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T1 _____	**67197**	F1 _____
T2 _____		F2 _____
T3 _____	Problem Chosen	F3 _____
T4 _____	**F**	F4 _____

2017 MCM/ICM

Simulation Utopian: an evolving model based on the Multiplex Network and Deep Learning

Summary

In order to design an economic-workforce-education system for migration on Mars, our idea is to establish a comprehensive model with plentiful properties of nodes which are consistent with the current states.

As to Task 1 & 2, for the sake of measuring the happiness of residents, we set up an evaluation system made up of three priority parameters(income,education and social equality). Having considered the differences between fields, the **ideal distribution** function is founded in separate fields. **Pearson correlation coefficient** is utilized to describe how the practical distribution is relative to the ideal, and the better correlation it indicates, the better the actual distribution is. On the basis of the analysis in Task 1, we generate a sample population of 10,000 people for migration from the **PUMS dataset**. The sampling algorithm focusing on the educational background and age, takes a group as a unit which is of maximum capacity.

When solving the Task 3 & 4, based on the parameters defined in Task 1, we establish **Multiplex human social relationship network** to depict the dynamic process that the human society develops. The connection of the actual situation and the network is set up under the assumption that the node degree and mediacy in the network reflect the contributions one makes. To predict this economic parameter, an idea is proposed to study the independencies other parameters serve through **Deep Learning**. After that, the **population development model based on differential equation** is utilized to describe the dynamic changes in population demographics with the variation of time. We divide the Population Zero into two groups(skilled and unskilled labor force) by virtue of **Spectral Bisection Method**.

When it comes to Task 5 & 6, we verify the accuracy and stability of our model by changing the population size and migration process. Taking the satisfaction as the ultimate goal, we study the sensitivity with **Times Series Model**. The result shows that the model is hardly affected by the size of population.

Integrating the models and analysis, we come up with a policy recommendation addressed to the director of LIFE, containing the policies, sensitivity and the expecting results.

Keywords: Multiplex human social relationship network; Pearson correlation coefficient; Spectral bisection method; Deep learning; Times Series Model

Contents

1 Introduction

1.1 Background

In the year of 2095, equipped with modern technology, the project called UTOPIA to migrate to the Mars is about to be under implementation. The international agency has completed the short-term planned experiments, which is utilized to guide the development of the migration planet and humanity society.

In the project, some people in USA are chosen to be the first batch of resident population, who have the responsibility to ensure the operation of the new place of residence. Considering that the Mars need support in all fields, such as industry, business, agriculture, education and so on, the first wave of migration, called Population Zero, will include 10,000 persons, consisting of people of different ages, from separate working fields.

For the sake of people in Utopian achieving the greatest quality of life with a vision of sustaining ability for 100 years, a series of policies have been planned and built on the earth that tested planned living conditions. It is the policies that provides the guideline of the advance in social equality, industrial progress, particularly, the high quality of residents' life. The Utopian is meant to make the living experience better than the Earthly one, which expresses at the aspect of the necessities, the equality at work and the basic education.

Broadly speaking, Population Zero aims to have optimal conditions in many workforce and social living factors. How to maximize the GDP and the happiness is connected with the policies and feature of the migration population.

1.2 Problem restatement and analysis

For Task 1, we are required to define parameters and specific outcomes related to the three priority factors (income, education, and social equality) in Population Zero, and then the outcome of the factors ought to be predicted.

Task 2 asks us to generate a sample population of 10,000 people to emigrate to Mars. In order to create the greatest value, people from varieties of fields are needed. In addition, the demographics distributions affect the sustainability of the human society.

As for Task 3, how to integrate the three factors in Task 1 and how the system of society operate with the approach of time is of great importance. The best strategy for childcare and paternity/maternity leave is required to be formulated.

In regard to Task 4, a global model is merged by three priority factors. We should consider the different attributes of the separate individualities to identify the major subgroups of workforce. Each group's priority needs evaluating and each one in the group differs from others in some aspect.

