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Research Article

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Assessment of Urban Development Level Based on Smart Growth

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Abstract Smart growth (SG) is an approach for sustainable urban development. We conduct the case study with SG. First, we select two mid-sized cites from two different continents, *i.e.* Geneva and Wellington, and collect the data for both cities in recent years. Second, we analyze the ten principles of SG and the three E's of sustainability, select a series of indicators of the impact on SG. We do comparative analysis between the two cities. Then, we apply the analytic hierarchy process (AHP) model to build a SG comprehensive evaluation system. Finally, we use entropy method and AHP to determine the weight of indicators at all levels, and give the comprehensive SG-entropy score of two cities. Our study may help promote sustainable urban development.

Keywords Smart growth, Comprehensive evaluation, Entropy method, AHP

1. Introduction

Smart growth (SG) is associated with the new urbanism primitive principles and is a holistic urban development plan [1]. In the 1990s, there was an infinite trend of urban sprawl, which led to problems such as traffic congestion, increased energy consumption and destruction of the ecosystem. For this reason, Smart Growth America has emerged from the stage of the times in order to control the disorderly growth and establish a good growth relationship and the core content of Smart Growth [2].

Smart growth aims to encourage the use of mixed-use buildings, the use of different types of housing and transport options, and the development of current communities and service communities to reduce the negative impact of urban suburbanization [2]. Smart growth has a strong vitality, because it represents the future. In the process of using smart growth theory, the original city will gradually become a resource-saving and environment-friendly city. Likewise, citizens can enjoy a convenient and comfortable life.

The world is rapidly urbanizing. Urban planning is more and more important and necessary to ensure that people get a fair and sustainable housing, resources and employment opportunities. Smart growth theory adheres to the 3E principles. That is, smart growth is designed to help each town has become a *economic prosperity, social justice and environmental sustainable* place to live [2]. Consider the fact that the implementation of smart growth is vague and the problem has plenty of subjective factors. Based on ten principles of smart growth [3], we build the following models. The article structure is as follows:

Step1: According to ten principles of smart growth and the three E's of sustainability, we set a measure of smart growth and the basic index evaluation system and search the relevant data from the Internet;

Step 2: Apply Analytical Hierarchy Process(AHP)[4,5] to this problem and determine the subjective weight selection index system;

Step 3: Use entropy method [6] and AHP to determine the weight of indicators at all levels, and further explore the influencing factors of city smart growth, and give the comprehensive SG-entropy score of two cities.

2. Main Research Method

In this paper, the entropy method [6] is used to determine the weight of indicators at all levels, and further explore the influencing factors of urban smart growth, and give the comprehensive SG-entropy score of two cities. Entropy method is an objective weight method, which can avoid the subjective factors in the process of determining the weights. The basic steps of the entropy method are as follows:

1) Construct the original index data matrix. If there are *n* annual or regional evaluation schemes and *m* evaluation indexes, then x_{ij} is the jth index value of the i-th scheme, which forms the original index data matrix of *n* rows and *m* columns.

2) Standardization of indicators. First, make the negative indicators be positive. Second, apply the extreme value method to normalize the indicators, that is

$$x_{ij}' = \frac{x_{ij} - \min\{x_{1j}, x_{2j}, ..., x_{nj}\}}{\max\{x_{1j}, x_{2j}, ..., x_{nj}\} - \min\{x_{1j}, x_{2j}, ..., x_{nj}\}}. \quad (1)$$

For the sake of convenience, the normalized data x_{ij}' is still recorded by x_{ij}.

3) The ratio of the i-th scheme to the indicator in item j:

$$p_{ij} = x_{ij} \Big/ \sum_{i=1}^{n} x_{ij}. \quad (2)$$

4) Entropy of the index of item j:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}), \quad (3)$$

where $k = 1/ln(n) > 0$, $e_j \geq 0$.

