For office use only	Team Control Number	For office use only
T1 ________________	83881	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	E	F4 ________________

2017 MCM Summary Sheet

A method applied to the Smart Growth

Abstract

As the urban population continues to grow, there is a shortage of social resources. The need to implement sound urban planning is almost certain. Smart growth encourages a wide range of building types and uses, multiple housing and transportation options. And its success is also the concern of many local governments. This is also the aim of this article

With regard to requirement 1, we define an indicator of how successful a city's smart growth is. Firstly, based on 3E and ten principles, we divide the indicators into two categories, smart city metrics and measures of development and construction. Secondly, we analyze the description of its main components. Thirdly, we quantify the measurement of the development and construction process, according to the ten principles. Then, we build **Land Mixed Index Model** based on entropy index. The model measures different levels of land mixing. We also establish a **Compact Design Model**, measuring compactness from four dimensions, based on the Moran coefficient. Based on the fuzzy set, we build **Diversity Model,** divided into low, medium and high diversity. In addition, a **Walking Audit Model** was established, based on PERS.

When it comes to requirement 2, we evaluated the success of the growth plans for the two designated cities. Firstly, we screened two representative cities, based on the sustainable development leaderboard. Then, we analyzed the existing policies of the two cities. Besides, in order to analyze its success, we establish the **AHP-based Smart Growth Composite Finger Model**. Finally, we get Minneapolis's composite success index of 0.6485, well above the 0.2758 of Belfast.

In requirement 3, we develop a growth plan for the city. The plan bases on the principle of smart growth. In order to measure the success of this growth plan, we built a **Benefit Index Model**. The model bases on the city's geographic location, expected growth rates, and economic opportunities. When the composite index is higher than 1, it shows that the plan can meet the needs of basic population growth. We draw conclusion that their plans are unsuccessful, since the success index of two cities is 0.54 and 0.83 respectively, and the growth rate is 31.2% and 43.5%.

In requirement 4, we establish a **Potential Measurement Index Model**. The model considers short-term benefits, long-term benefits, driving efficiency and cost loss. In result, the potential policy of Minneapolis ranks 9, 4, 3, 1, 5, 8, 6, 7, 10, 2. When it comes to Belfast, it ranks 2, 1, 8, 9, 0, 6, 7, 5, 4, 3.

According to requirement 5, we predict future traffic, housing and work needs based on population. First, the least square method is used to analyze the population number of the two cities in the future. Then, three models are built for transportation, employment and housing. Finally, relevant data are collected, and various prediction methods ,such as regression prediction, etc. ,are used to calculate whether the policy of smart growth can meet the impact of population change. The results show that our plan can meet the needs of future population growth.

Last but not least, we make sensitivity analysis and discuss strengths and weaknesses. Besides, the future work is proposed.

Keywords: AHP, Least Square Method, Regression Prediction, Interpolation Fitting

Content

1. Introduction

1.1. Background

As the urban population continues to grow, there is a shortage of social resources such as housing and land, and the need to implement sound urban planning is almost certain. Smart growth is a way of encouraging various types of buildings and uses, diverse housing and transport options, existing community development and community involvement.

Figure 1 The picture of smart city

There are a number of factors that need to be considered, whereby Smart Growth has officially developed a set of 10 basic principles that guide smart growth strategies:

- Mix land uses
- Take advantage of compact design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Direct development towards existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost effective
- Encourage community and stakeholder collaboration in development decisions

Each region can refer to one of the series of principles. Then they can formulate its own evaluation indicators, and measure the policy and success of intelligent growth. This is also the task of this article.

1.2. Our Tasks

Although there is a unified principle of wisdom growth, these broad principles must be effective for the unique needs of a community. Any successful measure of success must include a city's demographic, growth and geographical conditions, as well as the goal of adhering to the three E's. So, here are our tasks:

Task1: Define a measure of the success of urban smart growth in terms of 3E and smart growth ten principles.

Task2: Select two medium-sized cities located on different continents with a population of 100,000 to 500,000. Use the indicators defined in Task1 to measure whether the current growth plans of the two cities are in line with the smart growth plan. Evaluate how successful the current growth plan is.

Task3: Set the growth plan for the two cities, based on the principle of intelligent growth, in the coming decades. Based on the location of the city, expected growth rate and economic opportunity analysis, analyze why you specify such a plan. Measure the success of the plan with the metrics in Task1.

Task4: Compare the two cities' initiatives and their ranking changes after implementation.

Task5: Show that the population growth factor is considered in the plan. Even by 2050, the population of each city will increase by 50%, which will still achieve our goal of intelligent growth.

1.3. Data Source

In order to better understand the two cities, and more accurate and there model there. We look up a lot of data. The main source of the data is shown in Table 1.

Table 1 Data Source

Variable	Source
GDP per capita	Open Data Network
House prices	Zillow.com,Zoopla.com
Water pollution index	Numbeo.com
Internaional visitors per year	Belfast City Council, Minneapolis.org
Mixed land use	Minneapolis Geography Detail – MPLS PLAN

2. General Assumptions

We make the following assumptions to complete our model through this paper. Further improvements of these simplified assumptions will be achieved later with more reliable data.

- **The data we count through a variety of reliable channels are objective reality.**
- **It is assumed that the population growth in each city is in line with the world trend.** The topic calls for a 50% increase in the total population of every city in 2050, which is actually the growth trend of the world's urban population. However, the growth of population in every continent is related to many factors such as policy and idea. Therefore, in order to achieve the problem and simplify the problem, we believe that the number of population in every city is in line with the growth trend of population in the world.

3. Notions and Symbol Description

We will define the following variables here as they are widely used throughout our paper. Additional variables may be defined later, but will be confined to a particular section.

SYMBOL	DEFINITION
A_{ij}	The land use percentage of the j^{th} census area
N_j	Number of representative land uses in j^{th} census area
X_i	The proportion of land area in sub-area i
Y_i	The proportion of population or employment in sub-area i
A^{M}_{Bi}	Judgment matrix
ω^{M}_{Bi}	The weight of the corresponding judgment matrix
W	The smart city's success indicator
$G(F(t))$	The growth rate of people's needs
$F(t)$	A function of the population on time
τ	The influence factors of geographical position
U	City development potential benefits
S	New district residents travel

4. What Means the Success of Smart Growth?

In order to apply the theory of smart growth to urban design around the world, we need to define an indicator of how successful it is. To realize the wisdom growth, it is not only in the long run that eventually a smart city needs to be set up, and more attention should be paid to its wisdom and sustainability in the process of development and construction. Therefore, we will measure their success based on smart cities and construction and development perspectives respectively.

4.1. Smart City Metrics

"Smart growth is about helping every town and city become a more economically prosperous, socially equitable, and environmentally sustainable place to live."[1]We also call them 3E, determined by a variety of small indicators. In order to better measure each factor, we choose a number of representative indicators to measure.

- **Economically prosperous:** GDP
- **Socially equitable:** Housing price index, unemployment rate, literacy rate.
- **Environmentally sustainable:** AQI(Air Quality Index), water pollution index, dissatisfaction of garbage disposal.
- **Others:** land mixed utilization rate , Average annual tourist number , Traffic index.

