Growth. Meanwhile, we select three Smart Growth Cities estimated by EPA (United States Environmental Protection Agency) and regard them as the evaluation criterions. We find that the current growth plans of Reykjavik and Ann Arbor both meet the smart growth principles. To estimate the expected growth rates, we predict Per Capita GDP in 2050 by means of Grey Forecast Model. Using sensitivity analysis, we evaluate the dynamic of the model and influence of expected growth rates, geography and economic opportunities. In order to measure geography factor and economic opportunity factor, we introduced two parameters α and β to re-evaluate the weights of the model, and take change of α and β as influence of two factors.

Therefore, we set redesigned smart growth plans. Although the prosperity of Ann Arbor is based on Technology-oriented economy, the city still needs to improve community cohesion and search for renewable energy. On the contrary, Reykjavik should pay more attention to upgrade its industrial structure and develop a denser urban area. The geothermal energy guarantees an eco-friendly development of the city. In addition, we rank the potential of individual plans by Analytic Hierarchy Process. For Ann Arbor, social factors have the greatest potential, followed by environmental factors, and finally economic factors. While for Reykjavik, the most potential plan is industry upgrading, and the last one is environment plan. Society factor have middle potential.

Finally, we adjust our plan under the situation that the population increase by an additional 50% by 2050.We find that Ann Arbor is likely to have society and environment problems. However, it will benefit Reykjavik's economy.

Contents

1 Introduction

The world is facing in the challenge of urban sprawl now. Due to the population booming, there will be more crowded city in the future. To solve this problem, American start expanding urban area unplanned, which cause another problem-urban sprawl. According to Don Chen of Smart Growth America, a nationwide coalition of over 60 public interest groups, low-density suburban growth, or sprawl, has 4 dimensions: a population that is widely dispersed in low-density development; rigidly separated homes, shops, and workplaces; a network of roads marked by huge blocks and poor access; and a lack of well-defined, thriving activity centers, such as downtowns and town centers[1].These separated Zoning districts lead to resource waste, low sense of belonging and slowly economic growth. In response to the phenomenon, a new way of urban growth comes out-Smart Growth.

In the past years, most research focus on land use and transportation, leaving the humanity behind. With the development of economy and social consciousness, the importance of society and environment has aroused peoples attention. Smart Growth is so many different things. Its not just transportation; its a mindset to creating a more holistic community[2]. Today, the goal of the new Smart Growth is to achieve the harmonious of economy, society and environment.

Our objective is to develop an evaluation system to measure how successful a city meets the goal of Smart growth and the goal of three Es-Economically prosperous, socially Equitable, and Environmentally Sustainable. In addition, we need to create a metric to evaluate the smart growth quantitatively.

In this paper, we chose specific factors to integrate the three aspects. To evaluate the economically prosperous, we choose per capita Gross Domestic Product (GDP),Mean travel time to work , Per capita land , and Primary Enrollment Rate. In addition, we select male/female income ratio to represent socially equitable, urban green square rate to represent environmentally sustainable. Based on that, we measure several cities current plans and design unique Smart growth plans for them.

2 Assumptions

There are excessive factors impacting the urban growth. Because taking all of these into consider is impossible and may affect the accuracy of the model we choose several typical assumptions for our model:

- **No cataclysm happens in the area.**The cataclysm such as earthquake or Tsunami attacks the city can cause great damage to human security, infrastructure and economic development. This makes our model data meaningless. To ensure the availability of our models and plans, we assume that the natural environment is stable.

- **Urban area is stable and no expansion.** Our discussion focuses more on the measurement of economic, social, and environmental conditions within a given urban area. In reality, the scope of the city does change over time, but because one of the goals of the smart growth model is to limit urban sprawl, it is reasonable that our model is built on the assumption that the urban area is not growing.
- **There is no revolutionary scientific and technological development.** Technological progress will greatly promote economic development, political progress, and lifestyle changes, as well as changes in social consciousness. This will cause our growth model no longer relevant and difficult to predict for the future. This assumption is reasonable because our forecasts and plans are based on normal growth conditions.
- **Policy implementation is unimpeded.** The political situation is stable, government officials do not eliminate sabotage, there is no corruption or rent-seeking. Political stability is the basis for program implementation, which is used to ensure social security and to support policies. Under this assumption, we can guarantee that our model and plan run in a supported environment.

