For office use only	Team Control Number	For office use only
T1 ________________	59045	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	E	F4 ________________

2017
MCM/ICM
Summary Sheet

Smart Growth is the ultimate goal for a sustainable development. In this paper, we choose two cities, Raleigh in the United States and Wellington in New Zealand as our research background to put Smart Growth concept into practice.

For task 1, we establish a Smart Growth City Planning (SGCP) Model, which is a unified model containing three sub-models and a compilation of metrics, to quantify the effectiveness of smart growth from different perspectives. Further, we calculate the return on government investment (ROGI) towards the smart growth to measure the effectiveness and efficiency of local governments in building smart growth cities. ROGI in SGCP model can be tailored to different city's governmental budget to measure the ability of getting the most out of new development and maximizing the invested resources. The rigorous relationship among our metrics, three E and 10 smart growth principles are established by using Vensim and the dynamic relationship between our metrics is demonstrated by a causal loop diagram.

For task 2 and 3, after summarizing 13 major growth plans of Raleigh and 11 major growth plans of Wellington, we make use of the modelling algorithm and apply system dynamic scoring system to measure the performance of city's current growth plan in terms of our defined metrics and 10 smart growth principles. In order to accelerate the progress towards smart growth, we develop a growth plan for both cities over the next few decades responding to the three E and 10 smart growth principles, and demonstrate their practicability in terms of economic, geographic, demographic trend. We further proceed to employ ARIMA model, Goal Programming method and Agent-Based Model to provide a three-pronged measurement of our recommendations: the predicted city growth trends are used to customize the corresponding low, medium and high intensity city growth plans; the Goal Programming result is obtained by using Lingo; the simulation of city plans in implemented by using Netlogo.

For task 4, based on our metrics and other environmental, social, economic factors, we construct two quantifiable ranking methods: direct calculation on weighted average and calculation on weighted average by score conversion table, to rank our five recommendations. The resulted ranking tables show different standings of the five recommendations in two different cities.

FoR task 5, We use the Agent-Based Model to stimulate the situation that the carry capacity may not be able to satisfy the future 50 percent population increase. By make use of the controlled-variable experiment method, we can find out that cities can put more emphasis to increase the level of mixed land use, while do not sacrifice the amount of green areas. In addition, we come up with the solutions and implementation flowcharts for each city by 2050.

Contents

1 Introduction

With the development of science and technology, people in the world has entered an accelerating period of urbanization.It is projected that by 2050, 66 percent of the world's population will be urban, which resulted in a projected 2.5 billion people being added into the total urban population.The development of urbanization is at such a rate that threaten the ecology of the planet.Fortunately, there is an unrivalled urban planning approach to this situation called smart growth strategy.More specifically,smart growth is a development approach that draws a blueprint to greater communities, which possesses prosperous economy,thriving natural environment, equitable and sustainable civilization, and a wonderful legacy for our next generation.There are 10 commonly recognized principles of smart growth, which are regarded as the foundation of the smart growth and play a critical role throughout this report.

In this report, we first select two mid-sized cities with a population between 100,000 and 500,000 persons on two different continents, Raleigh in the United States and Wellington in New Zealand, as our research background. We are required to define metrics to measure the success of smart growth of a city considering the three E's of sustainability and the 10 principles of smart growth.Next, we need to explore the practicability regarding the current growth plan of our selected cities and test the degree of success according to our defined metric.

Apart from the problems mentioned above, we are expected to fulfill the remaining tasks throughout our report:

- Conduct a smart growth city design for our chosen cities by integrating the smart growth 10 principles and 3'E principles. All the components and initiatives should be supported from different perspectives including geography, expected growth rates and economic prospects and evaluated by our metric to test the level of success.
- Rank each individual initiative within our own smart growth plan as the most potential to the least potential and compare their ranking and impact between the two cities.
- Explain in what ways our plan can support the level of 50 percent population growth by 2050.

2 Assumptions and Rationale

- The impact of Non-Government-Organizations (NGOs) is excluded in our model

  The NGOs can be classified into various types on the basis of different factors like orientation or level of cooperation. Considering the complexity and difficultly to quantify the impacts of NGOs, we do not include the participation of them.
- Immigration factor is excluded

  The impacts of immigrants is immaterial to our analysis. For the purpose of simplify our model, we exclude the immigrants
- Force majeure factor is excluded

  We do not consider the Force majeure factor in implementing our city plans.
- The variances in total city areas is excluded

  We assume that the area of the chosen cities do not change over time. There are some cities annex the area of the rural for urban development, but this may post tremendous difficulty on the evaluation of the city growth plan.

3 Task 1: Smart Growth City Planning Model Model

3.1 Model overview

In formulating a quantitative measure of smart growth, we start with a reflection of the possible characterise for smart-growth-based cities that embrace the economically prosperity, socially equality and environmental sustainability. The possible outcomes of smart growth provide a more illuminating description about the impact of smart growth, which can be used as a solid foundation to define the metrics to evaluate the success of smart growth city.

According to the the principles of smart growth, our team quantify all the metrics that are perfectly coherent to the ideal smart growth city considering the geographic location, sustainable development and residents health level. In addition, our approach subsumes theoretical mathematics, statistics, environmental science, economics, cultural anthropology, and computational science to perform the solid evaluation model — Smart Growth City Planning Model Model. According to our designed evaluation model,we can calculate the return of government investment ($ROGI$) towards the smart growth city and measure the effectiveness and efficiency of local governments investment in building a smart growth city. Based on our Smart Growth City Planning Model, we can predict the potential return on investment for smart growth tailoring to different city's governmental budget and measure the proceeding towards smart growth.

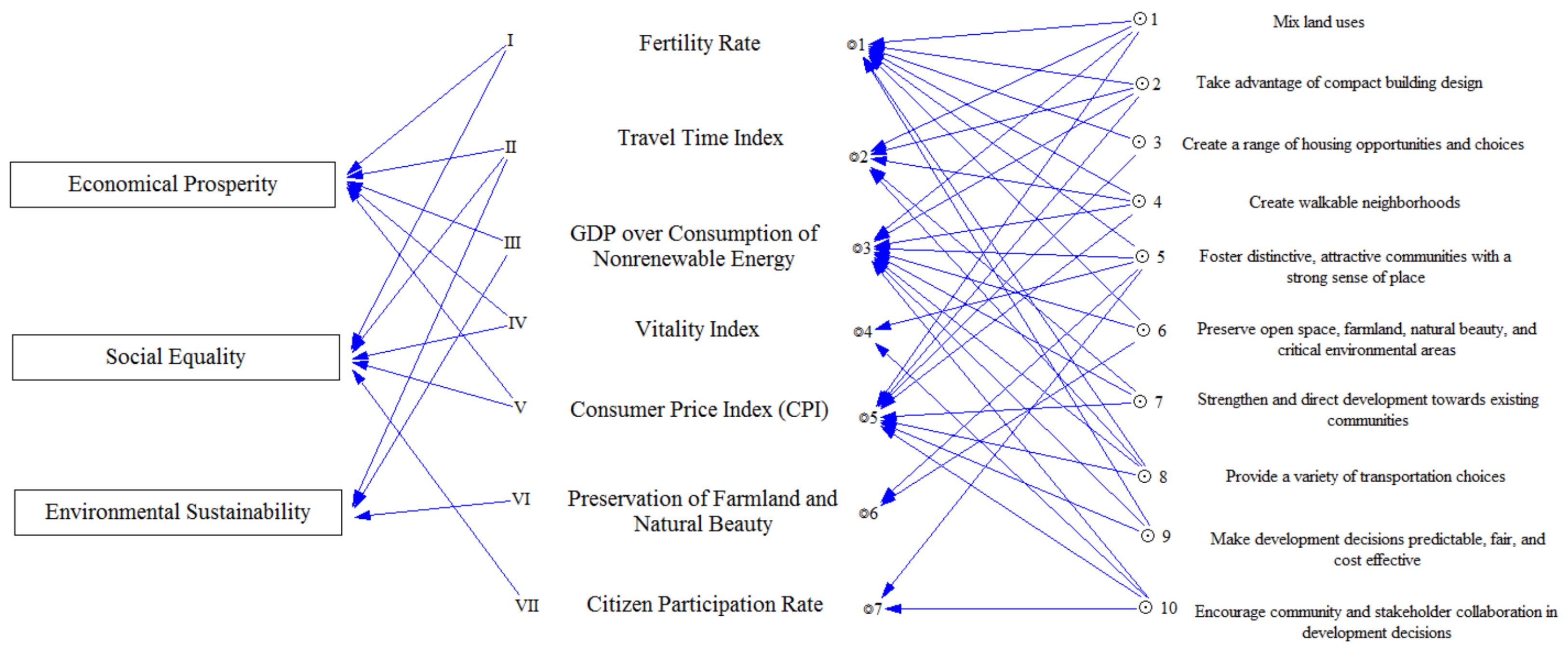
3.2 Symbol and Description

Table 1: Symbol and Description

Symbol	**Description**	**Unit**
I_{es}	Economic Sustainability Index	Unit-less
I_{lf}	Living Friendly Index	Unit-less
I_v	Vitality Index	Unit-less
I_c	Crime Index	Unit-less
$SGCI$	Smart Growth City Planning Index	Unit-less
GDP_{ne}	Gross Domestic Product over Consumption of Nonrenewable Energy	Unit-less
NPL	Natural Preservation Level	km^2
PI_c	Pollution Composite Index	Unit-less
TTI	Travel Time Index	Min
CPI	Consumer Price Index	Unit-less
P_{he}	Percentage of People Enroll in Higher Education under 25 years old	Unit-less
P_{hc}	Percentage of People Engaged in Health-care Industry	Unit-less
P_{ev}	Percentage of Effective Ballot Ticket over the Total Registered Electors	Unit-less
F	Fertility Rate	Unit-less
$ROGI$	Return on Government Investment	Unit-less
E_{sgc}	Annual Government Expenditure for Smart Growth City Purpose	US dollar
E_{total}	Total Annual Government Expenditure	US dollar

3.3 Justification of our Approach

Figure 1: Relationship among 3'E Principles, 10 Principles and our metrics



Our Smart Growth City Planning Model is a unified and universal evaluation model to measure the success of a smart growth city based on rigorous analysis on 3E principles and 10 smart growth principles. There are three major indexes in our Smart Growth City Planning Model: Environmental Sustainability Index, Living Friendly Index and Vitality index. Each index contains a compilation of metrics derived from the various aspects that can help to evaluate the overall performance of each index.