5) Information entropy redundancy:

$$d_j = 1 - e_j. \quad (4)$$

6) The weights of the indicators:

$$w_j = d_j \Big/ \sum_{j=1}^{m} d_j. \quad (5)$$

7) Comprehensive SG-entropy score of each scheme:

$$s_i = \sum_{j=1}^{m} w_j \cdot p_{ij}, \quad i = 1, 2, ...n. \quad (6)$$

3. Comparison between Two Cities with Smart Growth

3.1. Preliminary filtering of the cities

Table 1: Ten Principles of Smart Growth [2,3]

Principles	Description
Mix Land Uses	Smart growth supports mixed land uses as a critical component of achieving better places to live.
Take Advantage of Compact Building Design	Smart growth provides a means for communities to incorporate more-compact building design as an alternative to conventional, land-consumptive development.
Create a Range of Housing Opportunities and Choices	Providing quality housing for people of all income levels is an integral component in any smart growth strategy.
Create Walkable Neighborhoods	Walkable communities that are desirable places to live, work, learn, worship and play are a key component of smart growth.
Foster Distinctive, Attractive Communities with a Strong Sense of Place	Smart growth encourages communities to craft a vision and set standards for development that respect community values of architectural beauty and distinctiveness, as well as expand choices in housing and transportation.

Preserve Open Space, Farmland, Natural Beauty and Critical Environmental Areas	"Open space" refers to natural areas that provide important community space, habitat for plants and animals, and recreational opportunities, as well as farm and ranch land(working lands), places of natural beauty, and critical environmental areas (e.g. wetlands).
Strengthen and Direct Development Towards Existing Communities	Smart growth directs development towards existing communities already served by infrastructure, seeking to utilize the resources that existing neighborhoods offer, and conserve open space and irreplaceable natural resources on the urban fringe.
Provide a Variety of Transportation Choices	Providing people with more choices in housing, shopping, communities, and transportation is a key aim of smart growth.
Make Development Decisions Predictable, Fair and Cost Effective	For a community to be successful in implementing smart growth, the concept must be embraced by the private sector.
Encourage Community and Stakeholder Collaboration in Development Decisions	Growth can create great places to live, work and play—if it responds to a community's own sense of how and where it wants to grow.

Based on population characteristics, economic growth, geographical conditions and three E's, we select the following two cities: Geneva and Wellington [7].

Geneva is a city located in the Northern Hemisphere. It is inland and in mountainous area. The main industry in Geneva is the service sector. What's more, many international organizations put their Headquarters in Geneva such as WHO, UNHCR and WTO. The permanent resident population in Geneva is 194,565, while 48.4 percent of people are foreigners. The old age ratio in Geneva is 24.5 percent.

Compared to Geneva, Wellington is the capital city of New Zealand which is in the Southern Hemisphere. Wellington has a deep harbor. The finance industry in Wellington is flourishing. The total people in Wellington is 471,315,77 percent of them are European. 13.2 percent of people in Wellington Region are aged 65 years and over.

In general, Geneva is more developed economy than Wellington and people's life are more rich. But obviously, Wellington is two times more population than in Geneva, but less aging population than in Geneva. Therefore, in the future, the two cities need through the "smart growth" theory to maintain sustainable development and the construction of a harmonious community.

Based on the ten principles of smart growth, we investigated the development of these two cities and do comparative analysis. The ten principles is shown in Table 1. The following indicators interpretation and data sources mainly come from the National Bureaus of Statistics of New Zealand and Switzerland, as well as related websites [7].

3.2. Average annual growth rate of GDP

The GDP accounting system is an important comprehensive statistical indicators, and it is also the core indicators of economic accounting system. It reflects the economic strength and the size of the market of a country or region. Therefore, we select index 'The Average Annual Growth Rate of GDP' as one of economic benefits. Meanwhile, we could grasp the state of regional economy through the average annual growth rate of GDP.

3.3. Tax rate

Tax is a source of national revenue, is an important manifestation of social equity. The rationality of tax rate plays a very important role in the macro-control of the national economy. Hence, we believe that tax rate is an indicator. The following chart shows a comparison of the rates for the two cities.