3 Notations

Abbreviation	Full Name
SGM	Smart Growth Metric
EP	Economically Prosperous
SE	Social Equitable
ES	Environmental Sustainable
EPM	Economically Prosperous Metric
SEM	Social Equitable Metric
ESM	Environmental Sustainable Metric
GRA	Grey Relation Analysis
GFM	Grey Forecasting Model

Tab 1: Variable Description

4 Smart Growth Metric Model

In this section, firstly, we define a metric of smart growth and build the Smart Growth Metric Model to measure the success of smart growth of a city,named **Smart Growth Metric(SGM)**. Secondly, we select two mid-sized cities on two

different continents (Ann Arbor, America and Reykjavik, Iceland) and use the Smart Growth Metric Model to calculate those cities smart growth metrics. Finally, we compare the metrics of two cities between the metrics of three cities' that have been estimated as American Smart Growth Achievement by EPA[3] and draw a conclusion.

4.1 Assumptions

- For ES(defined in section 4.2),we only consider urban green space area. This assumption enables us to measure it by the urban green space ratio.
- In terms of SE(defined in section 4.2),we only consider the equality between male and female,which is measured by the ratio of per capita wage between them.Its because the education level between them is very close,and the corresponding data is lacking.
- Ignoring the impact of circumstances,mean travel time to work reflect the traffic condition.The shorter the time, the better the condition.

4.2 Smart Growth Metric

After analyzing the views of many scholars, we define smart growth as:in the premise of environmental sustainability, to fully promote economic prosperity, while ensuring that social equity is inviolable.

Economically Prosperous(EP) means having a strong current and potential economy.**Social Equitable(SE)** embodies a kind of equality of social relations between people.**Environmental Sustainable(ES)** refers to the capacity of providing people with a livable environment.These three elements are both independent and interrelated, and jointly promote the city's development.We name them **Economically Prosperous Metric(EPM)**,**Social Equitable Metric(SEM)** and **Environmental Sustainable Metric(ESM)**.The equation of SGM of a city c can be obtained by

$$SGM_c = w_1 EPM + w_2 SEM + w_3 ESM. \tag{1}$$

We provide some definition for factors in figure 1.

- Per Capita GDP is a measure of the total output of a country that takes gross domestic product(GDP) and divides it by the number of people in the country. GDP per capita is often used as a measure of economic development,and a large Per Capita GDP means a better Economically prosperous[4].
- Mean travel time to work is the average time spent on the road to work,which is highly depend on traffic condition.The less time imply the better traffic conditions,a phenomenon of economically prosperous.

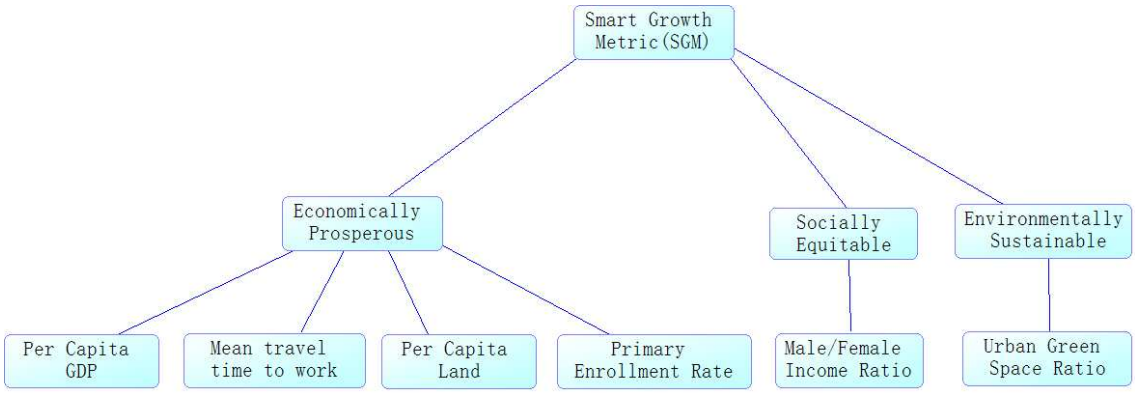

Fig 1: Main Factors of ESM

- Per Capita Land is the per capita share of urban land area.It can reflect population density to some degree.
- Primary Enrollment Rate is total number of students enrolled for primary education in their theoretical age,divided by the total population in that age group.It estimates the degree of population receiving basic education,which contains more economic opportunities.
- Male/Female Income ratio is the ratio of per capita income between male and female. Male/Female income ratio can represent socially equitable. It can reflect male or female get economy opportunity.Obviously,this result closer to 1,the more equitable between male and female.
- Urban Green Space Ratio refers to urban green space area in the proportion of the total urban space,which can reflect capability of environmentally sustainable.Urban green space, such as parks, forests, green roofs, streams, and community gardens, provides critical ecosystem services[5].