Table 2: Interpretations and Components of Economic Sustainability Index

Metrics	**Justification**
Economic Sustainability Index	The I_{es} measures the city's ability to create wealth on a environmentally sustained and sustainable basis and has positive impact towards the return on governmental investment.The index provides a composite profile of city's environmental stewardship based on a compilation of indicators derived from the following aspects: GDP_{ne}, PI_c, NPI
GDP over Total Nonrenewable Resource Consumption	There is a negative effects of resource dependence on economic growth and the GDP growth would not be sustainable if it requires large amount of nonrenewable resource to generate GDP. GDP_{ne} measures the energy efficiency of a nation economy. It is calculated as units of GDP per unit of nonrenewable consumption.
Pollution Composite Index	Pollution is harmful for sustainable economic. This parameter measures the water and air pollution level. PI_c is expressed as the average of the water and air pollution level.
Natural Preservation Level	A properly functioning natural processes is critical for human race and our economy. Therefore,NPI measures the total of natural preservation area over the total area of a city

The interconnections of each metric are justified because:

- Cities maintaining a good environment attract more investment opportunities and talents. In addition, a economy would be more sustainable if more portion of its GDP is "green", which indicates less dependence on nonrenewable energy consumption. Thus, GDP_{ne}, PI_c, NPI, can be used to measure the level of economic sustainability effectively.

Table 3: Interpretations and Components of Vitality Index

Metrics	**Justification**
Vitality Index	The I_v measures the city's vitality level in terms of its living atmosphere.It provides a composite profile of citizen's vitality based on a compilation of indicators derived from the following aspects: F, P_{he}, P_{ev}.
Fertility Rate	The fertility rate F of a population is the average number of children that would be born to a woman over her lifetime if, she can experience the exact current age-specific fertility rates through her lifetime, and survive from birth through the end of her reproductive life.
High Education Enrollment Level	Access to a good education is a key part of city vitality level.Therefore, P_{he} measures the percentage of persons over 25 years of age with bachelors degree or higher.
Citizen Participation Level	A vital society requires informed, organized, active and peaceful citizen participation.P_{ev} measures the percentage of effective ballot ticket over the total registered electors.
Health-care Level	Access to a good health-care resource is a key part of city vitality level.Therefore, P_{he} measures the percentage of persons engaged in health-care industry over the total population

The interconnections of each metric are justified because:

- Education empowers the lightning-fast development of the economy and keep a city full of wisdom. Moreover, vital communities have high-quality health care available and foster interaction between residents and government.In addition, proper fertility rate helps to ensure the youthfulness of a city and promote high potential for future development.Thus, F, P_{he}, P_{ev}, P_{hc} can measure the level of vitality of a city.

Table 4: Interpretations and Components of Living-Friendly Index

Metrics	**Justification**
Living-Friendly Index	The I_{lf} measures how comfortable are people living in a the city.It provides a composite profile of citizen's satisfactory about the overall life based on a compilation of indicators derived from the following aspects: TTI, CPI, SI.
Travel Time Index	a convenient life makes people feel comfortable. TTI measures the average one way time needed to transport, in minutes. Here we define the one way distance as 20 kilometers
Consumer Price Index	CPI is a measurement that examines the weighted average of prices of a basket of consumer goods and services, such as transportation, food and medical care. It is calculated by taking price changes for each item in the predetermined basket of goods and averaging them.
Crime Index	The feeling of safety is critical for a livable society. SI measures the number of crime per 100 people in a certain area.

The interconnections of each metric are justified because:

- How easily and safely we're able to get from one place to another has a major effect on our quality of life. In addition, higher level of cost of living will frustrate people and unsafe neighborhood makes people panic and reduce the livability. Thus, TTI, CPI, SI, can be appropriate measurements for a livable society.

3.4 Model formulation

3.4.1 Economic Sustainability Index Sub-model

Economic sustainability measures the ability of an economy to support a defined level of economic production indefinitely.True sustainability encourages the responsible use of resources, which involves not only making sure that the economy is growing, but that the operation is not creating environmental concerns that could cause harm to the balance of the local ecology.That is to say, Economic sustainability is positively related to GDP over Total Nonrenewable Resource Consumption and Natural Preservation Level, while negatively related to the Pollution Composite Level. Thus, we model that:

$$I_{es} = GDP_{ne} \cdot (1 + NPI) \cdot [1 - (PI_c)] \tag{1}$$

3.4.2 Living Friendly Index Sub-model

Living Friendly Index Sub-model measures the level of livability and life efficiency which encompasses multiply dimensions. Living Friendly Index is negatively related to the Crime Index and Travel Time Index, and follows the normal distribution centering at 100. Thus, we model that:

$$I_{lf} = \frac{1}{\frac{\ln(TTI)}{\ln(20)}} \cdot \mathrm{e}^{-2\cdot|1-\frac{CPI}{100}|} \cdot (1 - I_c) \tag{2}$$

3.4.3 Vitality Index Sub-model

The route to urban vitality lies in adopting policies that help people to thrive and to innovate.The Vitality Index mainly deals with citizen's ability to activate and generate city's future development potential.The Vitality Index is positively related to the Fertility Rate, High Education Enrollment Level, Citizen Participation Level and City's Health-care Level. Thus, we model that:

$$I_v = P_{he} \cdot (\frac{F}{2.1}) \cdot (1 + P_{hc}) \cdot (1 + P_{vr}) \tag{3}$$

3.4.4 Smart Growth City Planning Model

Smart Growth City Planning Model, which is a unified and universal evaluation model combining economic, environmental, social, cultural factors to quantify the effectiveness of government towards smart growth city. That is to say, Smart Growth City Planning Model is superimposed by three sub-models mentioned above:

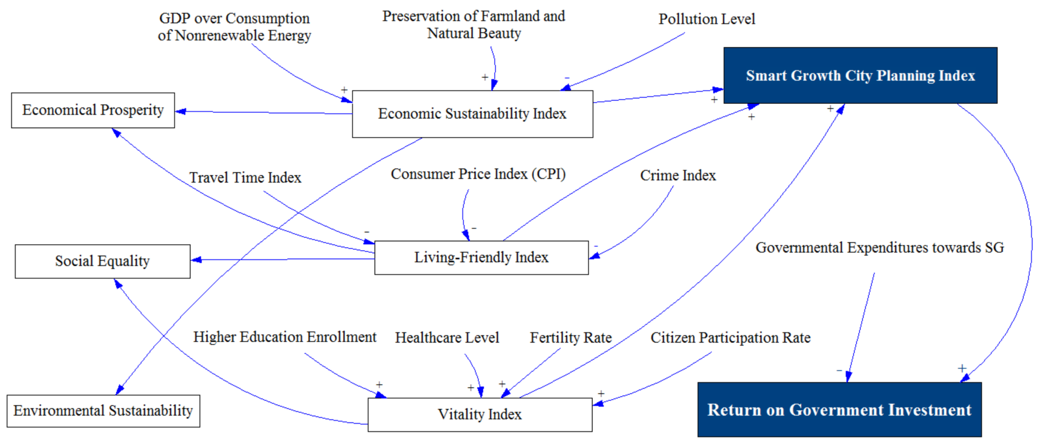
$$SGCI = I_{es} + I_{lf} + I_v \tag{4}$$

3.4.5 Return on Governmental Investment

Growth is smart when it provides good return on public investment.Return on Governmental Investment (ROGI) is to measure the overall efficiency that cities are looking for ways to get the most out of new development and maximize the invested resources.The effectiveness of Smart Growth City Planning is positively related to Return on Government Investment (*ROGI*) and total governmental expenditures towards smart growth. Thus, we further model that:

$$ROGI = \frac{SGCI}{\frac{E_{sgc}}{E_{total}}} \tag{5}$$

Figure 2: The relationship between sub-models, SGCPM, ROGI and 3'E Principles



4 Task 2:Discussion about Feasibility of Current Growth Plan

4.1 Background of Chosen Cities

4.1.1 Raleigh, the United States

Raleigh is the capital of the state of North Carolina, the seat of Wake County in the United States. The city covers a land area of 93440 acres with a total population of 451,066 as of July 1, 2015.