4.2. The Quantification of the Ten Principles

Cities should follow the ten basic principles mentioned above to guide their development, in achieving the goal of a smart city. In order to better measure the success of the growth process, we will thoroughly consider the connotation of these ten principles and quantify these indicators separately.

1. **Mix land uses**

Mixing land uses means buildings, in the same block or building, such as homes, offices, schools, parks, shops, restaurants and other types of development, in close proximity to each other. As the Figure2 shows:

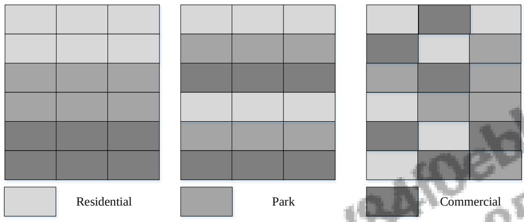

Figure 2 Three ways of mixed use of land

Different levels of mixing can bring more people to the community at multiple times of the day, boosting the vitality of the area.

Imagine three different neighborhoods with roughly 33 percent each of residential, commercial, and park recreational land use. In the first neighborhood, a single-use residential area borders a park, which in turn, borders a large commercial area. The second neighborhood, however, distributes the same proportion of land uses in a more fine-grained manner. The third exhibits an even more fine-grained mix of uses, with almost every parcel of each land-use lying adjacent to another complementary use. The assumed distance to either a commercial and recreational destination from any given residential location is much smaller in B or C than in the A. In fact, one could argue that B is “twice as mixed” as A as the average distance from any residential parcel to either commercial or recreational land use is roughly half of that in A. While these would score identically in an index based solely on proportions of land use, the transportation implications of each could be drastically different.

Therefore, it is an important partof achieving smart growth that rational useing land to generate greater value. By consulting the paper[2], we find that there are many ways to measure the structure of land use. Here, we choose the most popular method, entropy index, to quantitatively evaluate the land use structure.

It comes from outside the fields of geography and urban planning.We denote the land use percentage of the census area j^{th}. Number of representative land uses in j^{th} census area is N_j.Based on the entropy index formula, the index of mixed land use can be expressed as:

$$\frac{-\sum(A_{ij}\ln A_{ij})}{\ln N_j}$$

2. Take advantage of compact design

Using a compact building design means using the land already developed more efficiently. Compact design features high building area density, short commute distance between home, service and work. It encourages development and growth, rather than external expansion. Based on Yu-Hsin Tsa’s research, we can use a set of four dimensions, metropolitan size, density, degree of equal distribution and degree of clustering, to measure compactness. Each dimension has its own quantitative variables, we can see in the Figure3:

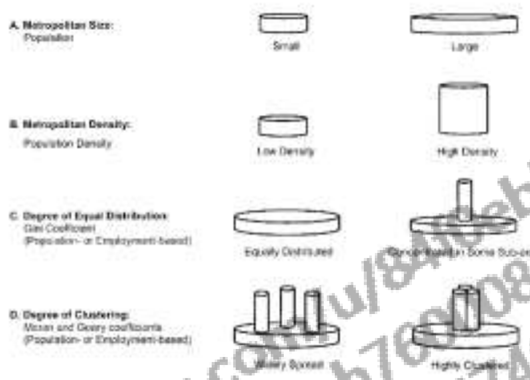

Figure 3 Four Definitions

- Dimension one: metropolitan size

Although A well characterizes the area of land, the population is more flexible in practice. It is not affected by the land consumption per capita, which is related to the second dimension, density, namely the reciprocal of density. In other words, the population is not related to density while the area of land is not, in theory.

- Dimension two: density

Density measures overall activity intensity in a metropolitan area, as B shows. It is the most commonly used variable, characterizing the urban morphology and intensity based on the tightness. However, density can not solve the activity distribution pattern in city. Since it can not distinguish differences among urban forms based on the spatial structure.

- Dimension three: Degree of equal distribution

Considering the size and density of the metropolis, in C, we explore the extent where the cities are equally or unevenly distributed. This dimension addresses the extent to which development is concentrated in a relatively small number of sub-areas. In order to quantitatively describe the extent of the average distribution, indices can be borrowed from those commonly, used to measure inequality in income distribution, including the Gini coefficient. Research shows that the relative entropy is suitable, since it is not affected by sub-regions. [3]The Shannon's relative entropy is used to measure the inequality in the distribution of population or employment in urban.

However, the relative entropy is not satisfied when the value of density is 0, which really does exist (for example, a park). To overcome this problem, partition boundaries need to be adjusted to avoid zero-density values. Since it combines two different areas (such as residential areas and parks), this value making no sense, this adjustment may not be appropriate. Therefore, we choose the Gini coefficient to characterize this dimension. Gini coefficients can also be used to measure inequality in the distribution of population or employment in spatial units in urban. The higher the Gini coefficient, which is close to 1, the higher the population or employment density in a few sub-regions. A Gini coefficient close to 0 means that population or employment is evenly distributed in the city. Gini coefficient is calculated as:

$$\text{Gini} = 0.5\sum_{i=1}^{N}|X_i - Y_i|$$

Where, N is the number of sub-areas; X_i is the proportion of land area in sub-area *; and Y_i is the proportion of population or employment in sub-area *.[4]

➢ Dimension four: Degree of clustering

However, Dimension 3 does not reveal the spatial relationship of high-density areas. When Gini coefficient is large, the distribution of urban population or employment isuneven. Thus, we establish the fourth dimension, the degree of aggregation, to estimate the degree of high-density partition aggregation or random distribution, as shown in D. In theory, our goal is to measure spatial relationships. In order to achieve this goal, we often use the Moran coefficient to quantify this dimension:

$$\text{Moran} = \frac{N\sum_{i=1}^{N}\sum_{i=1}^{N}W_{ij}(X_i - X)(X_j - X)}{\left(\sum_{i=1}^{N}\sum_{i=1}^{N}W_{ij}\right)(X_i - X)^2)}$$

Where, X is the mean of population or employment, and W_{ij} denotes the weighting between sub-areas i and j. The other variables are the same as above. The Moran coefficient ranges from -1 to +1, with a high positive value indicating that high-density sub-areas are closely clustered, a value close to zero meaning random scattering and a -1 value representing a'chessboard' pattern of development.