As to Task 5 & 6, a large number of population is going to migrate to the Mars. There are two migrating method: one is migrating during a long time, the other is migrating in a short period. Taking the satisfaction in society as the ultimately goal,

we study the way of migration to evaluate the sensitivity. The result shows that the model is hardly affected by the size of population.

2 Assumption

- The importance of a node in the network reflects the contributions of people in society.
- The capacity of the new-built manufactured cities is enough to accommodate the increasing number of population.
- In groups, the individuality considers his own benefit in priority and then the overall interests.
- Economic and psychological factors are taken into granted, but we regard that the political factors hardly influence the workforce.
- The data in the dataset can reflect the conditions of people in reality precisely.

3 Symbol Description

In this section, we use some symbols for constructing the model as follows:

Symbol	Description
$f(x)$	Evaluation function
$l(j)$	Level of educational background
$C(j)$	Childcare expenses
$h(d_w)$	Happiness of professional women
k_j	Node degree
$c_b(v_j)$	Mediacy of one node
$\mu(r,t)$	Mortality rate
$I(j)$	Ideal income
$S(j)$	Satisfaction of the society

P.S: Other symbol instructions will be given in the text.

4 Preparation for Model

4.1 Task 1: Metrics of Population Zero

The goal of Population Zero is optimum conditions, where the economic output reaches the maximum and the happiness of the residents is up to the best level. To qualify the status in many workforce and social living factors, three balancing factors are taken into granted:

- ***Income:*** Whether a resident affords the necessities determines the happiness of his life. Thus, when taking each person as a unit to analyze the influence of income, it is wise to set the minimum living allowance and offer the residents sufficient compensation to ensure his income meeting it.

- ***Education:*** In new-built manufactured cities, the development of human society has close connection with the capabilities that the new comers equipped. And the skills for work scarcely get rid of how well he educated.

- ***Equality:*** Nothing has the power to change the importance of the equality, which affects the enthusiasm in the workforce, and affects the healthy development of human society. In this case, the focus of the factor is the rights of women, specially on the maternity and paternity leave.

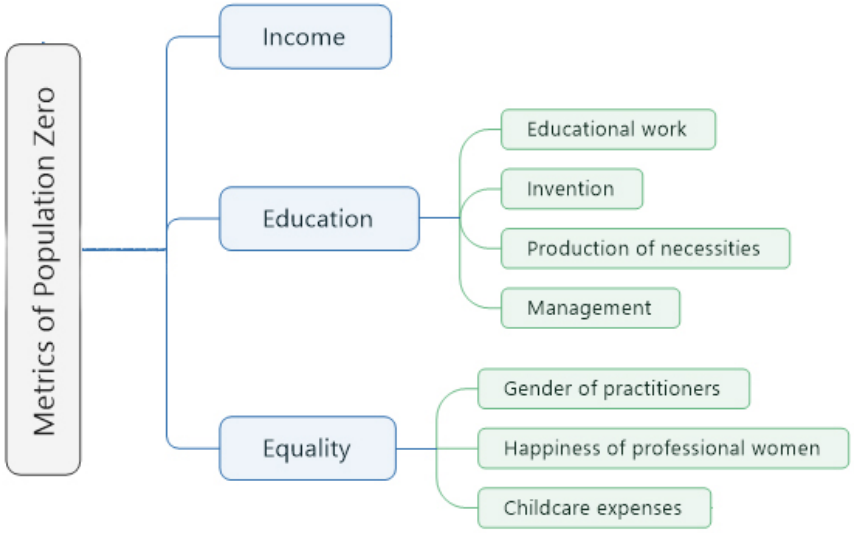

Figure 1: Establishment of metrics

As to incomes

From the personal perspective, we establish a evaluating function $f(i)$ to indicate how content he is with his life, where i represents the income one achieve per month. If a resident's income is too low to satisfy his basic needs, the value of $f(x)$ keeps the minimum status-0. On the contrary, when income is above the threshold, the income hardly works on how good their life is, and when the earning is not too high nor too low, the evaluating function show an increasing trend, which subjects to the Partial large Γ-distribution:

$$f(x) = \begin{cases} 0 & x < a \\ 1 - e^{k(x-30)} & x \geq a \end{cases} \tag{1}$$

As to education

The first wave of migration is responsible for promoting the development of the new land. That is the reason why the workers in different fields are in demand. The labor force are divided into four parts: those engage in educational work, technological

invention, the production of necessities and management, and meanwhile, the education received is divided into five levels, which are marked as 0 to 4, from the lowest one to the Combined the reality, we lay down the ideal distributions of population working for the four fields separately, depending on some existing functions.