4.1.2 Wellington, New Zealand

Wellington is New Zealands culinary and cultural capital that covers 109221 acres. The city is the countrys third most populous urban area with a population of 203,800

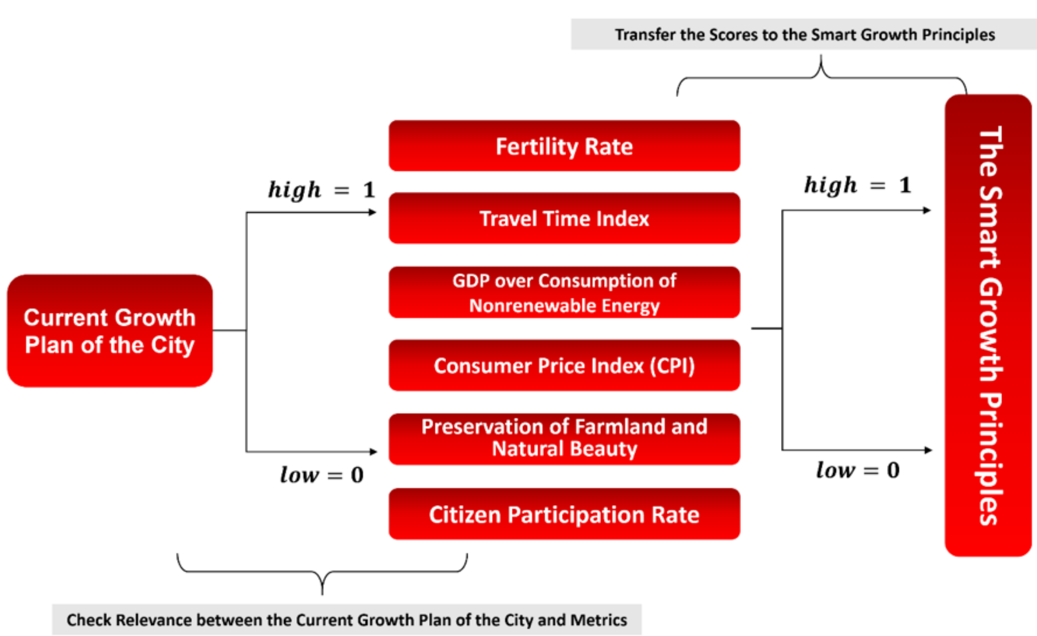
4.2 Evaluation of Current Growth Plan

The interrelationship stated in the causal diagram in Figure 1 sheds the light on measuring the success of current growth plan based on smart growth 10 principles and six metrics in our Smart Growth City Planning Model. Thus, we use the F, TTI, GDP_{ne}, CPI, NPL, P_{ev} and 10 smart growth principles, together with 1-0 logistic system and matrix application, to establish the objective weighted average scoring system.

Following is the algorithm for our objective weighted average scoring system:

First of all we establish the 1-0 system, we assign value 1 to the current growth plan that satisfied our metrics, otherwise, we assign value 0 to the unsatisfactory growth plan:

Figure 3: Flow chart of city planning performance measurement regarding smart growth principles

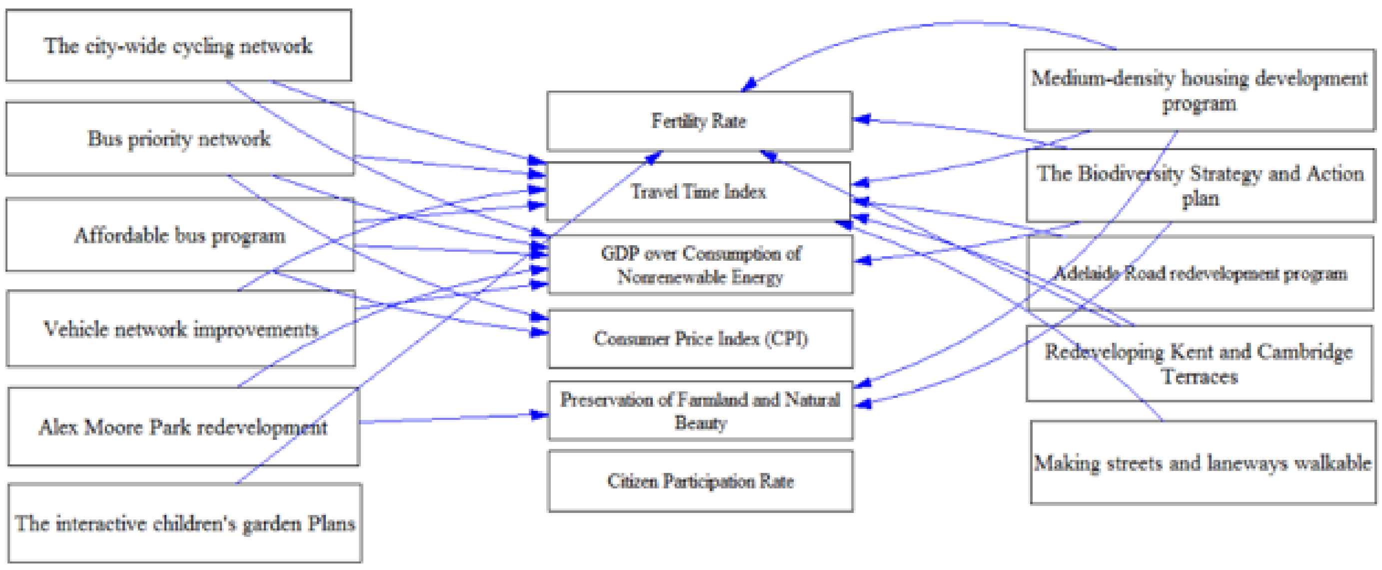


Then, we link the scores to 10 smart growth principles and divide by the number of current growth plans. According to the results of the scoring system, we can measure the performance of each city towards the smart growth.

Based on a comprehensive research, we make a summary for the current growth plan of each city. We proceed to use our objective weighted average scoring system to evaluate each citys smart growth plan by making good advantage of Venism.

Following is the performance evaluation of Wellingtons current growth plan by our scoring system:

Figure 4: Overview of city planning of Wellington based on six metrics



We can proceed to get:

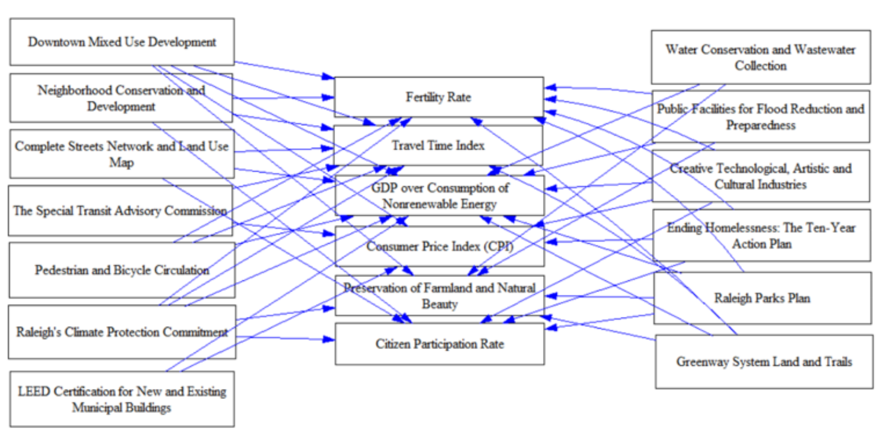
Table 5: Performance measurement of Wellington's current growth plan

City	F	TTI	GDP_{ne}	CPI	NPL	CPL
Wellington	4	8	6	2	3	0

According to the result of the scoring system, Travel Time Index (TTI) ranks the highest among the six metrics, while Citizen Participation Rate is rated as zero, which is unsatisfactory. This result indicates that the main focus of Wellingtons 11 major growth plan is to ameliorate the travel efficiency and facilitate sustainable economic development, rather than prompting public participation on citizens.

Following is the performance evaluation of Raleighs current growth plan by our scoring system:

Figure 5: Overview of city planning of Raleigh based on six metrics



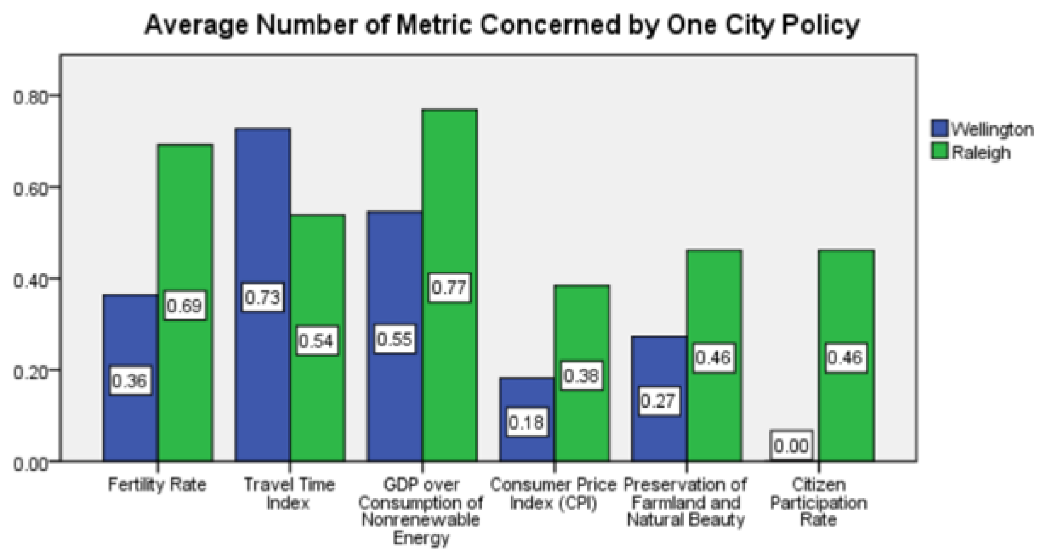
We can proceed to get:

Table 6: Performance measurement of Raleigh's current growth plan

City	F	TTI	GDP_{ne}	CPI	NPL	CPL
Raleigh	9	7	10	5	6	6

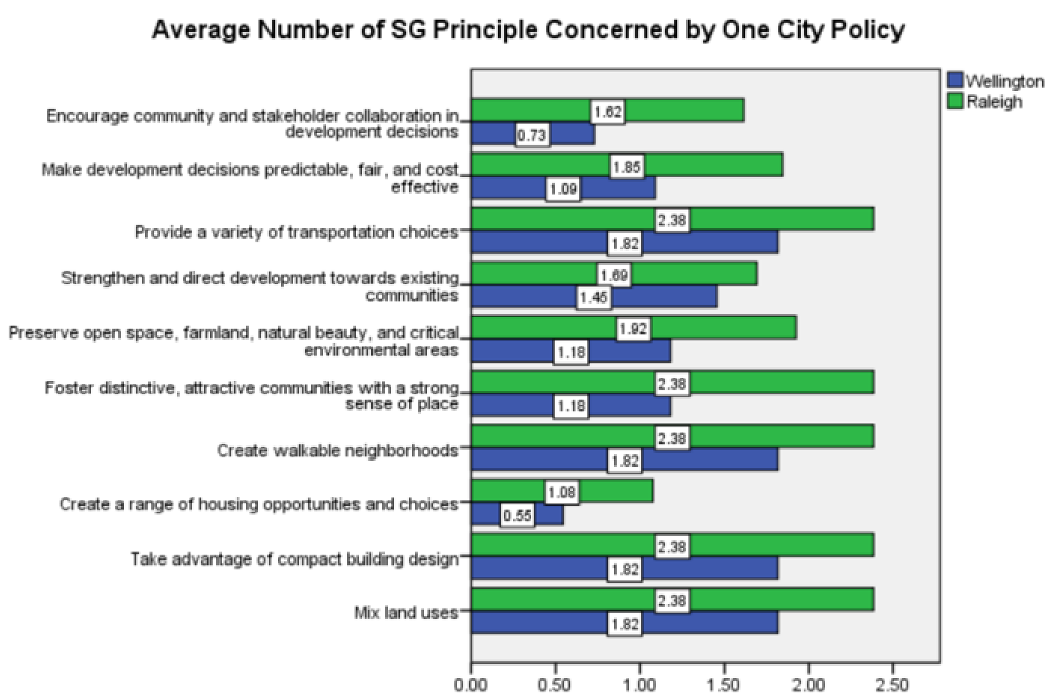
According to the result of the scoring systemGDP over Consumption of Nonrenewable Energy ranks the highest among the six metrics, while CPI ranks the lowest. Analyze from a whole picture, Raleighs 13 city growth plans assign reasonably weight on the holistic growth of economic, social and environmental issues, with particular emphasis on the green economy and population concern.

Figure 6: Average number of metric covered by one current growth policy



The above bar charts depict the average intensity of emphasis on six metrics of respective city plans. Overall, both city plans place more emphasis on reducing TTI and pollution brought about by economic development, while acting relatively inactive in CPI monitoring and citizen participation arousal. In addition, the result shows that the Raleigh government addresses the six issues at a stronger level compared to Wellington.

Figure 7: Average number of smart growth principle covered by one current growth policy



The above bar charts depict the average intensity of emphasis on ten smart growth principles of respective city plans. Overall, both cities place more emphasis on principle one, principle two, principle four and principle eight, while acting relatively inactive in addressing principle three. In addition, the result shows that the Raleigh government tends to address the ten principles at a stronger level compared with Wellington.

One thing worth mentioning, according to the result, we find out that both Raleigh and Wellington address the first, second, fourth and eighth principle in the same intensity, that is to say, satisfy s1=s2=s4=s8. This provides rationale to claim the interdependent relationship between these principles.

4.3 Modelling Algorithm

We further proceed to quantify the success of current plans based on our Smart Growth City Planning Model and 10 smart growth principles. We use Smart Growth City Planning Model and Return on Government Investment to analyze the effectiveness and future potential return of each citys current growth plan. Through information gathering, we obtain the data of Raleigh and Wellington required for modelling:

City	I_{es}	I_{lf}	I_v	I_{sgcp}	$ROGI$
Wellington	1.218	0.8809	0.2713	2.3702	2.667342
Raleigh	0.8415	0.8308	0.4981	2.1704	3.829217

I_{sgcp} of Wellington is larger than Raleighs, which indicates a better performance from the perspective of citys effectiveness towards smart growth city. On the other hand, $ROGI$ of Raleigh is higher than Wellington, which indicates a better performance from the perspective of potential return rate.

Particularly, Wellington has excellent performance among the two indexes: Economic Sustainability Index and Live Friendly Index, while Raleigh is in a dominant position in Vitality index. These variances can illustrate the effectiveness of current growth plan towards smart growth considering the development of environmental-friendly economic, reduction of pollution level and improvement of the transportation efficiency.

5 Task 4: Growth Plan Recommendation and Evaluation

5.1 Illustration of Recommended growth plan

- 1. **Make the city more cycle-friendly** We suggest that two cities can promote the bike share system, government can build bike borrowing and returning station in different places, making bikes more accessible to the public. In addition to build more bicycle lands, we recommend that building protected bike intersection to make cycling in central city area a lot safer. Moreover, we recommend that buses and metros should be equipped with racks that can carry bicycles, making cyclists with long commutes transfer through different public transportation easier.

- 2. **Make the streets more walkable**

  We suggest that both cities strive to become more walkable: redevelop the pedestrian (sidewalk) more walkable to make people get from store to store(commute) easily while reducing the parking and traffic issues. There is a critical importance of trees in making walking along a street more pleasant: providing shade in cities that are subjected to increasing heat waves, and serving as a carbon sink to make the air more breathable.

- 3. **Build more smart green space** Faced with the land shortage resulting from expected population growth, we suggest that both cities create more and more small green spaces, rather than larger parks and open areas. The intimate nature of these spaces means that they are accessed more frequently by more people than big green spaces.

- 4. **Promote environmentally-friendly events** We suggest that both cities should make good use of open spaces for environmentally-friendly events such as green technology expo, local products fair and university-oriented conservation activities. Raising public awareness of and concern about the environment and its associated issues is crucial to foster greener lifestyle and energy-saving movements.

- 5. **Take advantage of mixed land use development.** We recommend that both cities can use traditional zones and overlay zones to provide for a mixture of uses including education, retail, fresh food outlets,integrated public transport.In addition, the uses of non-residential purposes should be restricted in size to promote a local orientation and to limit adverse impacts on nearby residential areas.

5.2 Measurement of Recommended Growth Plan

5.2.1 Overview

Considering the complicated and dynamic nature of city growth, we employ three ways to measure the proposed growth plans, based on time-series, goal programming and agent-based simulation.

5.2.2 Prediction by ARIMA model

Under the situation that time-series can be used to predict the future development potential of a city, we first use ARIMA model together with the available 5 year data of each city, to predict the effectiveness and potential return of two citys smart growth planning in 2028. Due the large uncertainty of each years governmental expenditures towards smart growth, we assume that the percentage of governmental expenditures towards smart growth over total governmental expenditures remains the same in our linear regression prediction method. Based on this assumption, we can use 5 year data fitting to get each metrics value in 2028, which can be put into Equation (1), (2), and (3), to compute the performance in terms of Economic Sustainability Index, Living-Friendly Index, Vitality Index, and finally can be used to compute the overall effectiveness and potential return for smart growth planning. Particularly, two citys SGCI and ROGI will be increasing at the same rate based on the same rationale from the assumption mentioned above. After obtaining the modeling result, we employ statistics method to find out the 95 percent confidence interval and the final prediction interval of the three sub-models, which can be used as a foundation to analyze the goal programming.

Wellington's case

By Matlab, we can obtain the following results, then use statistics to construct the 95 percent prediction interval for our forecast:

$$ROGI = 3.13$$
$$SGCI = 2.78$$
$$\text{95 percent prediction interval of} ROGI = [3.07, 3.19]$$
$$\text{95 percent prediction interval of} SGCI = [2.72, 2.84]$$

Raleigh's case By Matlab, together with statistics, we obtain the estimation and the 95 percent prediction interval of SGCI and ROGI:

$$ROGI = 4.27$$
$$SGCI = 2.42$$
$$\text{95 percent prediction interval of} ROGI = [4.23, 4.31]$$
$$\text{95 percent prediction interval of} SGCI = [2.40, 2.44]$$

The formula of 95 percent prediction interval is given by:

$$\left[\hat{y} - t_{\frac{\alpha}{2},n-2} \cdot S_\varepsilon \cdot \sqrt{1 + \frac{(X_\varepsilon - \bar{X})^2}{(n-1) \cdot S_x^2} + \frac{1}{n}}, \hat{y} + t_{\frac{\alpha}{2},n-2} \cdot S_\varepsilon \cdot \sqrt{1 + \frac{(X_\varepsilon - \bar{X})^2}{(n-1) \cdot S_x^2} + \frac{1}{n}} xf\right]$$

- The result indicates the overall increase in the ROGI and SGCI; that is, in 2028, the ROGI and SGCI will increase by 17.7 percent in Wellington and 11.5 percent in Raleigh.
- The R^2 statistics of the two ARMA models exceed 0.99, indicating a good level of preciseness in fitting.

However, this result is obtained from the observed city growth and cannot reflect the dynamic nature of city growth plan. To address the specific goals of smart growth city plan, we introduce the objective programming method, which is elaborated in the following part.

5.2.3 Goal Programming Method

Based on the results obtained the ARIMA model and research on two citys geographic factor, population growth, protection towards environment and citizens educational level, we establish the city planning models under low, medium, and high intensity for each city. More specifically, the key city development projects requires high intensity while other projects may require medium to low intensity. Our model aims at maximizing the Return on Government Investment while satisfying the requirements in Goal Programming. Considering the variance of governmental expenditures towards smart growth under different intensities, we incorporate the penalty.constraint conditions of smart growth plans, to evaluate the impacts of cost-effectiveness in terms of the future city planning. This consideration will make our Goal Programming more close to the reality with high practical impacts.