3. Create a range of housing opportunities and choices

It is also an integral part of the smart growth that meeting the housing demonds, forresidents and providing diverse housing options for families with all life stages. Most discrete or continuous phenomena in the real world are inaccurate. Means, they have a certain degree of ambiguity in describing their nature. Therefore, we can use fuzzy sets theory to analyze and explain this inaccuracy ,for example, low heterogeneity, high income, medium age. In the fuzzy set approach, an inaccurate concept such as diversity can be defined in linguistic terms, such as "low, high, short, long, and very few." According to the nature of the phenomenon, many fuzzy sets can be defined. Each fuzzy set is completely determined by its membership function. Membership functions represent the degree, where an element belongs to a fuzzy set. There are many ways to select membership functions from a set of functions (Zimmermann 1991; Les 1991). Here, in the case of a fuzzy set, representing a diversity category, a linear representation may be selected as a membership function. Linear approximation is a good choice when it comes to concepts that are unknown or unclear. In summary, we propose the following membership functions to define low, medium and high diversity, respectively:

➢ **Low diversity**

$$f_{low}(x) = \begin{cases} 1 & \text{if } x = 0 \\ -\frac{4}{3}x + 1 & \text{if } x \in (0, \dots, 0.75) \\ 0 & \text{if } x \geq 0.75 \end{cases}$$

➢ **Medium diversity**

$$
f_{medium} = \begin{cases} 0 & \text{if } x = 0 \\ \frac{4}{3}x & \text{if } x \in (0, \ldots, 0.75) \\ 1 & \text{if } x = 0.75 \\ -4x + 4 & \text{if } x \in (0.75, \ldots, 1) \\ 0 & \text{if } x = 1 \end{cases}
$$

- **High diversity**

$$
f_{high}(x) = \begin{cases} 1 & \text{if } x \leq 0.75 \\ 4x - 3 & \text{if } x \in (0, \ldots, 0.75) \\ 1 & \text{if } x = 1 \end{cases}
$$

4. Create walkable neighborhoods

The walkable part is made through the use of mixed land and utilizes a compact design. However, smart street designs that make walking not only practical but also safe and easy to enjoy. The city's smarter growth needs to be properly engineered. In this way, people can get more pedestrian opportunities, as clearly shown in the Figure4. By the same kilometer, close pedestrianized street offers more opportunities for walking.

Compact design Loose design

Figure 4 Two ways of designing the street

According to the relevant information [5], we found that one of the most common ways to assess and measure walking ability. It is to conduct a walking audit. The widely used PERS (Pedestrian Environmental Review System) in the UK is the most popular walking audit tool of the moment. Thus, we chose to use it to measure the creation of pedestrian streets.

5. Foster distinctive, attractive communities with a strong sense of place

Communities, with a strong sense of place, are built on their unique history, identities and assets to foster community pride,. It increase social interaction, and promote communities to potential businesses and residents. The result can improve economic stability and increase the value of property, which has a great impact on the lives and memories of residents.

Urban expansion is creating a new image for a growing community, referred to as "America anywhere". The monotonous development of such a large-scaled development keeps people away from urban centers and from each other. The result also leads to the loss of millions of acres of farmland and open space, reduced investment in our cities, decreased social interaction, diversity and pride in citizens. In order to create a unique image and maintain the unique of a place, many communities are investing their history as a basis for new growth. The history of a region can be reflected in historical monuments and museums. The natural scenery is often created by the climate and ecology of the region. Thus, is also an important factor that reflects the local sense of place. By separately counting their numbers, they are given a certain weight. We can quantify the sense of square sense of the target.

6. Preserve open space, natural beauty, and critical environmental areas

It meets people's needs for housing and tourism, attracts employers to the city, and supports the agricultural industry. Protecting open spaces also makes communities more resilient, protecting them from natural disasters, protecting environmental resources and habitats of animals and plants. They are all elements worth considering.

5. Are the Two Cities Grow Smart?

To evaluate the success of the growth plan of two designated cities. We first need to screen two representative cities. Analyze the existing policies of the two cities. In order to analyze its success, we need to build a model and evaluate it with Task1.

5.1. The Determination of Two Cities

The Centre for Economic and Business Research (Cebr) assessed 100 of the world’s leading cities, using 32 different indicators, to develop an indicative ranking of the sustainability of each.[6] Based on the leaderboards, we searched the population of these cities in turn. Finally, we screene 5 cities that meet the requirements of the medium-sized cities.(The population of 10-50 million). They are Cape town, Zurich, Minneapolis, Nottingham and Belfast. By analyzing these five candidate cities, we find that these cities can be divided into two categories, according to different continents. The first are cities in the Americas, including Cape town, Minneapolis. The second are cities in continental Europe, which are Zurich, Nottingham and Belfast. In order to make the respondents representative, we ranked the two cities with the highest scores, based on the rankings in their leaderboards. They are Minneapolis and Belfast. Their basic information is in Table 2.

Table 2 Basic information on two cities

	Belfast	Minneapolis
Location		
Population	333,001	491,036

5.2. Current Growth Plan of Two Cities

Table 3 Current growth plan of two cities

	Minneapolis	Belfast
1	Build more housing, retail, and places for employment, especially near mass transit.	Support local economy and promote the development of land and buildings suitable for retail, leisure and office within the city center and district centers
2	Build more stores in under-served areas	Ensure a series of places suitable for employment
3	Become a less affordable place to live, especially for people of color	Ensure that there is enough suitable land to meet future demand and the appropriate type, size, tenure and mix of new residential developments
4	Make the city be more walkable, bikeable, and mass transit-friendly	——
5	——	Protect and strengthen the construction environment of local characteristics.
6	——	Protect and improve the historical environment
7	Retrofit existing buildings to reduce energy consumption	Provide convenient playground, sports and entertainment opportunities to support a healthy lifestyle.
8	Provide better mass transit to places of employment.	Promoting travel through more sustainable means of transport

5.3. Comprehensive index model of intelligent growth based on AHP

Analytic Hierarchy Process (AHP) is a simple, flexible and practical multi-criteria decision-making method for quantitative analysis of qualitative problems. It is characterized by the complexity of the various factors, through the division of the interconnected orderly level. According to a certain objective reality of the subjective judgments of the subjective judgments of the objective judgments directly and effectively combine the elements of a level two. The importance of both comparisons is quantitatively described. Then, we use mathematical method to calculate the weights that reflect the relative importance order of each level element, calculate and rank the relative weights of all the elements through the total ranking between all levels. The method is often used for urban planning because of its combination of quantitative and qualitative features. Here, we will use AHP to quantify smart city metrics.

Step1. Establish a hierarchical structure

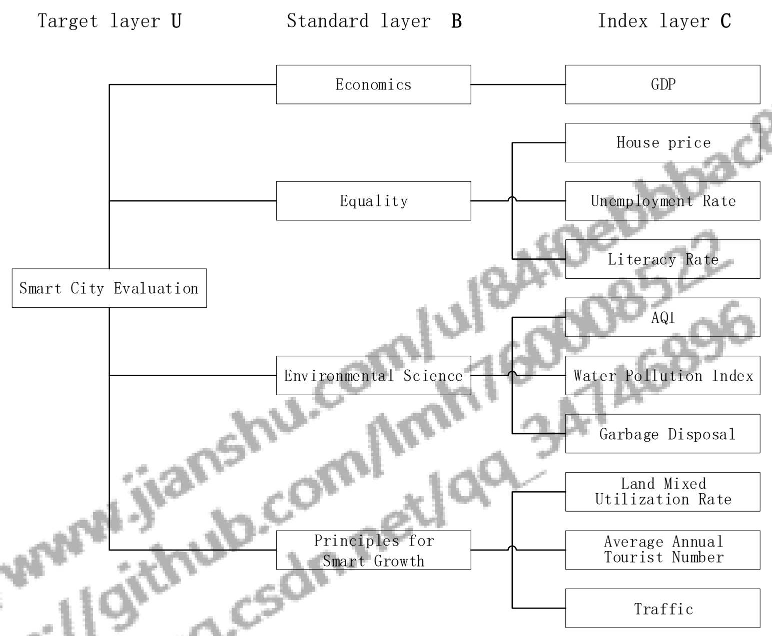

Figure 5 hierarchical structure

Step2. Construct judgment matrix

- Minneapolis composite index

By finding the relevant data of each indicator, We use Efficacy Function to transform the value between 0 to 1. The data for the ten indicators of indicator layer are as follows:

$$I^M=(0.6136,-0.2425,-0.24,0.96,-0.3152,-0.1324,0.2647,0.04,0.309,0.15)$$

Based on the policies in the comparison table above, we generalize the factors that have a significant impact on the indicators and the direction of their impact.