According to the above,EP is manifested in per capita GDP,mean travel time to work,per capita land and primary enrollment rate. The value of EPM of a city c can be obtained by

$$EPM_c = \sum_{j=1}^{k} w_j x_{cj} \tag{2}$$

4.3 Grey Relation Analysis(GRA)

Smart Growth is manifested in EP ,SE and ES.The correlation between them is complex and uncertain,and these correlation are interacting.Its hard to give a accurate correlation. The value of the EPM is the same.**Grey Relation Analysis(GRA)** is a branch of Grey System theory.The correlation between each factors

is measured by the degree of similarity or dissimilarity between the development trend of factors,which reveals the dynamic correlation between things.In this model,we follow the steps below to calculate the weight of each factors.

Step 1:Normalize the data. According to the actual situation, the index data and a reference sequence normalized to between 0-1. There are two types of indicators:

One is the positive indicator, that is, the higher the index value the better,and it normalized by

$$x_{ij} \leftarrow \frac{x_{ij} - m_j}{M_j - m_j},$$

The other is a negative index, that is, the lower the index value the better,.according to the specific circumstances,it normalized by

$$x_{ij} \leftarrow \frac{M_j}{x_{ij}},$$

or

$$x_{ij} \leftarrow 1 - \left|1 - x_{ij}\right|,$$

where x_{ij} is the ith city observation on jth factor and $M_j = \max_j x_{ij}$,$m_j = \max_j x_{ij}$.

Step 2:Set reference sequence. The reference sequence is the row vector composed of the optimal values of each index. After step1, normalizing the data, the index value is the bigger the better.The reference sequence is

$$X_0 = \{X_{oj} \,|\, j = 1,2,\cdots,n\} = \{x_{01}, x_{02}, \cdots x_{on}\},$$

with $x_{0j} = 1$ for all factors $j = 1,2,\cdots,k$.

Step 3:Computing grey rational coefficient ξ_{ij},which is an index describing the degree of association between the comparison sequence and the reference sequence.the equation is

$$\xi_{ij} = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_{ij} + \rho\Delta_{\max}},$$

where $\Delta_{ij} = x_{ij} - x_{0j}$,$\Delta_{\max} = \max_i \max_j \Delta_{ij}$,$\Delta_{\min} = \min_i \min_j \Delta_{ij}$,and resolution ratio $\rho = 0.5$.

Step 4:Computing the rational grade of each factor on EP,the equation is

$$r_j = \frac{1}{n}\sum_{i=1}^{n} \xi_{ij},$$

Step 5:Calculating the weigh of each factor j,the equation is

$$w_j = \frac{r_j}{\sum_{j=1}^{k} r_j}.$$

4.4 Application of GRA

Result

In order to discuss if the current growth plan of each city meets the smart growth principles, we choose three cities that have been estimated as American Smart Growth Achievement by EPA(United States Environmental Protection Agency), such as Newark(NJ), Jackson(TN) and Hamltion(OH)[3] and take them for the evaluation criterions. Our data is from Census[6].

Besides, we use Grey Relation Analysis(GRA) to calculate Economically Prosperous Index as follow Table 2.

City	EPM
Reykjavik	0.8600
Ann Arbor	0.4487
Newark, NJ	0.1410
Jackson, TN	0.4856
Hamilton, OH	0.5758

Tab 2: Economically Prosperous Metric

Then, we use GRA to determine the weight of each factor based on the relation size of its grade, weights of factors in Table 3.