Let E_w and E_r be the percentage of government expenditure for smart growth city purpose in Wellington and Raleigh, respectively. Our detailed objective programming plan for Wellington and Raleigh is provided in the following:

Figure 8: Description of low intensity and high intensity plans in Wellington based on results in ARIMA model

	ARIMA	Low intensity plan	High intensity plan
F	1.77	$\geq$ 1.85	$\geq$ 2.1
TTI	35.18	$\leq$ 32	$\leq$ 25
NPL	0.144	$\geq$ 0.15	$\geq$ 0.18
P_{he}	0.53	$\geq$ 0.55	$\geq$ 0.65
P_{hc}	0.131	$\geq$ 0.14	$\geq$ 0.18
GDP_{ne}	1.43	$\geq$ 1.5	$\geq$ 1.75

$$E_w = \frac{E_{sgc}}{E_{total}} \cdot (\frac{F}{1.46} - 0.1) \cdot (\frac{TTI}{26.06} + 0.1) \cdot (\frac{NPL}{0.095} - 0.1) \cdot (\frac{P_{he}}{0.329} - 0.1) \cdot (\frac{P_{hc}}{0.114} - 0.1) \cdot (\frac{GDP_{ne}}{1.87} - 0.1)$$

Figure 9: Description of low intensity and high intensity plans in Raleigh based on results in ARIMA model

	ARIMA	Low intensity plan	High intensity plan
F	1.46	$\geq$ 1.55	$\geq$ 1.75
TTI	26.06	$\leq$ 25	$\leq$ 20
NPL	0.095	$\geq$ 0.10	$\geq$ 0.13
P_{he}	0.329	$\geq$ 0.35	$\geq$ 0.45
P_{hc}	0.114	$\geq$ 0.12	$\geq$ 0.15
GDP_{ne}	1.87	$\geq$ 2	$\geq$ 2.15

$$E_r = \frac{E_{sgc}}{E_{total}} \cdot (\frac{F}{1.77} - 0.1) \cdot (\frac{TTI}{35.18} + 0.1) \cdot (\frac{NPL}{0.144} - 0.1) \cdot (\frac{P_{he}}{0.53} - 0.1) \cdot (\frac{P_{hc}}{0.131} - 0.1) \cdot (\frac{GDP_{ne}}{1.43} - 0.1)$$

We use MATLAB to do the Goal Programming, we can measure the effectiveness of a citys planning towards smart growth, when a city puts emphasis on one of the metrics: fertility rate, travel time index, natural preservation level, higher education level, health-care level and green economy. The following is the results:

Figure 10: Matlab Result of SGCI and ROGI in both cities with respect to Goal Programming

	Wellington		Raleigh	
	SGCI	ROGI	SGCI	ROGI
Fertility	3.138	4.022	2.672	5.350
TTI	3.143	3.605	2.653	4.668
NP	3.124	3.436	2.618	4.932
Edu	3.211	3.575	2.701	5.174
Health	3.089	3.545	2.610	4.567
GDP/C	3.206	4.336	2.776	5.393

The above result shows that in both cities, adopting Goal Programming method yields greater values of SGCI and ROGI in comparison with those of ARIMA model, which indicates that targeting specific goals on smart growth city planning can yield better outcome in terms of effectiveness and return potential. Overall, increasing the Gross Domestic Product over Consumption of Nonrenewable Energy is the wisest strategy for both cities, in terms of return potential. On the other hand, while placing more emphasis on Gross Domestic Product over Consumption of Nonrenewable Energy yields the best result of SGCI in Raleigh, enhancing higher education leads to the greatest improvement of SGCI in Wellington.

In addition, we can adjust different level of intensity to quantify the result regarding different city planning. Next part we further proceed to use Agent-Based Simulation Method to simulate the effectiveness of the city planning towards smart growth.

5.2.4 Agent-based Model

In order to analyze our recommended plans effectiveness in the overall city system and impacts on each individual , we use the agent-based model to do a comprehensive analysis and evaluation. In our agent-based model, each PEOPLE will choose a HOUSE as his or her FAMILY and we link each PEOPLE to FAMILY. Every PEOPLE processes two characteristics: ENERGY and VIGOR. PEOPLE will consume ENERGY and VIGOR when they are working. The supplementary law of ENERGY and VIGOR is illustrated as below:

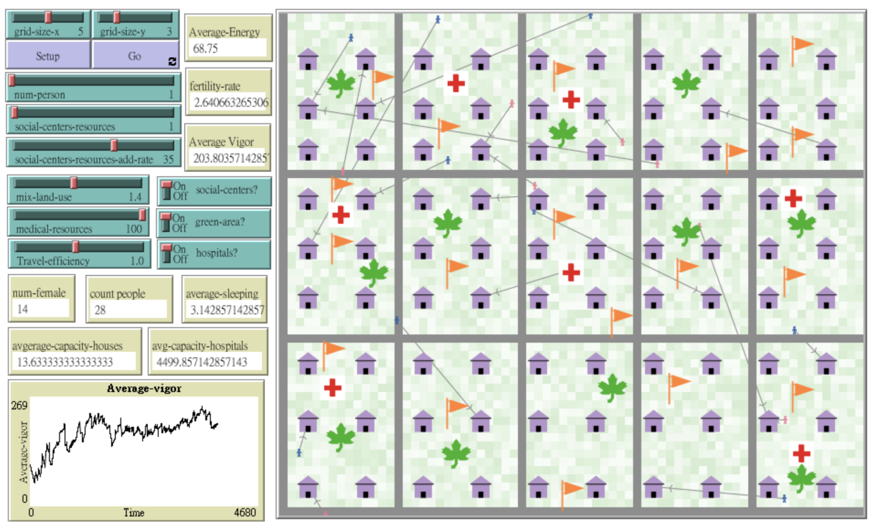


Figure 11: Illustration of Agent-Based Simulation

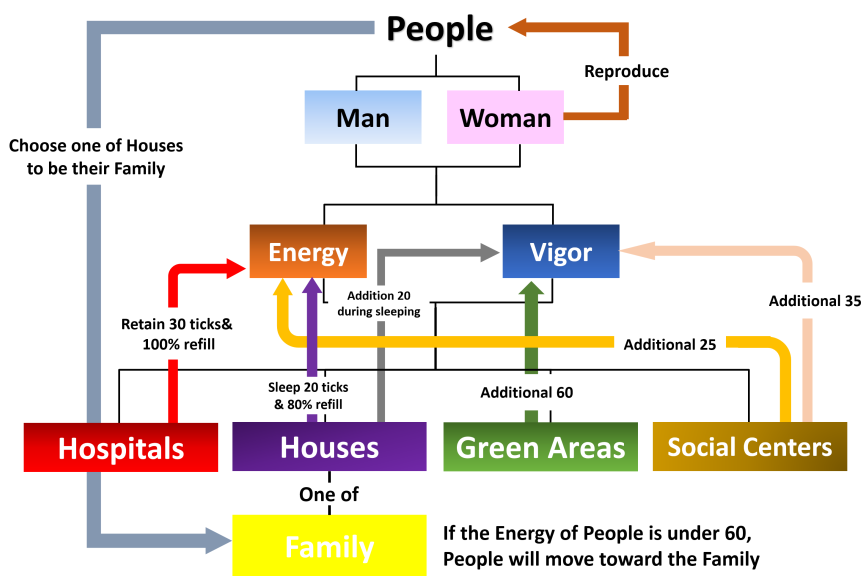


Figure 12: The Supplementary Law of ENERGY and VIGOR

Based on the Smart Growth City Planning Model and analysis above, we can find out that fertility rate is a key parameter to evaluate one citys progress towards a Smart Growth City. In our agent-based model, the value of fertility rate is computed by taking the average of ENERGY and VIGOR of PEOPLE, the formula is as below:

Simulation Strategy and Results We measure the city growth plan for six strategies

(1) Close everything (Without planning)

(2) Open hospital, while closing other facilities

(3) Open society center, while closing other facilities

(4) Open green area, while closing other facilities

(5) Reduce travel time, while closing other facilities

(6) Open every facility and reduce travel time

In order to normalize the results, we simulate the strategies for 50 times and getting their average values. The results of simulation are indicated below:

Figure 13: Simulation results of vigor, energy and people with respect to six strategies

	Strategy (1)	Strategy (2)	Strategy (3)	Strategy (4)	Strategy (5)	Strategy (6)
Vigor	155.24	155.79	177.88	197.60	199.86	199.86
Energy	67.38	67.96	67.85	67.39	68.36	68.36
People	2019.6	1998.77	2025.18	2004.34	2153.08	2153.08

Analysis of Result

- Overall, the comprehensive plan (strategy 6) that opens all public facilities and reduces travel time yields the greatest average simulation results. This result corresponds to the expected situation.
- In terms of vigor, except for strategy 6, opening green areas generates the best simulation result.
- By hypothesis testing, due to insufficient samples and inadequately small variances, we cannot conclude the best way to achieve highest energy.

6 Task 4: Comparison and Contrast:Ranking of City Plan under Different Scenario

6.1 Method 1: Using the Result from Goal Programming: direct calculation on weighted average

Our Goal Programming method provides a quantifiable index for the evaluation of smart growth city plan with different targets. We first adopt the weighted average scheme in evaluating the effectiveness (SGCI) and potential (ROGI) of the five recommendations.

Our simple algorithms can be expressed as following:

$$\text{score} = \frac{thesumofthecorrespondingvaluesonfigure.10}{thenumberoffocusestherecommendationhas}$$

Using this algorithm, we obtain the weighted average result, which is shown in the table:

Figure 14: The weighted average scoring for each recommendation

Recommendation	Focus	Wellington		Raleigh	
		SGCI	ROGI	SGCI	ROGI
Make the city more cycle-friendly	*F, TTI, GDP*$_{ne}$	3.162	3.988	2.700	5.137
Make the streets more walkable	*F, TTI, GDP*$_{ne}$	3.162	3.988	2.700	5.137
Build more smart green space	*F, NPL, GDP*$_{ne}$	3.156	3.931	2.689	5.225
Promote environmentally-friendly events	P_{he}, *GDP*$_{ne}$, *NPL*	3.180	3.782	2.698	5.166
Take advantage of mixed land use development.	*F, TTI*, P_{he}	3.164	3.734	2.675	5.064

Based on the above results, we obtain the ranking system from the greatest value to the lowest:

Figure 15: Ranking of the recommendations by Method 1

Recommendation	Wellington		Raleigh	
	SGCI	ROGI	SGCI	ROGI
Make the city more cycle-friendly	3	1	1	3
Make the streets more walkable	3	1	1	3
Build more smart green space	5	3	4	1
Promote environmentally-friendly events	1	4	3	2
Take advantage of mixed land use development	2	5	5	5

6.2 Method 2 Using the Result from Goal Programming: calculation on weighted average by scoring system

Apart from directly calculating the weighted average scores, we can first generate a score conversion table in ranking the policies. According to the magnitude of the six metrics in Goal Programming method, we rank 1 for the lowest and 6 for the greatest, by columns.