Table 4 The influence of Index

	Index	Influence
Minneapoils	Water-pollution	–
	Unemployment	–
	House-price	–
	Traffic	+

Judge the degree of influence, get the final judgment matrix.

$$A_{B2}^M=\begin{bmatrix}1 & 1 & 3\\ 1 & 1 & 3\\ 1/3 & 1/3 & 1\end{bmatrix}\qquad A_{B3}^M=\begin{bmatrix}1 & 1/3 & 1\\ 3 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}\qquad A_{B4}^M=\begin{bmatrix}1 & 1 & 1/3\\ 1 & 1 & 1\\ 3 & 1 & 1\end{bmatrix}$$

$$A_U^M=\begin{bmatrix}1 & 1/6 & 1/3 & 1/3\\ 6 & 1 & 3 & 3\\ 3 & 1/3 & 1 & 1\\ 3 & 1/3 & 1 & 1\end{bmatrix}$$

Step3. Calculate the weight

Calculate the weight of the corresponding judgment matrix.

$$\omega_{B2}^{M} = (0.42857{,}0.42857{,}0.14286)$$
$$\omega_{B3}^{M} = (0.22112{,}0.45996{,}0.31892)$$
$$\omega_{B4}^{M} = (0.22112{,}0.31592{,}0.45996)$$
$$\omega_{U}^{M} = (0.072821{,}0.5345{,}0.1963{,}0.1963)$$

Multiply the weights of the guideline layers and the indicators of the corresponding indicator layer to get the final weights of the ten indicators.

$$\omega^{M} = (0.072821{,}0.227627515{,}0.227627515{,}0.07635867{,}0.043425486{,}\ 0.090290148{,}0.062603996{,}0.043425486{,}0.062603996{,}0.090290148)$$

Step4. Measure the success of existing policies in both places

Assume that the smart city's success indicator is W, I_i is the ith indicator. Combining these weights gives the following linear relationship.

$$W = \sum_{i=1}^{10} \omega_i I_i$$

Bring into data I^M, we can obtain Wisdom Growth Composite Index.

$$W^M = 0.6485$$

Similarly, Belfast's Wisdom Growth Composite Index is available. Related information, matrix can be seen in appendix.

$$\omega^{B} = (0.072821{,}0.227627515{,}0.227627515{,}0.07635867{,}0.043425486{,}\ 0.090290148{,}0.062603996{,}0.043425486{,}0.062603996{,}0.090290148)$$
$$W^B = 0.2758$$

Water can be accumulated and reserved in reservoirs created by dams. First of all, mark the water storage capacity of i^{th} reservoir as $V(t,i)$. Then, the water balance equation can be stated as follows:

$$V(t+1,i) = V(t,i) + Q_{in}(t,i) - Q_{out}(t,i) - L(t,i) - W(t,i) \tag{5}$$

Where $V(t+1,i)$ and $V(t,i)$ stand for the water storage at the time of t+1 and t. $Q_{in}(t,i)$ refers to the water inflow of the i^{th} reservoir form upper reach. $Q_{out}(t,i)$ stands for the discharge of the i^{th} reservoir to lower reaches. $Q_{ge}(t,i)$ is the part in discharge that is used to generate electricity and $O(t,i)$ is the rest that are drained directly. $L(t,i)$ is the internal loss of reservoir, the majority of which are loss through evaporation and permeation. $W(t,i)$ represents the part of water for external use, including agriculture, industry and domestic water.

Owing to the limit in reservoir's scale and serviceability, the restraints are listed as follows:

- Restraints of $V(t,i)$

We should guarantee that the water storage is smaller than the reservoir's maximum storage volume and greater than its dead storage capacity, which is presented as follows:

$$V_{min}^{i} \le V(t,i) \le V_{max}^{i} \tag{6}$$

Where V_{min}^{i} refers to the dead storage capacity and V_{max}^{i} refers to the maximum storage volume. The maximum storage volume can be categorized into two parts. V_{max1} stands for the maximum water allowed to store under normal circumstances. V_{max2} stands for the maximum water for use through flooding. Therefore, $V_{flood} = V_{max2} - V_{max1}$ represents the flood control capacity needs to be retained.

- Restraint of $Q_{out}(t, i)$

There are two ways for discharge, one is direct drainage, named flow capacity, the other is water drained off during electricity generation, named discharge capacity. For each kind of drainage, the restraint can be states as follows:

$$O(t,i) \leq O_{max}^{i}(h)$$

$$Q_{ge}(t,i) \leq O_{gemax}^{i}(h)$$

Where h is the water level, $O_{max}^{i}(h)$ and $O_{gemax}^{i}(h)$ are the maximum flow capacity and maximum discharge capacity if the i^{th} dam, Both of which are related to the water level.

6. The development of the Smart Growth Plan

Based on the principle of intelligent growth, we need to develop a growth plan for two cities based on their characteristics. To measure the success of the growth plan, we have to consider the location of the city, the expected growth rate and the economic opportunity.

6.1. Smart Growth Plan for Minneapoils

- During the peak demand period, we can charge variable pricing with high cost. Establish convenient Park parking facilities or shared parking facilities, as well as shuttle or walking connections to the desired destination.
- Develop and maintain strong and successful commercial and mixed use areas with a wide range of character and functions to serve the needs of current and future users.
- Provide incentives to encourage local communities to increase the building density, such as the provision of density bonuses and the creation of coverage areas.
- Build a safe and supportive infrastructure for walking, cycling, and other non mobile ways of travel.
- Implement preferential tax policies and protect historical resources
- Improve the local community and build open cultural space composed of multi purpose green space, library, entertainment and conference hall.
- Adopt development incentives, such as speeding up the licensing process in existing infrastructure areas.
- Affordable housing for permanent residents and seasonal residents.
- Waste and sewage are used as a resource to increase recovery and reuse.
- We need to initiate grass-roots discussions and local group decisions to promote change, and let professional intermediaries communicate with community agenda and cultivate greater sense of autonomy and choice.

6.2. Smart Growth Plan for Belfast

- Strengthen public transport on water and link it with pedestrians and land transit systems.
- Create overlay and special area zones that permit horizontal and vertical mix of uses）

- Create a walking community and emphasize the pedestrian passageway along the beach.
- Use the building code to determine the proper height of the building and ensure the visibility of special scenic spots or landscapes.
- Historical and cultural structures are integrated into development projects, including buildings, wharfs and wharfs and other coastal areas.
- Plan for nature, predict dynamic coastal and coastal processes, and manage ecosystem to adapt to changes caused by human activities.
- Promoting the scientific improvement of risk management in marine ecosystems.
- Promoting community based waterfront revitalization.
- Create a consensus among the different stakeholders to set goals for all stakeholders.
- Create an inclusive partition, which requires new construction, including some of the affordable units.