Factors	Weight
EPM	0.269
SEM	0.321
ESM	0.410

Tab 3: The Weight of Factors

Thus, our Smart Growth Metric can be renewed:

$$SGM = 0.269 * EPM + 0.321 * SEM + 0.410 * ESM \tag{3}$$

Finally, we use the weights to calculate the metrics of five cities, the metrics results in Table 4.

conclusion

From Table 4, we can see the metrics of Ann Arbor and Reykjavik both exceed the metrics of three Smart Growth Cities. Therefore, we draw a conclusion that the current growth plans of Reykjavik and Ann Arbor both meet the smart growth principles.

City	SGM
Reykjavik	1.0000
Ann Arbor	0.2840
Newark, NJ	0.1318
Jackson, TN	0.2698
Hamilton, OH	0.2191

Tab 4: SGM of Different City

4.5 Case Analysis

Case 1: Reykjavik
The current plans of Reykjavik are listed below

- City by the Sea:This emphasizes the densification of the urban structure in order to create a more compact and attractive city.It propose to mixed urban areas and create a denser urban area which reduces travel distances, cost of transport and the environmental impact of transport.
- Creative City:This emphasizes strengthening Reykjaviks economic base and promoting Reykjavik as a competitive international capital city
- Green City:This emphasizes the stimulation of changes in travel behavior, preserving green open spaces, reducing pollution and encouraging a more sustainable lifestyle in the urban neighborhoods.
- City for People:This emphasizes improvement of the quality of life within the city and in the local neighborhoods as well as stimulating more ambitious design of buildings and spaces between them.[7]

The current growth plans are also highly relevant to the smart growth principles. Divided into four parts, these plans are considered as the economic, social and environmental factors comprehensively, which are correspond to the goals of three Es and the ten principles of smart growth. The current growth plans are extremely successful.

Case 2: Ann Arbor
The current growth plans of Ann Arbor are listed below:

- Downtown Zoning Amendments:Several opportunities were offered for everyone interested in learning about and participating in the Evaluation.
- Reimagine Washtenaw:Reimagine Washtenaw is a multi-jurisdictional planning effort to improve land use and transportation along the Washtenaw Avenue corridor.

- Zoning Ordinance Reorganization (ZORO):A project to clarify and reorganize the Zoning Ordinance and ten other development-related Ordinances.
- City-Initiated Annexations:A strategic process of gradually annexing township island parcels in the Citys Ultimate Service Area.
- R4C/R2A District Amendments:Re-planning for the potential problems of the R4C/R2A District.
- Accessory Dwelling Units:Develop a second, smaller dwelling units out of an existing single family house or as part of an accessory structure to add additional affordable housing units and provide some income to existing home-owners.[8]

Ann arbors current growth plans are well correspond with the smart growth principle. These plans take into account urban planning, land use, housing availability and community participation in development decisions. In addition, based on the characteristics of the city, the governments develop their own unique growth plans, such as the transformation of the old district, and Accessory Dwelling Units plan. However, there are still tiny shortages in existing programs, adding more weight to economic factors in its policies, but ignoring environmental and social factors. This is in line with our assessment, Ann arbors current growth plans almost succeed.

5 Forecasting Model

In this section, we construct a Forecasting Model to forecast economic factor growth next few decades. Economic growth can be measured by Per Capita GDP change. Thus, we can predict Per Capita GDP of both cities next few decades. Our data is generated from World Bank[9] and Statistics Iceland[10].

5.1 Assumptions

- No financial crisis happens next few decades. Financial crisis can cause Per Capita GDP change sharply. To ensure prediction result is reliable, we don't considered this influence, which guarantees relevance high between prediction result and known data.
- Other factors of SGM except Per Capita GDP are not change. Change of other factors will affect Per Capita GDP prediction more or less. In Forecasting Model, we take other factors as constant value.

5.2 Grey Forecasting Model

Grey forecasting is based on GM model to estimate and forecast the development of behavior characteristics of a system, and also to estimate the time of occurrence of abnormal behavior, and to make the future time distribution of events in a certain time zone Research and so on.There are the steps of the GFM:

Step 1:The original data sequence is

$$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \cdots, X^{(0)}(n)\},$$

Step 2:Throught the AGO,we get the accumulated generation sequence,that is,

$$X^{(1)} = \{X^{(1)}(1), X^{(1)}(2), \cdots, X^{(1)}(n)\},$$

where

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1, 2, \cdots, n,$$

Step 3:Using the GM (1,1) model and the least square,we can get the time response equation:

$$\hat{X}^{(1)}(k+1) = \left(X^{(0)}(1) - \frac{b}{a}\right) e^{-ak} + \frac{b}{a},$$

Step 4:then we can get the prediction value by

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1, 2, \cdots, n-1.$$

5.3 Application of GFM

Result

We pick Per Capita GDP data in 8 years of Reykjavik and Ann Arbor to predict Per Capita GDP next few years. Figure 2 shows Per Capita GDP prediction result of Reykjavik and Figure 3 shows Per Capita GDP prediction result of Ann Arbor.