Thus, our score conversion table can be indicated below:

Figure 16: Score conversion by Method 2

Metric	Wellington		Raleigh	
	SGCI	ROGI	SGCI	ROGI
F	3	5	4	5
TTI	4	4	3	2
NPL	2	1	2	3
P_{he},	6	3	5	4
P_{hc}	1	2	1	1
GDP_{ne}	5	6	6	6

From the score conversion table, we obtain the weighted average result, which is shown in the following table:

Figure 17: Scoring of the recommendations by Method 2

Recommendation	Focus	Wellington		Raleigh	
		SGCI	ROGI	SGCI	ROGI
Make the city more cycle-friendly	F, TTI, GDP_{ne}	4	5	4.33	4.33
Make the streets more walkable	F, TTI, GDP_{ne}	4	5	4.33	4.33
Build more smart green space	F, NPL, GDP_{ne}	3.33	4	4	4.67
Promote environmentally-friendly events	P_{he}, GDP_{ne}, NPL	4.33	3.33	4.33	4.33
Take advantage of mixed land use development	F, TTI, P_{he}	4.33	4	4	3.67

Based on the above results, we obtain the ranking system from the greatest value to the lowest:

Figure 18: Ranking of the recommendations by Method 2

Recommendation	Wellington		Raleigh	
	SGCI	ROGI	SGCI	ROGI
Make the city more cycle-friendly	3	1	1	2
Make the streets more walkable	3	1	1	2
Build more smart green space	5	3	4	1
Promote environmentally-friendly events	1	5	1	2
Take advantage of mixed land use development	1	3	4	5

7 Task 5:Future Population Threat

7.1 Overview

In order to analyze coping strategies under the senario that the population of each city will increase by an additional 50 percent by 2050, we include the constraint conditions in agent-based model:

- The whole system will stop once the average capacity of HOUSE is below zero, which indicates that the population size overrides the citys carry capacity.
- We define the replacement level of total fertility rate as 2.1 according to the definition from the United Nation Next we proceed to do the Fitting experiment.

Figure 19: Agent-based simulation including constrain conditions

7.2 Agent-Based Model Simulation

We use default value of population size = 3000, Fertility rate =2.1 and ticks =3000 to do the experiment of three controlled variables: Mix Land Use, Social Center, Hospital and Green Area, for a better approach to find out the critical points.

Through many experiments, we find out that the adjustment for Mix Land Use has the best positive effect of a city towards smart growth. More specifically, the mean of ticks before failure is the highest when we increase mix land use by 0.2, Thus, we continue to adjust the level of mix land use until the system finishes 3000 ticks with 80 percent successful rate. In addition, we separate the effect among three factors by only increasing the level of mix land use, which results in a decrease in successful rate.

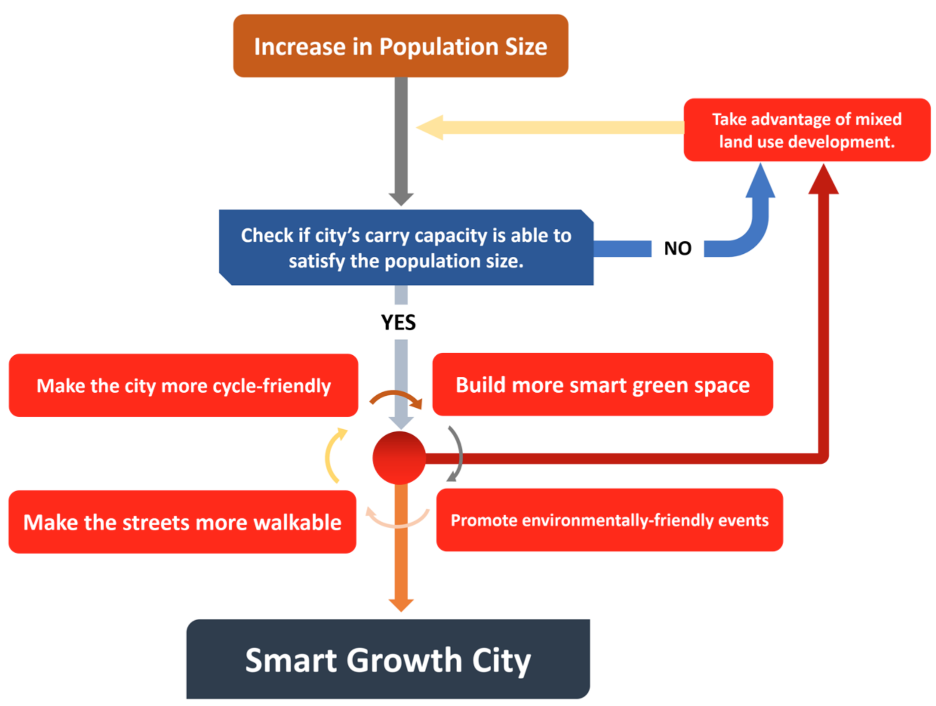
Figure 20: Illustration of our controlled variables simulation

Use Control Variate Method to Find the most Influential Factors				
	Times	Succeed	Fail	The Mean of Ticks when Fail
No Change	10	0	10	469
Add Social-Centers	10	0	10	515
Add Green Areas	10	0	10	51
Add hospitals	10	0	10	484
Add Three Factors	10	0	10	517
Mix Land Use Increase 0.2	10	0	10	559
↓ ↓ ↓ ↓ ↓				
Set 3000 people & Fertility rate = 2.1 & ticks = 3000 &Add Add Three Factors				
Mix Land Use	Times	Succeed	Fail	The Mean of Ticks when Fail
No Change	10	0	10	517
Increase 0.2	10	0	10	589
......				
Increase 3.6	10	0	10	2783
Increase 3.8	10	8	2	2970
Withoout Three Factors	10	1	9	2893

Thus, we can conclude that when the citys population size in growing at a rapid rate, how to provide enough house for all the people is one of the most critical challenges faced by the city. Based on our analysis, adding Social Center, Green Areas, Hospitals and the level of Mix Land Use can both increase the successful rate while the level of Mix Land Use plays a most important role in the simulation. That is to say, all other factors complement each other simultaneously and amplify the effects of Mix Land Use while can not exact critical influences singularly. In addition, among the other three factors, adding Green Areas is the least influential factors and should be put into strategy at the final stage.

Our co - ordinated global response to 50 percent population growth by 2050 is illustrated below:

Figure 21: Illustration of our controlled variables simulation



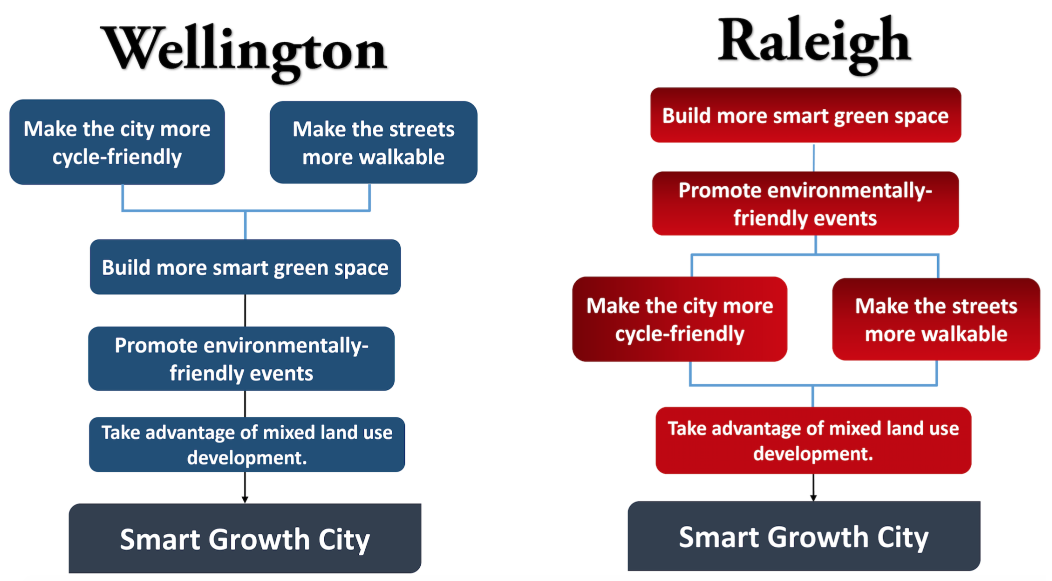
Wellingtons case First of all, we make judgement whether the citys carry capacity is able to satisfy the growth of population size.

If the answer if no, Priority will be given to increase the level of mix land use with the synergy from other three projects. When citys can carry capacity is able to satisfy the population size, city will implement different project according to their ranking.

Raleighs case Similarity, we will check whether the citys carry capacity is able to satisfy the population size or not.

If the answer is no, Priority will be given to increase the level of mix land use with the synergy from other three projects. When citys can carry capacity is able to satisfy the population size, city will implement different project according to their ranking.

Figure 22: Flowchart of two cities' co - ordinated response when population size is satisfied by carry capacity



8 Sensitivity Analysis

Our Smart Growth City Planning Model may be sensitive to the change in some inputs. To test the robustness of the model, we employ 5 percent, 10 percent, 15 percent as thresholds of changes in metrics and evaluate the change in the outputs. The analysis provides evidence that our model does not show a chaotic behavior, demonstrating great sensitivity.