6.3. Evaluate the Success of Smart Growth Plans

In order to illustrate the rationality of the policy, we are from the geographical location of the city, the expected rate of growth and the success of the economic opportunity analysis.

First of all, we define these three factors respectively:

- The influence factors of geographical position $\boldsymbol{\tau}$:

  Belfast is a coastal city, and the marine industry is developed. It is an important factor of geographical influence; Minneapoils forms "Twin Cities" with the neighboring state capital of St. Paul, which are closely linked。
- Expected growth rate $G(F(t))$:

  It is the growth rate of people's needs, in which $F(t)$ is a function of the population on time.
- Economic opportunities can be useful for the additional economic benefits $W(t)$:

For Belfast, its economic opportunities are mainly from the ocean. For Minneapolis, economic opportunities are mainly derived from their culture and art. With the richness of the material world, people pay more attention to the spiritual world, so the development of culture and art can bring about great development of tourism.

The sum of economic benefits is obtained by summing up the benefits, generated from various economic opportunities. The impact of different economic opportunities on the total benefits.

$$W(t) = \sum_{i=1}^{N} \theta_i w_i(t)$$

Where, θ_i is the impact factor of the opportunity; $w_i(t)$ is the normalized benefit value of the ith economic opportunity.

We can get the intelligent growth index model in Task1, where we can get:

$$\boldsymbol{W} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{N}} \boldsymbol{\alpha_i} \frac{W(t)^{self} + W(t)}{G(F(t)) \times W_0} \boldsymbol{\tau}$$

Where, $W(t)^{self}$ denotes the self-economic effect, while W_0 is called existing values.

$G(F(t)) \times W_0$ is expressed as the amount of increase of the original revenue, if calculated according to the expected growth rate. The numerator is expressed as the current amount of growth, the ratio of the two, the ratio of the current program to that of the past.

According to the index in Task1, we recalculated the weight of each policy, as shown in Table 5.

Table 5 Intelligent growth index of the two cities

	Policy1	Policy 2	Policy 3	Policy 4	Policy 5	Policy 6	Policy 7	Policy 8	Policy 9	Policy 10
Minneapolis	1.246264	1.342727	1.150466	1.720238	1.383071	1.132651	2.106115	1.360426	1.567412	1.793529
Belfast	1.382233	1.199038	1.436236	1.580803	1.468778	1.548046	1.73985	1.422143	1.623572	1.531737

In the same way as the Task1 method, the value of W is recalculated. The success index of two cities is **0.54** and **0.83** respectively, and the growth rate is **31.2%** and **43.5%**, respectively. As a result, the policy we set up can promote the development of the intelligent city to a certain extent.

7. Which policy is more potential?

Measuring the city's ranking is a measure of its development potential. City development potential benefits of U is the molecular of formula, which is mainly composed of the short-term benefits of $f(t)$, $g(t)$, the long-term benefits W_L and cost benefit C.The short-term benefits of the period of rapid development of this industry's revenue, the long-term benefits of this industry after a stable long-term operating income, benefit this industry drives other industries benefit, and cost for its social adverse effects on the environment and other aspects. Denominator of formula can be explained as the benefit that can be brought about according to the current development model.

$$\mathrm{U} = \frac{\alpha \int_{beg1}^{fin1} f(t)dt + \beta \int_{beg2}^{fin2} g(t)dt + (1-\alpha-\beta)(W_L - C)}{W_0(1+\delta)(fin - beg)}$$

Where, W_0 is the current income， δ is annual growth rate。 fin and beg represent the beginning and the end of the year, respectively. Here we take $fin = 2015$， $beg = 2020$； α， β are its variable parameter, belong to [0,1]. By researching the relevant data, we normalize the potential value of each specific policy, as shown in Table 6 :

Table 6 Potential Value of each policy

	Policy1	Policy 2	Policy 3	Policy 4	Policy 5	Policy 6	Policy 7	Policy 8	Policy 9	Policy 10
Minneapolis	1.634417	1.162528	1.667874	1.722099	1.474439	1.284087	1.227734	1.3461	1.854828	1.213012
Belfast	1.958471	2.258731	1.198128	1.213232	1.439638	1.51934	1.508139	1.687019	1.572896	1.526219

From the table above, we know the potential policy of Minneapolis ranks 9, 4, 3, 1, 5, 8, 6, 7, 10, 2. When it comes to Belfast, it ranks 2, 1, 8, 9, 0, 6, 7, 5, 4, 3.

8. What will happen to 2050?

With the gradual improvement of urban construction, the city's population has become more and more attractive. It is estimated that by 2050, 66% of the world's population will be urban and this will result in an estimated 2.5 billion people joining the urban population. The trend of population growth can be seen from the figure below.

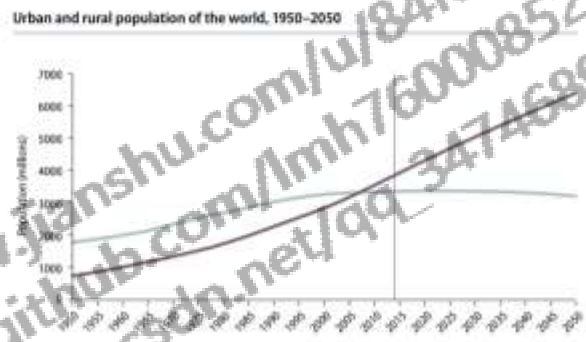

Figure 6 World population forecast

According to the world trend, we can interpolate the annual population by interpolation to figure out the urban population growth trend. As shown in the figure, the total population of each of the five cities in each of the five cities is as follows.

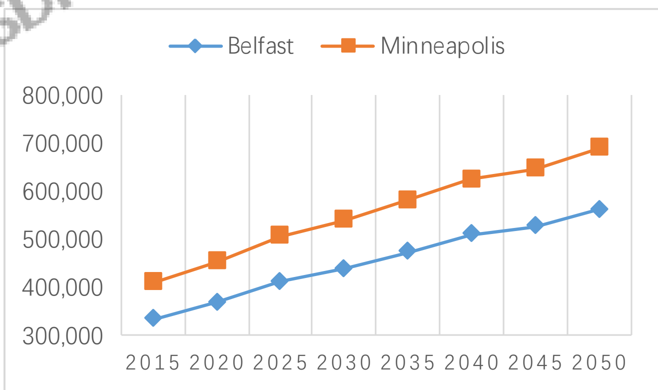

Figure 7 Population forecast

	Belfast	Minneapolis
2015	333,871	410116
2020	369015.3	453286.1053
2025	412945.7	507248.7368
2030	439303.9	539626.3158
2035	474448.3	582796.4211
2040	509592.6	625966.5263
2045	527164.7	647551.5789
2050	562309.1	690721.6842

The table specifically reflects the population of the two cities in the future. By 2025, Balfast population will reach 562309.1, Minneapolis will reach 690721.6842. Given the expected rate of growth, in the future, existing conditions such as transportation, housing and employment opportunities can not meet the needs of an excessive population. However, if we adopt our policy plan, these pressures can be resolved. Below, we will explain how they are supported in transportation, housing and employment opportunities.