According to, bachelor's degree is required for a teacher qualification, so those take part in the education work is of high cultural background. Thus, most of them are masters, and others are bachelor. The distribution is expressed by:

$$f(l_e) = \frac{1}{l_e\sqrt{2\pi}\delta} e^{-\frac{(\ln l_e - \mu)^2}{2\delta^2}} \tag{2}$$

Similarly, as for the workers go in for the technological invention, the peak value is between 3 to 4, and the broad trend is the same as the distribution of educational workers, where $\delta = 0.5$:

$$f(l_i) = f(-l_e + 4) \tag{3}$$

Here, $E(x) = e^{\mu+\delta^2/2}$ and $\mu = -0.818$. The education level of managers is relatively high, and a mass of them are of bachelor degree. The amount of those that has the educational background below junior high school graduation certification is too small to be neglected. The trend of distribution can be depicted by the segmentation equation (4), in which the first part and the third part is index function that can grow rapidly with the magnifying of dependent variable and the second part is logarithmic function whose increasing trend of growth is slow:

$$f(m) = \begin{cases} -(m-0.5)(m-4)/7.146\,, & 0.5 \le l_m < a \\ 0, & others \end{cases} \tag{4}$$

In the same way, as to those who work on the production of necessities, there is no strict requirement on their background. Assuming that the number of samples is large enough, the ideal distribution obeys the normal distribution, and the set of its mean is between 2 to 3:

$$f(l_p) = \frac{1}{\sqrt{2\pi}\delta} e^{-\frac{(x-\mu)^2}{2\delta^2}} \tag{5}$$

The ideal distribution of each field is indicated:

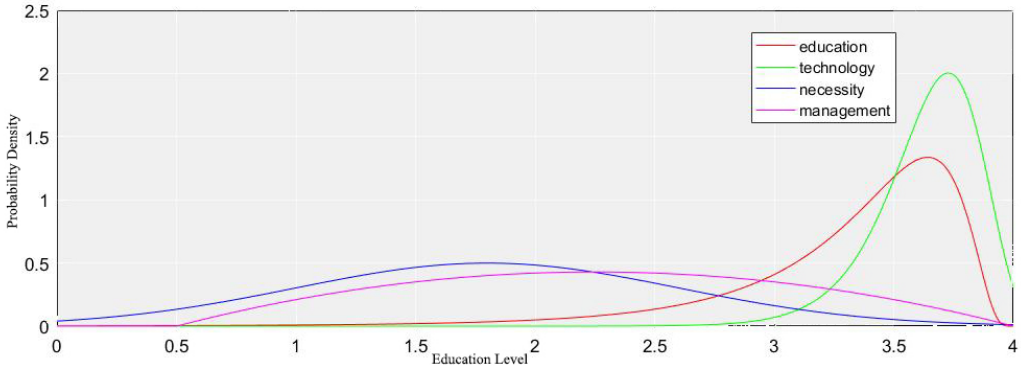

Figure 2: Ideal distribution

As to equality

Three parameters, equality for practitioners, happiness of professional women and childcare expenses, donate to the evaluation of social equality.