Taking Per Capita GDP in 2050 for examples, we can get Table 5:

City	Per Capita GDP prediction result in 2050 ($)
Reykjavik	209711.5
Ann Arbor	158325.0

Tab 5: Per Capita GDP in 2050

Conclusion

From Figure 2 and Figure 3, we can see that Per Capita GDP of both cities in 2050 outclass recent Per Capita GDP. And Per Capita GDP of Reykjavik outclasses that of Ann Arbor. Thus, we need transvalue the metrics of both cities in 2050.

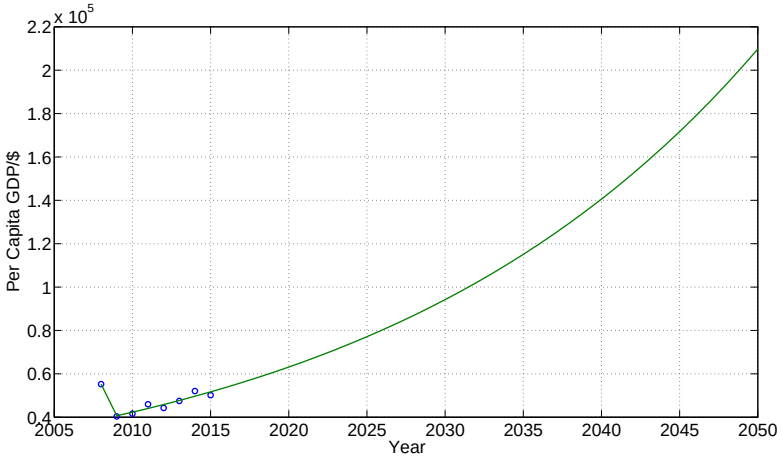

Fig 2: Per Capita GDP prediction result of Reykjavik

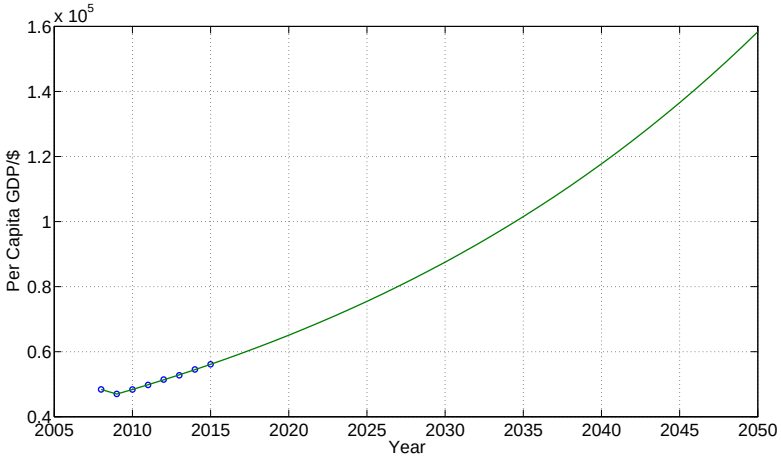

Fig 3: Per Capita GDP prediction result of Ann Arbor

6 Sensitivity Analysis

The results of SGM Model evaluate the metric of smart growth. However, the model is based on recent three E metrics. In reality, three E metrics are Dynamic rather than static. The result of section 4 also shows a bigsignificant change of Per Capita GDP in 2050.

So here hence, we will conduct sensitivity analysis to determine the again depending upon dynamic factors.

6.1 The Influence of Per Capita GDP Growth

We use Per Capita GDP in 2050 of both cities re-calculate SGM. We can get Table 6.