8.1. Traffic demand: provide a variety of transport options

The growth of the population is bound to bring about the increase of traffic flow. However, population travel can be divided into permanent and mobile population trips. As a result, the following formula can be obtained:

$$S = \sum_{i=1}^{q} (P_i T_{P_i} + P_{i,f} T_{P_i t})$$

Where S refers to new district residents travel, q is the number of traffic area, while P_i , T_{P_i} represent traffic area resident population and per capita number of trips. $P_{i,f}$, $T_{P_i t}$,namely, the number of floating population and the number of per capita trips in the traffic area respectively, and the number of trips per capita depend on the status quo of the major transport areas and the economic development level and intensity of land use in the planned years.

Assume per capita number of trips for 2 times, work. According to the survey data, Minneapolis has 10 major districts and Belfast has 8 major districts. The traffic population in the traffic area is the product of the time and the number of trips. Bring the above formula to calculate the total amount of traffic, as shown in Table6.

Table 7 Total traffic traffic flow

	Belfast	Minneapolis
2015	667742	820232
2020	738030.6316	906572.2105
2025	825891.4211	1014497.474
2030	878607.8947	1079252.632
2035	948896.5263	1165592.842
2040	1019185.158	1251933.053
2045	1054329.474	1295103.158
2050	1124618.105	1381443.368

Table 8 Total public transport traffic flow

	Belfast	Minneapolis
2015	534193.6	656185.6
2020	516621.4421	634600.5474
2025	495534.8526	608698.4842
2030	439303.9474	539626.3158
2035	398536.5411	489548.9937
2040	356714.8053	438176.5684
2045	295212.2526	362628.8842
2050	224923.6211	276288.6737

In order to solve the housing problem, we have formulated the policy of building compact construction, and the road is more closely linked. At the same time, the mixed use of land and construction of more sidewalks made the work, entertainment and residential areas closer. Through our series of policies, nearly 80% of the people in the future can meet the demand of living and entertainment through walking or cycling, and the rest can be solved according to the existing public transportation. This makes the required traffic flow greatly reduced. Therefore, based on the 80% choice of walking or cycling out of the calculation, we can estimate the demand for public transport as shown in Table7.

They can be shown Figure8:

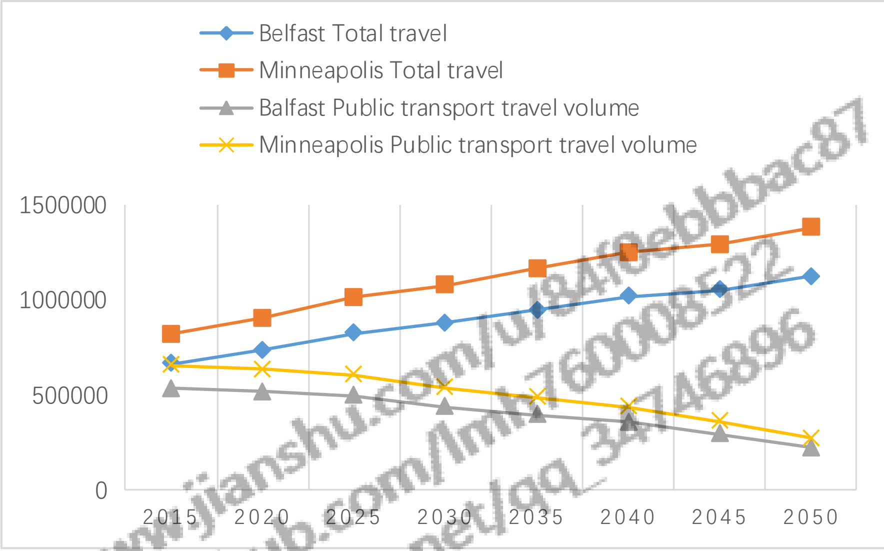

Figure 8 Total transport traffic flow

From the trend chart, we can see that through our policy, public transport demand will show a clear downward trend in the future. This shows that our policy is effective in alleviating traffic pressure.

8.2. Housing needs: compact housing solution

The sharp increase in urban population will inevitably lead to housing tensions. How to expand the capacity in a limited urban space is a question the government needs to think about. By reviewing the official documents, we have obtained the housing supply and average household size of Minneapolis and Belfast in recent years at 4 and 2.23, respectively. The demand for housing can be calculated by dividing the total population by the average household size. As for the housing supply after the policy change, we estimate the number of housing units that can be provided per year based on the closely designed policies and the existing community rehabilitation plan. Thus, we get the following figure by linear fitting:

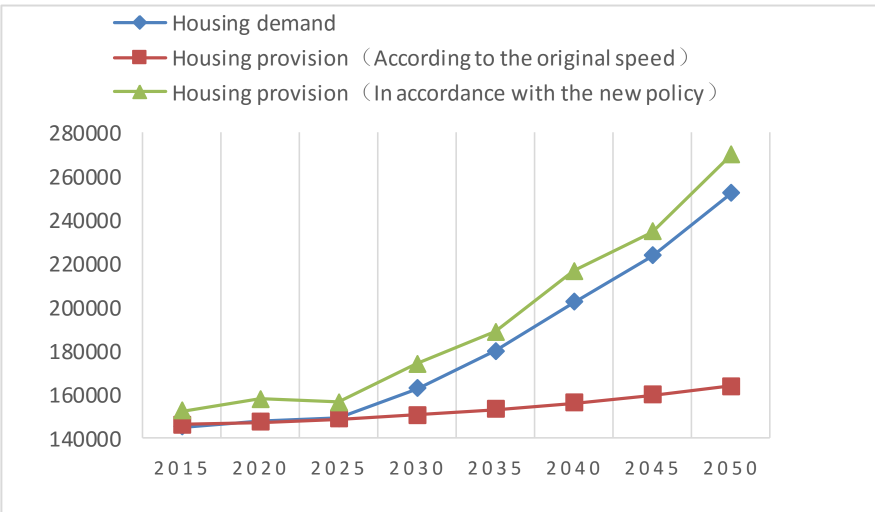

Figure 9 Housing Problem of Minneapolis

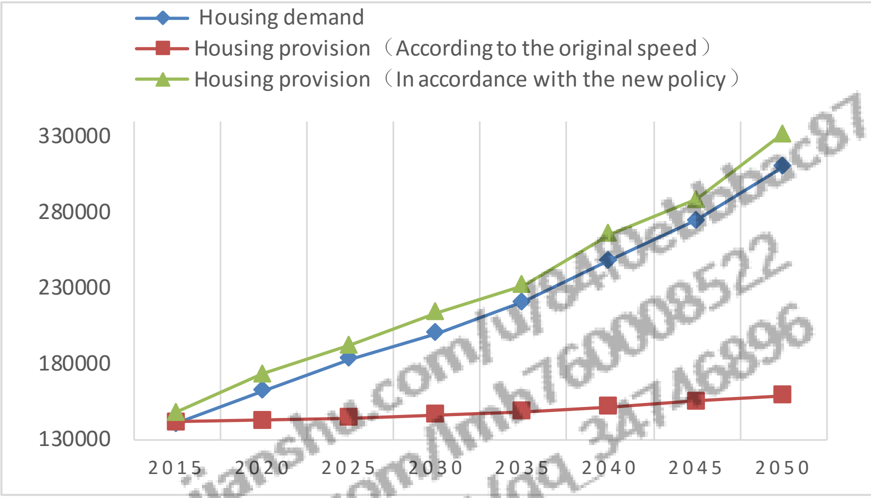

Figure 10 Housing Problem of Belfast

From the Figure 9 and Figure 10, we can see that for the two cities, the existing housing supply tree is far higher than the original policy and is increasing year by year. Housing demand and policy changes in housing supply trees almost coincide, we can see that our policies can effectively solve the housing needs.