Equality for practitioners: Two elements, income and proportion of employees in fields, is selected to structure normalized evaluating function.In reality, income reflects the recognition and respect from others, and the sex ratio of practitioners in each field is the reflection of the discrimination in most cases. We construct the evaluating function:

$$\varpi_1 \frac{|i_w - i_m|}{|i_w + i_m|} + \varpi_2 \sum_{j=1}^{4} \frac{|n_{wj} - n_{mj}|}{|n_{wj} + n_{mj}|} \tag{6}$$

Where i_w and i_m is on behalf of the women and men's average income, n_wj and n_mj represents the number of female and male workers in the j_th field. The four fields have been accounted for in the above.

Happiness of professional women: In this part, we focus on the length of maternity and paternity leave, considering that women of chidbearing age occupy a large proportion. The element itself influence the satisfaction of work both in physic and psychologic, we establish the evaluating function $h(d)$ of length d_w and d_m, where d_w and d_m means the the length of maternity and paternity leave separately. Based on the fact that the longer the holiday is, the larger the value of the function is. Two extreme situations must be paid attention to-One is that if the length of the holiday is so short that she is hardly content with the status. At this point, the value of the $h(d)$ is up to the minimum; the other is that if the paid leave is rich enough to recover and take good care of baby, the length impacts a little on her life, which means that $h(d)$ is prescribed value. In total, the evaluating function of wealth subjects to the partial large Cauchy distribution:

$$h(d_w) = \begin{cases} 0 & d_w < a \\ \frac{1}{1+\alpha(d_w - a)^{-\beta}} & d_w \geq a \end{cases} \tag{7}$$

According to business management, the limited length of maternity is 200 days. Thus, the value of a is 10, meanwhile, $\alpha = 20$ and $\beta = -1$. Meanwhile, there is a loss that the society suffers due to the maternity and paternity leave. The effects of paid leave is larger with the increase of length, which is similar to the index distribution:

$$p(d_w) = ke^{d_w/200} + b \tag{8}$$

Here, the parameter k satisfies the equation $k = \frac{1}{e} = 0.3679$. To integrate the equation (7)and(8) on the basis of reality, we establish a comprehensive model:

$$h(d_w, d_m) = \varpi_{11} h(d_w) + \varpi_{12} h(d_w) h(d_m) - [\varpi_{21} p(d_w) + \varpi_{22} p(d_m)] \tag{9}$$

In the equation, the values of the weights are 0.65, 0.12, 0.5 and 0.5.

Childcare expenses: For the sake of sustainability, the affordable cost of childcare is required. When some youths of chidbearing age don't have the ability to pay for it, the equal balance changes. An appraising model exits:

$$C = \frac{C_k}{i_t} \tag{10}$$

Where the C_k represents the cost of childcare, and i_t the total incomes of a family.

4.2 Task 2: Sample population for migration

Population Zero aims to have optimal conditions in many workforce and social living factors, so the first wave of migration has to take the responsibility to build the new place of residence. The age is related to whether one is sufficient in energy to complete the complex work, and the education connects to how much one contributes to the progress of the cosmic colony. The two decisive factors are the criterion for sampling, and the exact operating methods are based on the set of Task 1:

As to educational background:

To ensure the immigrants make contributions to all works of life, we set the proportion of each field. In Task 1, the ideal distribution of the educational background for Population Zero has been given in separate fields, with which the number of persons in each education level is figured out:

$$N(l) = N_s p_j f(l) \tag{11}$$

Where p symbolizes the ratio of each field, which satisfies the equation $\sum_{j=1}^{4} p_j = 1$, and N_s represents the amount of population.