City	SGM
Reykjavik	1.0000
Ann Arbor	0.3070

Tab 6: SGM in 2050

Compared with two cities EPMs in 2050, EPM of Reykjavik will increase while EPM of Ann Arbor will reduce. If compared with EPMs in 2050 and recent EPMs, the EPMs of two cities will increase. Hence, in theory, SGM will both increase. However, because recent SGM of Reykjavik is very high (equal to 1), SGM in 2050 remain one(no change).

In conclusion, Per Capita GDP growth make SGM remain high(for Reykjavik) or increase slightly(for Ann Arbor).

6.2 The Influence of Economic Opportunities and Geography

Owing to the influence being difficult to measure, we use two parameters α and β to incorporate SEM and ESM compared to ESM,$\alpha > 1$ implies SEM is considered more crucial than EPM, $\beta > 1$ means ESM is more important than EPM, $\alpha > \beta$ means SEM is more significant than ESM. With the help of α and β, the equation of SGM of a city is given below:

$$SGM = \frac{EPM + \alpha * SEM + \beta * ESM}{1 + \alpha + \beta} \tag{4}$$

Economic Opportunity is related to some policies and city governments policies influence EPM and SEM. Geography is related to ESM and for example, some natural resource reserve in certain places restrict the developments of cities. We change α and β respectively from 0.5 to 1.5 and present the results in Figure 4 and Figure 5.

From the follow figures, we conclude Reykjavik is affected uneasily by α or β change. It is because that recent SGM is very high. And with α parameter increasing, SGM of Ann Arbor reduce while β parameter increasing, SGM of Ann Arbor increase.

In summarize, Ann Arbor's main purpose is to raise the value of β to promote the development based on smart growth principles. For instance, government can increase city green space. For Reykjavik, the city need keep recent plan in order to remain SGM high.

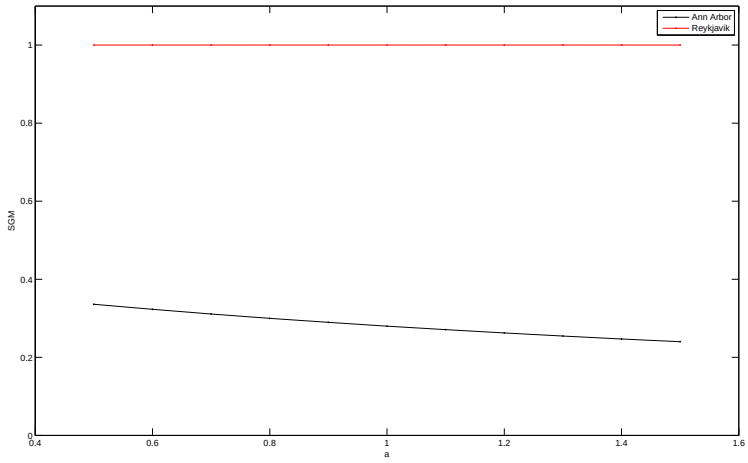

Fig 4: Sensitivity Analysis of $\alpha(\beta = 1)$

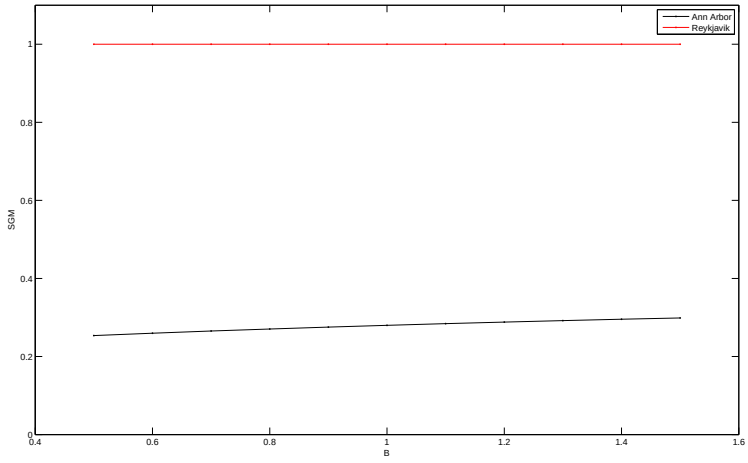

Fig 5: Sensitivity Analysis of $\beta(\alpha = 1)$

7 Smart Growth Plan

In this section, based on potential about Geography, Expected growth rates and Economic opportunities, we use AHP to evaluate and rank the individual initiatives for two cities. Finally, we set plans for both cities individually.