8.3. Employment needs: equal resources to solve

There are currently 245,000 people employed in Belfast. This is c.38,000 more than in 2001 and, with the exception of two years (2009 and 2012) when 10,000 jobs were lost in the city, figures have been on consistent upward trend. In fact, sine the decline in 2012, Belfast has gained over 14,000 more jobs. However, as the population increases, so does the need for employment, and there is a greater need for equitable employment resources.

Take Belfast as an example. About 70% of its population structure is working age, and its total population is obtained by referring to the data to calculate the demand-employment population. Based on the employment demand in recent years, the total number of people in need of employment in the future can be predicted. Estimate the number of jobs available each year according to our policies and calculate the demand per square kilometer by area, as shown in the Table: 9

Table 9 Employment of Balfast

	Employment （km^2）	Need employment	Employed population(km^2)
2015	2681.91459	233709.7	2554.204372
2020	2907.760029	258310.7211	2823.06799
2025	3380.287838	289061.9974	3159.147512
2030	3663.266796	307512.7632	3360.795226
2035	3702.252021	332113.7842	3629.658844
2040	3898.522462	356714.8053	3898.522462
2045	4395.920155	369015.3158	4032.954271
2050	4430.872426	393616.3368	4301.817889

Visualize it, you get the following image:

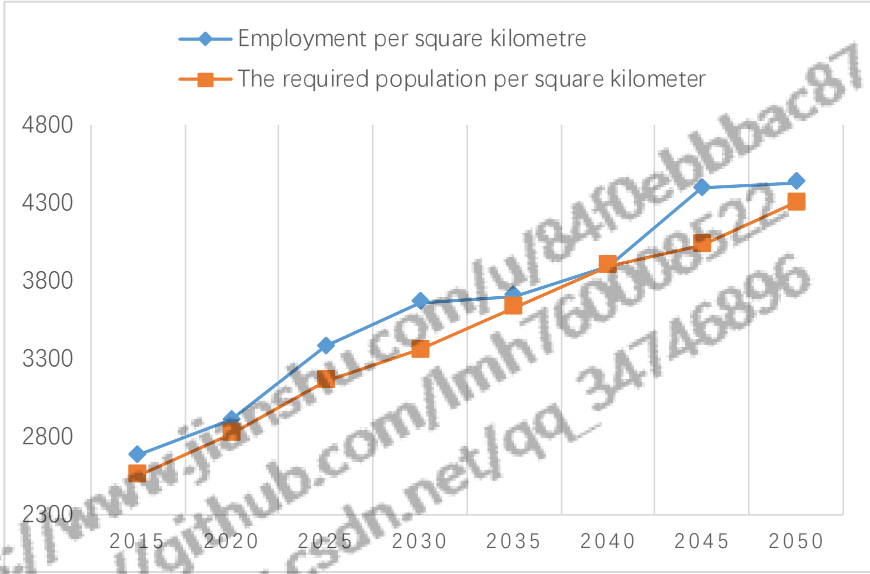

Figure 11 Employment of Belfast

From the Figure 11 we can see that according to our policy, the number of jobs that can be provided per square kilometer can meet the demand in the future and the supply and demand are almost in balance. It can be seen that our policy can effectively solve the problem of equality of employment resources.

Similarly, the supply and demand of Minneapolis can be predicted.

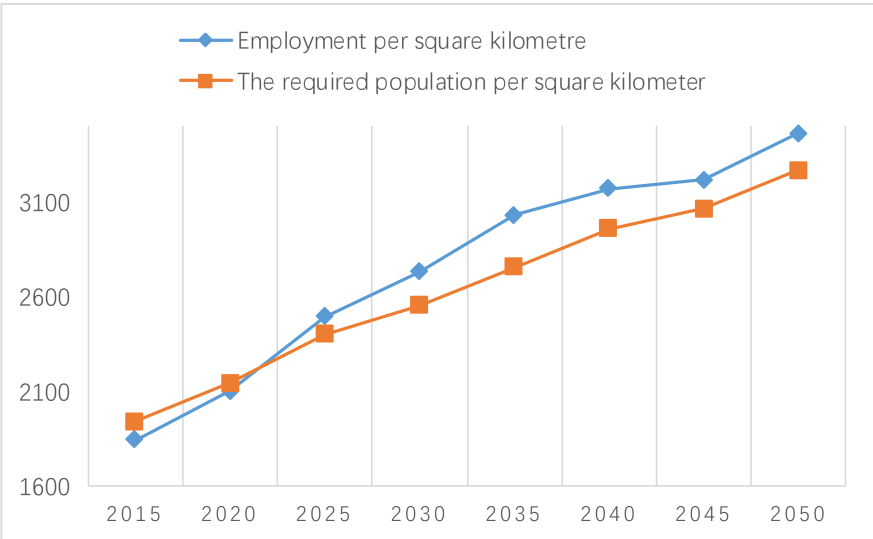

Figure 12 Employment of Minneapolis

After 2020, the employment volume will be slightly larger than the demand, which can effectively meet the needs of work. Before 2020, because Minneapolis is located in the United States, there are a large number of immigrants and the policy adjustment takes a long time. There may be a period of supply shortage.

9. Model Analysis

9.1. Sensitivity Analysis

Since Minneapolis is a famous 'Twin Town', which is closely linked with neighboring states. Belfast is famous for its coastal bay. Therefore, the great geographical difference between the two cities brings different indicators. Therefore, we select the urban population travel total model for sensitivity analysis.

The huge geographical differences lead to the difference of average number of trips of the floating population. Therefore, we will fluctuate 20% times of the average number of trips of the floating population, that is to take 2 times, 2.5 times and 3 times, and get the Figure 12 and Figure 13.