The table below describes the changes in SGCI with respect to the changes in our metrics. Note that the changes in SGCI are the same as the changes in ROGI.

Figure 23: Sensitivity Analysis Smart Growth City Planning Model

Changes	GDP_{ne}	NPL	PI_c	TTI	P_{he}	P_{hc}	P_{ev}	F
-15%	-7.71%	-0.66%	2.43%	1.97%	-1.71%	-0.15%	-0.53%	-1.72%
-10%	-5.14%	-0.44%	1.61%	1.27%	-1.14%	-0.10%	-0.35%	-1.14%
-5%	-2.57%	-0.22%	0.81%	0.60%	-0.57%	-0.05%	-0.18%	-0.57%
0%	0%	0%	0%	0%	0%	0%	0%	0%
5%	2.57%	0.64%	-0.82%	-0.54%	0.57%	0.05%	0.18%	0.57%
10%	5.14%	0.43%	-1.63%	-1.06%	1.15%	0.10%	0.36%	1.14%
15%	7.71%	0.21%	-2.45%	-1.56%	1.72%	0.15%	0.54%	1.72%

Among the eight metrics, the greatest change of SGCI (7.71 percent)is witnessed when adding or subtracting 15 percent of GDP_{ne}. This indicates that the model is robust.

9 Strengths and Weaknesses

Strengths:

- 1. Versatility of The Smart Growth City Model The Smart Growth City Model is used extensively throughout the paper. It not only links our metrics together and provides the measurement for the city growth plans, but also extends for goal programming, which enables us to visualize the effectiveness and return potential to targeted plans.
- 2. Visibility and simplicity of scoring and ranking systems The scoring and ranking algorithms are not only intelligible but also sound in making evaluations.
- 3. Clear causal relationship throughout our paper The system dynamic diagram and causal loop diagram provide clear and insightful interrelationships among our metrics and various principles.
- 4. Netlogo can help us achieve the visibility of our program and support multiple trials to increase the accuracy of our model.

Weaknesses:

- The model establishment process is relatively complicated
- Our model requires large amount of data that will pose difficulty on data mining process.

10 Future Work

- 1. Extended use of goal programming Our model only analyze the goal-oriented city growth plan for one specific goals. There is critical interest in considering more influential factors in our model and extending the use of goal programming in evaluating the plans with multi-goals.

11 References

[1] Angelidou, Margarita.(2015).Smart cities: A conjuncture of four forces. Cities , 47,95106
[2] Belanche, Daniel., Casal, Luis V., Ors, Carlos .(2016). City attachment and use of urban services: Benefits for smart cities. Cities, 50, 7581
[3]Begg J.G., Mazengarb C., Geology of the Wellington area, 1:50 000, in: Geological Map 22, Institute of Geological and Nuclear Sciences, 1996, 128 p., 1 sheet.
[4]Brown, Barbara B., et al. "Mixed land use and walkability: Variations in land use measures and relationships with BMI, overweight, and obesity." Health place 15.4 (2009): 1130-1141.
[5]Cappiella, K., Wright, T., Schuler, T., 2005. Urban watershed forestry manual. Part 1:Methods for increasing forest cover in a watershed. Center for Watershed Protection
[6]City of Raleigh . (n.d.). Retrieved January 21, 2017, from https://www.raleighnc.gov/
[7]Durand, Casey P., et al. "A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning." Obesity Reviews 12.5 (2011): e173-e182.
[8]Daniels, Tom. "Smart growth: A new American approach to regional planning." Planning practice and research 16.3-4 (2001): 271-279.
[9]Handy, Susan. "Smart growth and the transportation-land use connection: What does the research tell us?." International Regional Science Review 28.2 (2005): 146-167.
[10] North Carolina State Energy Profile. (n.d.). Retrieved January 23, 2017, from https://www.eia.gov/state/print.cfm?sid=NC
[11]Statistics New Zealand, Wellington. "Monitoring progress towards a sustainable New Zealand." (2002).
[12]Wellington City Council. (n.d.). Retrieved January 21, 2017, from http://wellington.govt.nz/
[13]Ten Year Plan of Wellington. (n.d.). Retrieved January 22, 2017, from http://www.our10yearplan.co.nz
[14] U.S. Census Bureau, American FactFinder, North Carolina, Table B25040, House Heating Fuel, 2010-14 American Community Survey 5-Year Estimate.
[15]30 Year Comprehensive Plan of Raleigh. (n.d.). from https://www.raleighnc.gov/content/extra/Books/PlanDev/2030CompPlan

12 Appendix

```
globals
[grid-x-inc
grid-y-inc
intersections
roads
delined-poplation-count-houses
delined-poplation-count-restaurants
fertility-rate]
breed[people person]
breed[social-centers social-cente]
breed[houses house]
breed[hospitals hospital]
breed[green-areas green-area]
green-areas-own[come name]
hospitals-own[capacity name]
social-centers-own[capacity name]
houses-own[capacity name]
people-own[ life Vigor name energy sleeping working birth-rate family healing]
patches-own [ intersection? my-row my-column my-phase]
;———————————————————— to setup
ca
setup-hospital
setup-bulid-social-centers
setup-bulid-house
setup-globals
setup-patches
setup-bulid-green-area
create-people num-person
set-default-shape turtles "person"
ask people [set color one-of [blue 135]]
ask people [setxy random-xcor random-ycor
set life 1000 - random-float 200
set energy 90
set Vigor 90 + count green-areas
set working 1
set healing 0
set family one-of houses
create-link-to family
set birth-rate 0
if color = 135
[set birth-rate 800 - random-float 300 ] ]
;watch one-of people
set delined-poplation-count-houses 0
reset-ticks
end
;———————————————————— to setup-globals
set grid-x-inc world-width / grid-size-x
set grid-y-inc world-height / grid-size-y
end
;———————————————————— to setup-patches
ask patches
[ set my-row -1
set my-column -1
set my-phase -1
set pcolor 58.9 + random-float 1
```

```
] set roads patches with
[(floor((pxcor + max-pxcor - floor(grid-x-inc - 1)) mod grid-x-inc) = 0) or
(floor((pycor + max-pycor) mod grid-y-inc) = 0)] set intersections roads with
[(floor((pxcor + max-pxcor - floor(grid-x-inc - 1)) mod grid-x-inc) = 0) and
(floor((pycor + max-pycor) mod grid-y-inc) = 0)] ask roads [ set pcolor gray ]
setup-intersections
end
;———————————————————— to setup-intersections
ask intersections
[ set intersection? true
set my-row floor((pycor + max-pycor) / grid-y-inc)
set my-column floor((pxcor + max-pxcor) / grid-x-inc)
] end
;———————————————————— to setup-fertility-rate
set fertility-rate (( mean [Vigor] of people / 100 ) * (mean [energy] of people / 100) + 1.3)
if mean [Vigor] of people ¡ 50 and mean [energy] of people ¡ 50
[set fertility-rate 1]
end
;———————————————————— to go
if count people = 0
[stop]
if ticks = 5500
[stop]
if mean [capacity] of houses ¡ 0
[user-message (word ”There are too many people, and the house can’t afford them” )
stop]
if all? houses [capacity = 0]
[user-message (word ”There are too many people, and the house can’t afford them” )
stop] setup-fertility-rate
people-death-birth move-people social-centers-add
go-social-centers sleep
heal
green-GDP tick end
;————————————————————— to move-people ask people [ fd working
set energy energy - 1 set Vigor Vigor - 0.5
set birth-rate birth-rate - 1 set life life - 1
] end ;———————————————————— to green-GDP
ask people [
if any? green-areas-here [
let target one-of green-areas-here
ask target [set come (come + 1)]
set Vigor (Vigor + 60)]]
end
;————————————————————— to go-social-centers ask people [ if any? social-centers-here [
let target one-of social-centers-here ask target [set capacity (capacity - 1)] set energy (energy + 25)
set Vigor (Vigor + 35)]]
end
;—————————————————————- to heal ask people [
if life ¿ 30 and energy ¡ 60 and any? hospitals-here [
let target one-of hospitals-here
ask target [set capacity (capacity - 1)]
set energy 100
set Vigor 75
set healing (healing + 1)
set working 0]
if healing ¿ 0 and healing ¡ 30
[set healing (healing + 1)
```

```
set Vigor 75
set energy 100
set working 0]
if healing = 30 and any? hospitals-here
[let target one-of hospitals-here
ask target [
set capacity (capacity + 1)]
set Vigor (Vigor + 10 )
set energy 100
set healing 0
right random 360
set working Travel-efficiency
] ] end
;——————————————————————- to social-centers-add
ask social-centers [
if capacity ¡ [capacity] of self
[ set capacity (capacity + social-centers-resources-add-rate) ]
if capacity ¿ [capacity] of self
[ set capacity (capacity = [capacity] of self )
]]
end
;—————————————————————— to sleep
ask people [
if energy ¡ 60 and not any? houses-here
[set heading towards [family] of self ]
if energy ¡ 60 and any? houses-here [
let target one-of houses-here
ask target [
set capacity (capacity - 1)]
set energy 80
set sleeping (sleeping + 1)
set working 0]
if sleeping ¿ 0 and sleeping ¡ 20
[set sleeping (sleeping + 1)
set Vigor (Vigor + 2)
set energy 80
set working 0]
if sleeping = 20 and any? houses-here
[let target one-of houses-here
ask target [
set capacity (capacity + 1)]
set energy 80 set sleeping 0 right random 360 set working Travel-efficiency]]
end
;————————————————————— to people-death-birth
ask people [ if life ¡ 0 [die]
if birth-rate ¡ 150 and 149 ¡ birth-rate
[ hatch-people floor fertility-rate [
setxy random-xcor random-ycor
set color one-of [blue 135]
set life (1000 - random-float 200)
set sleeping 0 set healing 0 set energy 90 set Vigor 90 set working Travel-efficiency
set healing 0 set family one-of houses create-link-to family set birth-rate 0 if color = 135
[set birth-rate (800 - random-float 400) ]
] ]] end ;——————————————————————- to bulid-social-centers [x y s n c]
create-social-centers 1
[ set xcor x
set ycor y
```

```
set size s
set name n
set capacity c
;set accepted-person-count 0
set color 26
] end ;—————————————————————— to bulid-green-area [x y s ]
create-green-areas 1
[ set xcor x set ycor y set size s set come 0 ;set accepted-person-count 0
set color green ] end ;—————————————————————— to bulid-hospitals [x y s n c ]
create-hospitals 1
[ set xcor x set ycor y set size s set name n set capacity c
;set accepted-person-count 0
set color red]
end
;——————————————————————- to setup-bulid-green-area
if green-area? = true
[ set-default-shape green-areas "leaf"
bulid-green-area 7 22 4
bulid-green-area 49 22 4
bulid-green-area 49 4 4 bulid-green-area 7 -21 4
bulid-green-area 20 5 4 bulid-green-area 63 5 4
bulid-green-area 21 -23 4
bulid-green-area 40 -15 4 bulid-green-area 34 16 4
bulid-green-area 63 -26 4 bulid-green-area 11 -1 4
] end
;——————————————————————- to setup-bulid-social-centers if social-centers? = true
[ set-default-shape social-centers "flag"
bulid-social-centers 7 2 4 "H1" (50 * social-centers-resources)
bulid-social-centers 12 22 4 "H2" (69 * social-centers-resources)
bulid-social-centers 55 13 4 "H3" (35 * social-centers-resources)
bulid-social-centers 63 26 4 "H4" (62 * social-centers-resources)
bulid-social-centers 41 -7 4 "H5" (42 * social-centers-resources)
bulid-social-centers 21 -18 4 "H6" (89 * social-centers-resources)
bulid-social-centers 35 -28 4 "H7" (69 * social-centers-resources)
bulid-social-centers 48 -15 4 "H8" (71 * social-centers-resources)
bulid-social-centers 7 9 4 "H9" (40 * social-centers-resources)
bulid-social-centers 63 -16 4 "H10" (69 * social-centers-resources)
bulid-social-centers 21 -1 4 "H11" (67 * social-centers-resources)
bulid-social-centers 6 -11 4 "H12" (47 * social-centers-resources)
bulid-social-centers 20 16 4 "H13" (55 * social-centers-resources)
bulid-social-centers 34 23 4 "H14" (42 * social-centers-resources)
bulid-social-centers 34 5 4 "H15" (52 * social-centers-resources)
bulid-social-centers 62 -2 4 "H16" (65 * social-centers-resources)
bulid-social-centers 63 15 4 "H17" (69 * social-centers-resources)
bulid-social-centers 49 -1 4 "H18" (71 * social-centers-resources)
] end
;—————————————————————— to setup-hospital if hospitals? = true [ set-default-shape hospitals
"hospital"
bulid-hospitals 63 -23 3 "H1" 45 * medical-resources
bulid-hospitals 7 6 3 "H2" 45 * medical-resources bulid-hospitals 35 -1 3 "H3" 45 * medical-resources
bulid-hospitals 21 22 3 "H3" 45 * medical-resources bulid-hospitals 62 8 3 "H2" 45 * medical-resources
bulid-hospitals 35 20 3 "H3" 45 * medical-resources bulid-hospitals 6 -15 3 "H3" 45 * medical-resources
] end ;——————————————————————- to bulid-house [a b c d v ] create-houses 1
[ set xcor a set ycor b set size c set name d set capacity v set color 117]
end
;—————————————————————— to setup-bulid-house set-default-shape houses "house"
bulid-house 3 25 3 "H1" (10 * mix-land-use)
```