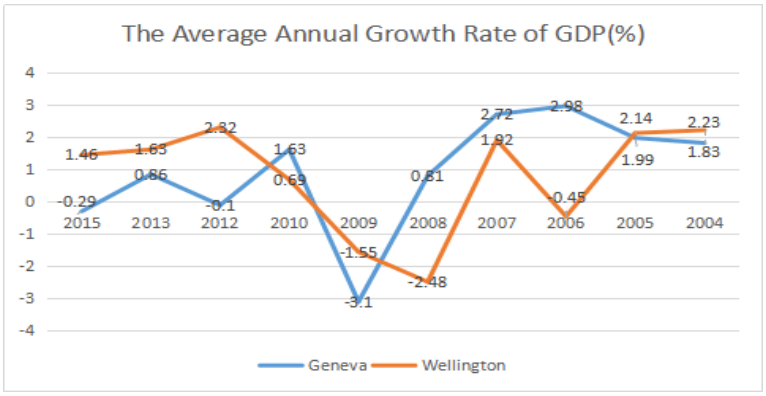

Figure 1: The Average Annual Growth Rate of GDP

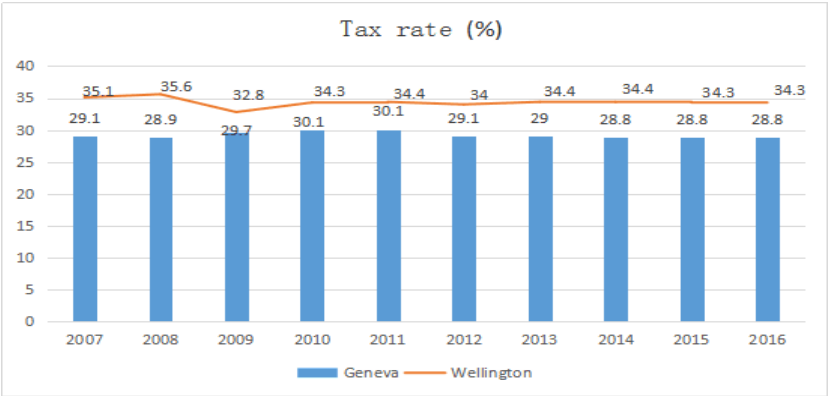

Figure 2: Tax rate

3.4. Employment Rate

On the one hand, as a social problem, employment is closely related to each family. To a certain extent, the employment problem has aroused widespread concern in society, especially the employment of graduates. On the other hand, the employment situation is severe. High unemployment rate may cause the unstable elements in society.

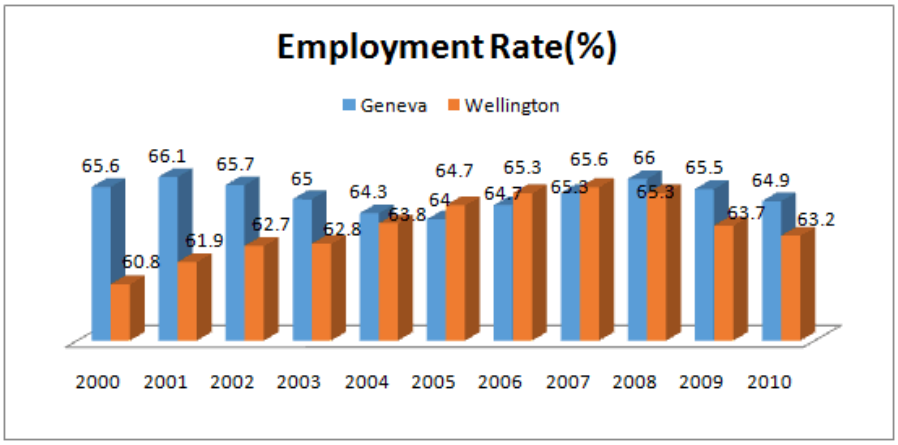

Figure 3: Employment Rate

3.5. Urban Population Growth Rate

In the process of urbanization, population is a key factor. The growth rate of urban population could embody the change of urban population. Changes in the urban population will bring changes in other social areas as well. With this data, we anticipate further population growth and help build a smart growth strategy.

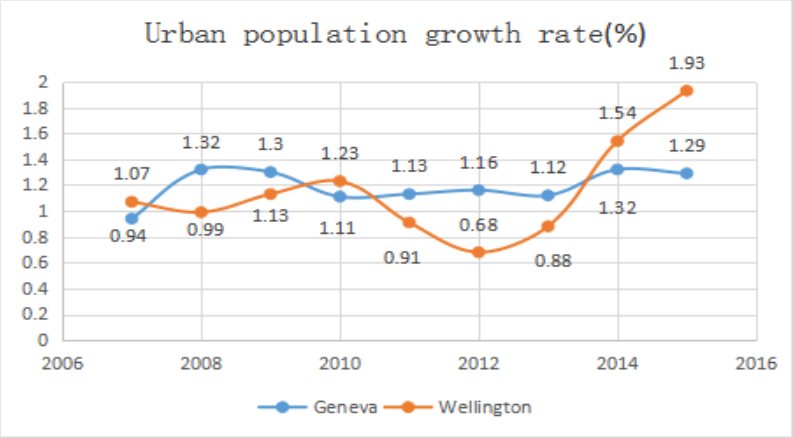

Figure 4: Urban Population Growth Rate

3.6. Public Transport Rate

In the urbanization process, the construction of public infrastructure is supposed to meet the growth process. The proportion of public transport trip not only reflects the level of development of public transport system, but also reflects the habit of citizen's travel. In addition, the public transportation plays a catalytic role in improving air quality and traffic conditions for the harmonious development of the city to a certain extent.