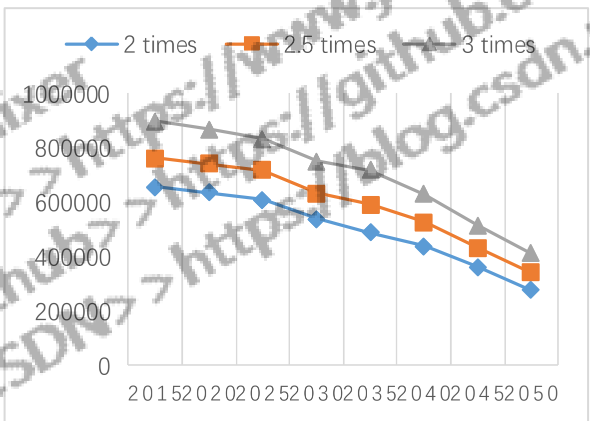

Figure 13 Sensitive Analysis of Minneapolis

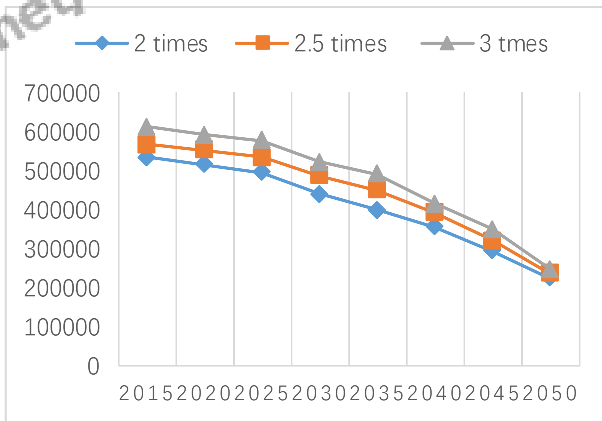

Figure 14 Sensitive Analysis of Balfast

Figure.12 and Figure.13 shows the sensitivity analysis of $T_{P_i t}$. The maximum number of travel in Minneapolis appeared in 2015, floating up and down about **12.5%**. With the increase of year, the deviation became smaller and smaller, and the minimum value in 2050 was **5%**. As for Balfast, it's worth floating between **0.5%** and **8%**. This indicates that the model is **insensitive** to $T_{P_i t}$. Besides, the volatility of the year shows that our policy not only solves the travel problems of the local people, but also considers the impact of the floating population on the trip. Comparing the two graphs, we can see clearly that the fluctuation of BF is much less than that of MN. This is because BF is a famous tourist city, and the floating population is mostly tourists; however, the floating population of MN is mostly migrant workers and students.

9.2. Error Analysis

In the population forecast model, we predict the total population of two cities according to the change rate of the world population, which will bring some error. Therefore, we calculate the difference between the population change rate and the actual situation in two cities, and the results are shown in the Table ?.

Table 10 Error Analysis

Minneapolis	-0.00646	-0.00805	-0.00283	0.009	-0.00287	0.008017	0.003033
Belfast	-0.00647	-0.00947	-0.00705	-0.00016	-0.0108	-0.00158	-0.00352

All the errors are less than 1%, so it can be judged that the population forecast in two cities is more reliable.

9.3. Strength and Weaknesses

1. Strength

- We have considered all possible factors as much as possible.
- We have collected a lot of reliable data by various means.
- Analytic hierarchy process (AHP) is a good way to deal with qualitative and quantitative problems. The decision maker's subjective judgement and policy experience are introduced into the model and quantified.

2. Weaknesses

- Some predicted data will produce errors that are not exactly the same as the real ones.
- The weight of the data is difficult to be determined because the data statistics are too large when the index is too much.

10. Future Work

Some places in the United States are sprawling out and some places are building in compact, connected ways. The difference between these two strategies affects the lives of millions of Americans. That means, in addition to intelligent growth, urban sprawl is a possible phenomenon, if city managers do not plan a good city.

In 2002, the smart growth of the United States has issued a survey of the spread and its impact. The spread is related to physical inactivity, obesity, traffic accidents, poor air quality, residential energy use, emergency response time, youth driving, lack of social capital and commuting distance and number of private cars. There are four main factors used by researchers: residence and employment density; family neighborhood structure, work and service; activity center and urban intensity; and accessibility of street network evaluation in these aspects of development and distribution of a spread index score.

Therefore, we should explore the relationship between the spread index score and the life of the community. As the city's compact index rises, how people's quality of life, health is affected, and how governments at all levels can support their efforts.

11. Conclusion

This paper has developed an intelligent growth strategy and measured the success of the original strategies of the two cities and the success of the new strategy.

With regard to Task 1, we define the smart growth of a city as a sign of success. First of all, we divide the index into two categories and analyze the description of its main components. Secondly, the development and construction process is quantified according to the ten principles. Then, the land mixing index model, diversity model and human based walking audit model based on entropy index are established.

When it comes to Task 2, we assess the success of the growth plan of two designated cities. First, we screened two representative cities based on the list of sustainable development. Then, the current policy of the two cities is analyzed. In addition, in order to analyze its success, we set up a composite finger model of intelligent growth based on analytic hierarchy process.

In Task 3, we have developed a growth plan for the city. In order to measure the success of this growth plan, we set up a benefit index model. The model is based on the location of the city, the expected rate of growth and the economic opportunity.

In Task 4, we have established a potential metric model. The model takes into account the short-term benefits, long-term benefits, driving efficiency and cost loss.

According to Task 5, we predict future transportation, housing and work requirements according to the population. First, the least square method is used to analyze the population of the two cities in the future. Then, three models are established for transportation, employment and housing. Finally, we collect relevant data and use a variety of prediction methods, such as regression forecasting, to calculate whether the intelligent growth policy can meet the influence of population change.

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Appendices

1.PROGRAM

AHP Matlab

```
A = [
      1 1/6 1/3 1/3;
      6 1 3 3;
      3 1/3 1 1;
      3 1/3 1 1;
]

[n,n] = size(A);
[v,d] = eig(A);
r = d(1,1);
CI = (r-n)/(n-1);
RI = [0 0 0.58 0.90 1.12 1.24 1.32 1.41 1.45 1.49 1.52 1.54 1.56 1.58 1.59]
CR = CI/RI(n);
if CR < 0.10
      CR_Result = '通过';
else
      CR_Result = '不通过';
end

w = v(:,1)/sum(v(:,1));
w = w';

disp('该判断矩阵权向量计算报告：');
disp(['一致性指标：' num2str(CI)]);
disp(['一致性比例 ：' num2str(CR)]);
disp(['一致性检验结果：' CR_Result]);
disp(['特征值：' num2str(r)]);
disp(['权向量：' num2str(w)]);
```


2.TABLE： Some important data

Data Item	Minneapolis	Belfast
GDP per capita ($)	61360	47254

House prices($)	242500	218150
Unemployment rate	2.4%	4.2%
Literacy rate	96%	82%
AQI	31.5263	45
Water pollution index	26.47	15.38
Dissatisfaction with Garbage Disposal	13.24%	23.21%
Mixed land use	0.4%	0.2%
International visitors per year(million)	30.9	7.59
Traffic index	149.88	121.96
Oak Graduate School	53	52

3.Result of Task1 for Balfast

$$I^B = (0.4725, -0.2182, -0.42, 0.82, -0.45, -0.2321, -0.1538, 0.02, 0.0759, 0.122)$$

	Index	Influence
Belfast	Mixed use	+
	Unemployment	-
	Tourism	+
	Traffic	+

Weight matrix：

$$A^B_{B2} = \begin{bmatrix} 1 & 1/6 & 3 \\ 6 & 1 & 3 \\ 1/3 & 1/3 & 1 \end{bmatrix} \quad A^B_{B3} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad A^B_{B4} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$A^B_U = \begin{bmatrix} 1 & 3 & 3 & 1/3 \\ 1/3 & 1 & 1 & 1/6 \\ 1/3 & 1 & 1 & 1/6 \\ 3 & 6 & 6 & 1 \end{bmatrix}$$