bulid-house 10 25 3 ”H2” (10 * mix-land-use) bulid-house 17 25 3 ”H3” (10 * mix-land-use)
bulid-house 24 25 3 ”H4” (10 * mix-land-use) bulid-house 31 25 3 ”H1” (10 * mix-land-use)
bulid-house 38 25 3 ”H2” (10 * mix-land-use) bulid-house 45 25 3 ”H3” (10 * mix-land-use)
bulid-house 52 25 3 ”H4” (10 * mix-land-use) bulid-house 59 25 3 ”H6” (10 * mix-land-use)
bulid-house 66 25 3 ”H1” (10 * mix-land-use) ;———————— bulid-house 3 19 3 ”H1” (10 * mix-land-use) bulid-house 10 19 3 ”H2” (10 * mix-land-use)
bulid-house 17 19 3 ”H3” (10 * mix-land-use)
bulid-house 24 19 3 ”H4” (10 * mix-land-use) bulid-house 31 19 3 ”H1” (10 * mix-land-use)
bulid-house 38 19 3 ”H2” (10 * mix-land-use) bulid-house 45 19 3 ”H3” (10 * mix-land-use)
bulid-house 52 19 3 ”H4” (10 * mix-land-use) bulid-house 59 19 3 ”H6” (10 * mix-land-use)
bulid-house 66 19 3 ”H1” (10 * mix-land-use)
;———————— bulid-house 3 14 3 ”H1” (10 * mix-land-use) bulid-house 10 14 3 ”H2” (10 * mix-land-use)
bulid-house 17 14 3 ”H3” (10 * mix-land-use) bulid-house 24 14 3 ”H4” (10 * mix-land-use)
bulid-house 31 14 3 ”H1” (10 * mix-land-use) bulid-house 38 14 3 ”H2” (10 * mix-land-use)
bulid-house 45 14 3 ”H3” (10 * mix-land-use) bulid-house 52 14 3 ”H4” (10 * mix-land-use)
bulid-house 59 14 3 ”H6” (10 * mix-land-use) bulid-house 66 14 3 ”H1” (10 * mix-land-use)
;———————— bulid-house 3 8 3 ”H1” (10 * mix-land-use) bulid-house 10 8 3 ”H2” (10 * mix-land-use)
bulid-house 17 8 3 ”H3” (10 * mix-land-use) bulid-house 24 8 3 ”H4” (10 * mix-land-use)
bulid-house 31 8 3 ”H1” (10 * mix-land-use) bulid-house 38 8 3 ”H2” (10 * mix-land-use)
bulid-house 45 8 3 ”H3” (10 * mix-land-use) bulid-house 52 8 3 ”H4” (10 * mix-land-use)
bulid-house 59 8 3 ”H6” (10 * mix-land-use) bulid-house 66 8 3 ”H1” (10 * mix-land-use)
;———————— bulid-house 3 2 3 ”H1” (10 * mix-land-use) bulid-house 10 2 3 ”H2” (10 * mix-land-use)
bulid-house 17 2 3 ”H3” (10 * mix-land-use) bulid-house 24 2 3 ”H4” (10 * mix-land-use)
bulid-house 31 2 3 ”H1” (10 * mix-land-use) bulid-house 38 2 3 ”H2” (10 * mix-land-use)
bulid-house 45 2 3 ”H3” (10 * mix-land-use) bulid-house 52 2 3 ”H4” (10 * mix-land-use)
bulid-house 59 2 3 ”H6” (10 * mix-land-use) bulid-house 66 2 3 ”H1” (10 * mix-land-use)
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bulid-house 17 -4 3 ”H3” (10 * mix-land-use)
bulid-house 24 -4 3 ”H4” (10 * mix-land-use) bulid-house 31 -4 3 ”H1” (10 * mix-land-use)
bulid-house 38 -4 3 ”H2” (10 * mix-land-use) bulid-house 45 -4 3 ”H3” (10 * mix-land-use)
bulid-house 52 -4 3 ”H4” (10 * mix-land-use)
bulid-house 59 -4 3 ”H6” (10 * mix-land-use) bulid-house 66 -4 3 ”H1” (10 * mix-land-use)
;———————— bulid-house 3 -12 3 ”H1” (10 * mix-land-use)
bulid-house 10 -12 3 ”H2” (10 * mix-land-use) bulid-house 17 -12 3 ”H3” (10 * mix-land-use)
bulid-house 24 -12 3 ”H4” (10 * mix-land-use)
bulid-house 31 -12 3 ”H1” (10 * mix-land-use)
bulid-house 38 -12 3 ”H2” (10 * mix-land-use) bulid-house 45 -12 3 ”H3” (10 * mix-land-use)
bulid-house 52 -12 3 ”H4” (10 * mix-land-use) bulid-house 59 -12 3 ”H6” (10 * mix-land-use)
bulid-house 66 -12 3 ”H1” (10 * mix-land-use)
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bulid-house 17 -19 3 ”H3” (10 * mix-land-use) bulid-house 24 -19 3 ”H4” (10 * mix-land-use)
bulid-house 31 -19 3 ”H1” (10 * mix-land-use) bulid-house 38 -19 3 ”H2” (10 * mix-land-use)
bulid-house 45 -19 3 ”H3” (10 * mix-land-use) bulid-house 52 -19 3 ”H4” (10 * mix-land-use)
bulid-house 59 -19 3 ”H6” (10 * mix-land-use) bulid-house 66 -19 3 ”H1” (10 * mix-land-use)
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bulid-house 17 -27 3 ”H3” (10 * mix-land-use)
bulid-house 24 -27 3 ”H4” (10 * mix-land-use)
bulid-house 31 -27 3 ”H1” (10 * mix-land-use)
bulid-house 38 -27 3 ”H2” (10 * mix-land-use) bulid-house 45 -27 3 ”H3” (10 * mix-land-use)
bulid-house 52 -27 3 ”H4” (10 * mix-land-use) bulid-house 59 -27 3 ”H6” (10 * mix-land-use)
bulid-house 66 -27 3 ”H1” (10 * mix-land-use)
end