7.1 For Ann Arbor

Condition

1. Geography:Ann Arbor is situated on the Huron River in a productive agricultural and fruit-growing region.[11]The landscape of Ann Arbor consists of hills and valleys, with the terrain becoming steeper near the Huron River.[12]

2. Expected growth rates:The 2010 census recorded its population to be 113,934, making it the sixth largest city in Michigan.[13] according to our estimate,urban population will be more .In 2010, Ann Arbor was home to over 120,000 jobs. That figure is expected to grow to 145,000 by 2040.[14]

3. Economic opportunities:The University of Michigan shapes Ann Arbor's economy significantly. High tech, health services and biotechnology are other major components of the city's economy. [14]According to the high level of science and technology, Ann Arbors economic opportunities focus on Technology-oriented development.

Smart growth plan

1. Keep the technology-oriented development.The University of Michigan is the top employers in the Ann Arbor area, having 16,143 employees. Whats more, Educational Services is the top industries by employment, offering 30% jobs of the area. Current growth mode is highly in accordance to smart growth principle.

2. Improve community cohesion and community communication. Involve the public participate to the community decision. The government should also increase social welfare expenditure. About 4.6% of families and 16.6% of the population below the poverty line, including 7.3% of those under age 18 and 5.1% of those age 65 or over.[15]

3. Search for Renewable Energy to support the city.Landed in the plain, Ann Arbor has an advantage of industry development. The energy used most in the urban is oil and other non-renewable energy. Since the booming of population in the visible future, we should search for Renewable Energy to support the city.

Rank for Potentials

Considering each city unique demographics, growth needs, and geographical conditions, we use AHP to evaluate or rank the potentials . Table 7 shows judgement matrix of Ann Arbors potentials. Table 8 shows weights of those potentials.

	EP	SE	ES
EP	1	$\frac{1}{2}$	$\frac{1}{3}$
SE	2	1	2
ES	3	$\frac{1}{2}$	1

Tab 7: Judgement Matrix of Ann Arbors Potentials

metric	weight
EPM	0.1677
SEM	0.4836
ESM	0.3487

Tab 8: Weights of Ann Arbors Potentials

Limited by natural resources such as land resources, there is no room for Ann Arbor to spatial growth. Therefore, it is difficult to plan for a significant growth in the aspect of environment, thus there is tiny potential left here.When it comes to economy factors, Technology-oriented economy has already contributed significantly to economic growth, and achieving extra high-speed growth in decades seems hard. Finally yet importantly, social factors show the greatest potential in the end. Ann Arbor still needs to improve its community structure and narrow the gap between the rich and the poor. Improvement of social aspect can promote a livable city.

7.2 For Reykjavik

Condition

1. Geography:Reykjavłk is located on the Seltjarnarnes peninsula with the coastline characterized by peninsulas, coves, straits, and islands.[16] The district of the city is separated and linked by the main traffic arteries, which indicates a low-density

2. urban:The geothermal energy is the mainly energy of Reykjavik , therefore, Reykjavik rarely use oil, coal and other resources to generate energy.,and thus a high level of environment quality.

3. Expected growth rates:The increase of population in the capital region has been rapid in the past few years or an average of 1.6% per annum for the past 20 years, whereas the increase in population has been around 0.97% per annum in Reykjavik.[17]On the contrary, the growth rate of labor is declining, this may not conducive to economic development

4. Economic opportunities:As the capital of Iceland, Reykjavik is Iceland's economic, political and cultural center and has a relatively large population and employment opportunities, so there is a huge potential for economic development. Besides, relying on geothermal energy to develop related industries can bring Reykjavik's economic growth opportunities.

Smart growth plan

1. Adjust the industrial structure:Current economic development in Reykjavik mainly depends on cotton, fishing, agriculture and shipbuilding. We should adjust the industrial structure from product-oriented development to technology-oriented development. Government should pay more attention on education development and attach more importance on technology. In addition, because of its unique geographical environment, Reykjavik attract people all-around the world every year. Tourism is another way to develop the economy.

2. Develop a denser urban area:Government should develop a denser urban area, as it can reduces the time cost of transport and the environmental pollution of transport.