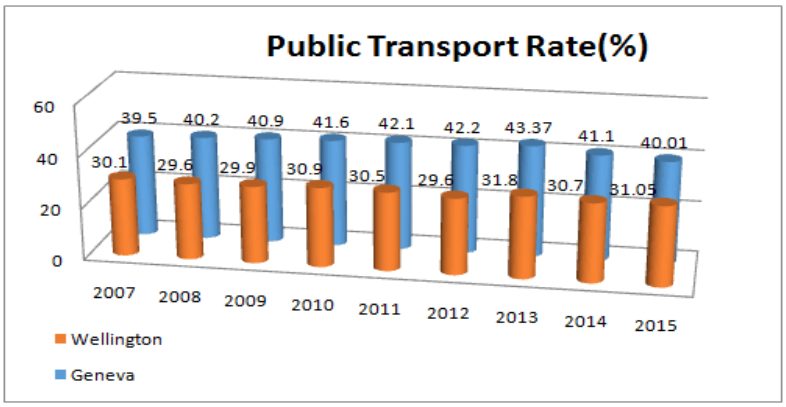

Figure 5: Public Transport Rate

3.7. Air quality (PM10)

Nowadays, air quality is placed in an increasingly important position. In general, the pollutants from the sulfur dioxide, PM10 and nitrogen oxides. However, the city's development can not be separated from the excellent urban environment, therefore, we must maintain air quality at a stable level. From the long-term development perspective, air quality improvement is extremely necessary. Here we select PM10 as the air quality consideration.

3.8. Ratio of land occupation

Urban development inevitably takes up land resources. When the total land area of the city is constant, it is necessary to control the expansion of urban land occupation proportion and to enhance mixed land use, especially for agricultural and construction land, while the proportion of commercial and traffic land must be balanced. Yet, we choose this index to assess the growth of the city.

3.9. Proportion of renewable energy

Resources are limited in our blue planet, so we must use resources rationally, and use more renewable energy sources, such as solar energy, tidal energy and biomass energy. The utilization of renewable energy is one of the important indicators of urban sustainable development. We could effectively reduce pollutant emissions through the use of renewable energy and protect people's natural environment so that people live under the mountains and green water.

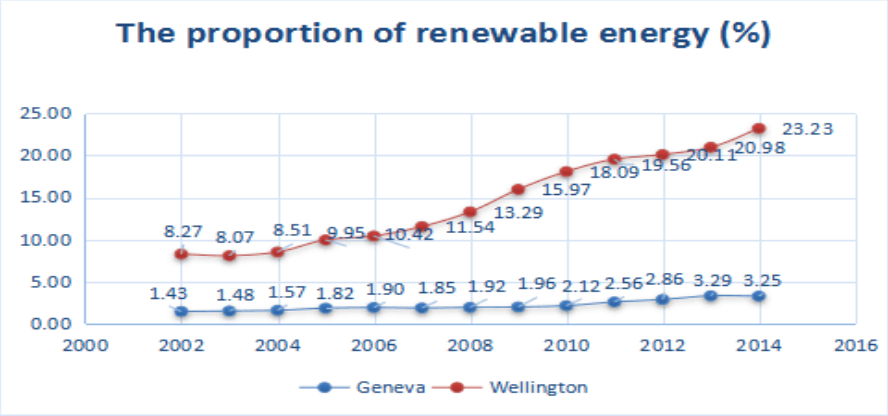

Figure 6: The Proportion of Renewable Energy

4. Comprehensive Evaluation System of Urban Development Level

4.1. Metric selection method

Because of many influence factors, it is difficult from a single one to find out the next layer of specific indicators. According to the following flow chart, we further search:

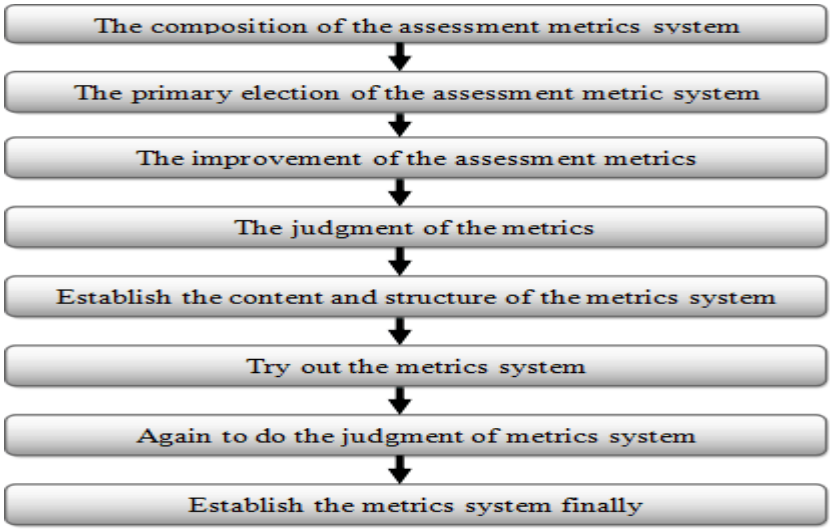

Figure 7: Screening Method Flow Chart

4.2. AHP-based evaluation system

The aim of the smart growth is to boost the economic progress, promote social justice and improve environment. These are the important contents of sustainable development [8,9]. Due to the principles of assessment metrics system: objectivity, scientificity and comparability [4-6], we establish a total metric named growth density. Then, we divide the total metric into three parts---economic benefits, ecological benefits and social benefits. Then, three parts consist of more detailed indexes.

Table 2: Evaluation system

Overall Layer	Feature Layer	Index Layer
Growth Density	Economic Benefits	P1:Average Annual Growth Rate of GDP
		P2:Tax Rate
	Social Benefits	P3:Employment Rate
		P4:Urban Population Growth Rate
		P5:Public Transport Rate
	Ecological Benefits	P6:Air Quality
		P7:Ratio of Land Occupation
		P8:Proportion of Renewable Energy

5. Calculation and Empirical Analysis

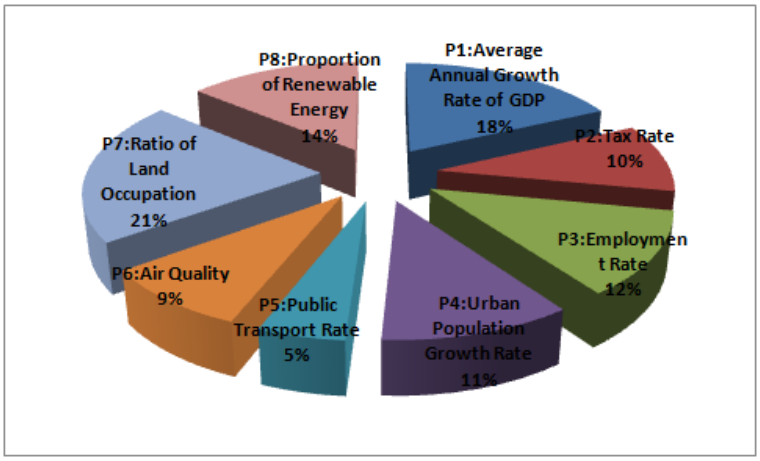

Figure 8: Weight of Index

By entropy method and Analytical Hierarchy Process (AHP), we get the weight vector including eight evaluation indexes. See figure 6. The establishment of the weight model of smart growth is applied to calculate the comprehensive score of urban smart growth metric. The weight of the ratio of land occupation, the average annual growth rate of GDP and the proportion of renewable energy is bigger than other index by analyzing the weight value of smart growth, which shows that these factors should be considered well. Through AHP and entropy method, we also get the comprehensive scores of two cities: Geneva 0.57 and Wellington 0.43 by averaging for the last three years in the data set. This shows the smart growth plan of Geneva is more successful than one of Wellington.

6. Conclusion

In summary, we have performed comprehensive evaluation of urban development level based on smart growth. We selected two mid-sized cites of Geneva and Wellington and did empirical research. By analyzing the ten principles of SG and the three E's of sustainability, we did comparative analysis between the two cities with a series of indicators of the impact on SG. We applied the AHP model to build a SG comprehensive evaluation system. Finally, we further explored the influencing factors of city smart growth by means of entropy method and AHP.

Acknowledgments

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