3. Continue using eco-friendly energy:Continue using environmentally friendly energy and create a livable city. One goal of Smart growth is to achieve environmentally sustainable. Reykjavik is among the cleanest, greenest, and safest cities in the world.[18]

Rank for Potentials

Same as Ann Arbors Plan, we use AHP to evaluate or rank the potentials, Judgement Matrix shown in Table X and Weights of Reykjaviks Potentials shown in Table Y.

	EP	SE	ES
EP	1	2	3
SE	$\frac{1}{2}$	1	3
ES	$\frac{1}{3}$	$\frac{1}{3}$	1

Tab 9: Judgement Matrix of Reykjaviks Potentials

metric	weight
EPM	0.5278
SEM	0.3325
ESM	0.1396

Tab 10: Weights of Reykjaviks Potentials

Famous for its cleanest environment, Reykjavik has fully meets the goal of Environmentally Sustainable. Besides, well-developed social welfare system makes Reykjavik a relatively equitable society. According to our metric, the only weakness of Reykjavik is the economic factor. Reykjavik currently relies mainly on secondary industries to develop. If it can transform the industrial structure, with the tertiary industry as the main development goals or improving its science and technology level, its economy will usher in great prosperity. In conclusion, economy factors show the most potential.

8 Population Growth

Ann Arbor

- Economically prosperous. Employment demand will be increased accordingly. We estimate that Technology-oriented economy can provide enough job opportunities, thus the increase of population will not result in desperate of economy.This imply that we don't need to change our plan.
- socially Equitable.The population explosion may lead to a widening gap between the rich and the poor, and increase the crime rate at the same time. We need to improve the existing social welfare and security system and involve more people in decision-making on social issues.
- Environmentally Sustainable. Resource shortages and environmental pollution problems will arise. Too many people will need more resources, while human industrial production, travel traffic will adversely affect the environment. To deal with this problem, we must as soon as possible to find renewable energy sources and actively manage environmental pollution.

Reykjavik

- Under the current condition, The Municipal Plan estimates that jobs in Reykjavik will be increased, at least in line with increase in the citys population.(a) Our plan suggest Reykjavik transform to a better economy growth mode, which will increase employment opportunities. The increase in population will meet the needs of the labor force and promote the economic prosperity of Reykjavik.

- Reykjavik has a lot of empty land, so the influx of people will not cause urban congestion
- Reykjavik mainly depend on the abundant geothermal energy, a clean energy. Population growth will not lead to resource or environmental problems.

9 Conclusion

In this paper, we modeled the metric of Smart Growth considering some Smart Growth principles and the three E's of sustainability. We divided Metric Smart Growth Model into Economically Prosperous Metric, socially Equitable Metric, and Environmentally Sustainable Metric. And each Metric is divide into several factors. In addition, we use Grey Relation Analysis to determine the weights of each factor and use SGM to evaluate the success of two cities (Reykjavik and Ann Arbor). Current growth plans of Reykjavik and Ann Arbor both meet the smart growth principles. Then, we predict Per Capita GDP in 2050 and consider influence of dynamic Per Capita GDP for SGM. In order to measure the influence of Economic Opportunities and Geography, we use sensitivity analysis and draw a conclusion that Ann Arbor will increase drastically by increasing ESM. Whats more, we use AHP analyze potential of growth plan based on the geography, expected growth rates, and economic opportunities. The Rank of the potential for Ann Arbor is Social factors >Economic factors>Environmental factor while The Rank of the potential for Reykjavik is Economic factors>Social factors>Environmental factor. Finally, we make the smart plans for each city, and analyze effects of population increasing for the plans. Population increasing for Reykjavik is good for Smart Growth and it is bad for Ann Arbor but our plans can deal with it.

10 Strengths and Weaknesses

10.1 Strengths

1. Our metric for SGM takes economy, social and environment into comprehensive consideration, which are easily calculable and involve a wide range.
2. We apply Grey Relation Analysis to determine the weights of SGM, which is objective.
3. We use sensitivity analysis to quantify the influence of Economic Opportunities and Geography which is difficult to be measure.

10.2 Weaknesses

- In SGM Model, we just evaluate how successful of certain city development plan at certain time. We don't solve problem which of compare between future condition and recent condition for a city.
- Our Model cannot deal with some factors changing sharply, such as financial crisis and cataclysm.
- We cannot get a universal metric of Smart Growth for every cities in the world. We just can evaluate specific city based on its condition and plan.

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