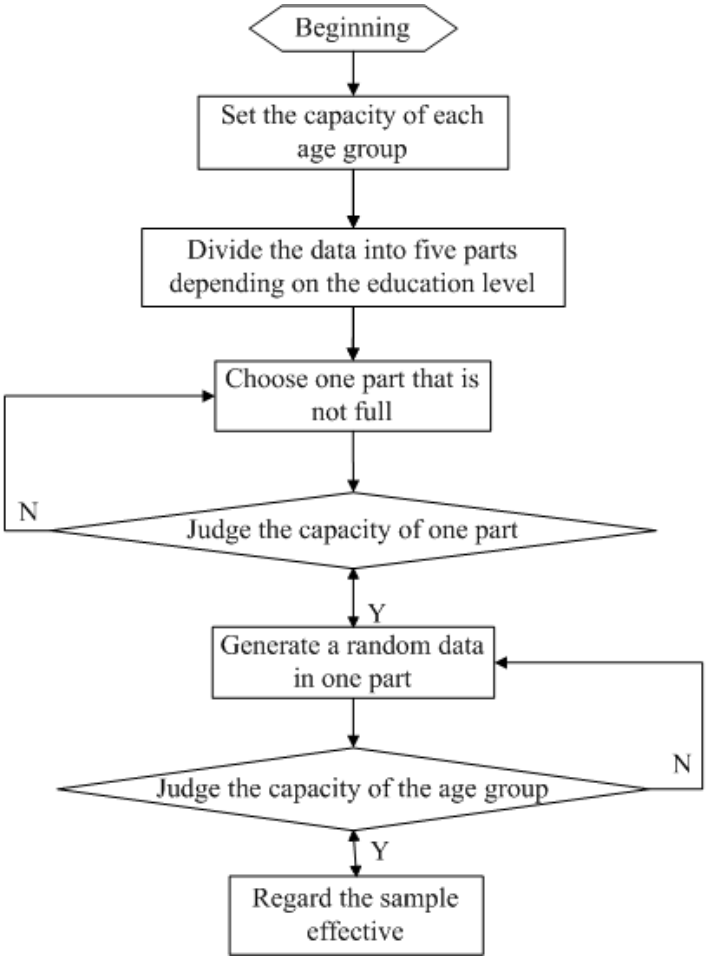

Figure 3: Flowchart of sampling algorithm

As to age:

Taking ten years as a unit, we divide the people into ten groups by how old he is, and then calculate the average income each group gets. On account of the assumption that, the more income one achieves, the greater value he possesses, the principle of sampling is set like that, the greater value one group possesses, the more persons are chosen in this group, which is indicated in the Equation (12):

$$p_j = \frac{i_{tj}}{i_t} \tag{12}$$

The ratio of the j_{th} group is p_j, and the i_t and i_{tj} relates to the total income of the whole population and the the total income of one group. With the help of Equation (12), the number of each group in the sample is certain.

After the treating process, the number of population in different cases, where the educational background and age differs, is unambiguous.

Process of sampling:

Step 1: Divide the data in the dataset into five parts depending on the level of educational background in Task 1.

Step 2: Figure out the number of population in each education level and age group, which is regarded as the upper limit in each case.

Step 3: Generate a random number in one part, and judge which age group it belongs to.

Step 4: Determine if the capacity of the age group is up to the upper limit. If so, regenerate a random number; If not, the random data is regarded as an effective sample.

Step 5: Repeat Step 2 and Step 3 to fill each educational part and age group.

The flow of the algorithm can be seen in the Figure 3.

The distribution of sample:

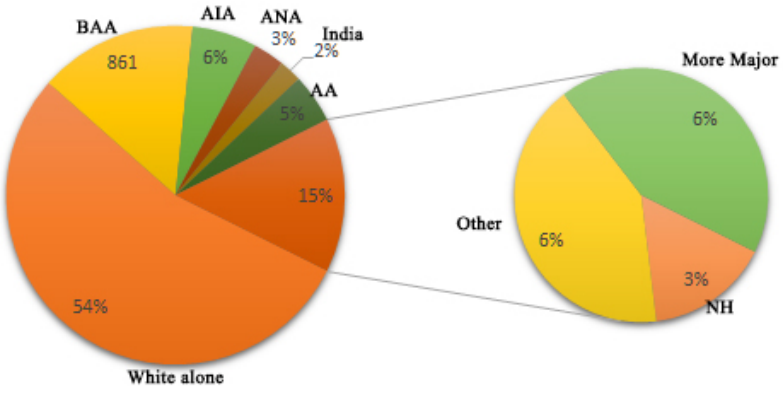

Figure 4: Distribution of race

The distribution of the race shows that there are many races of population made up of the sample.

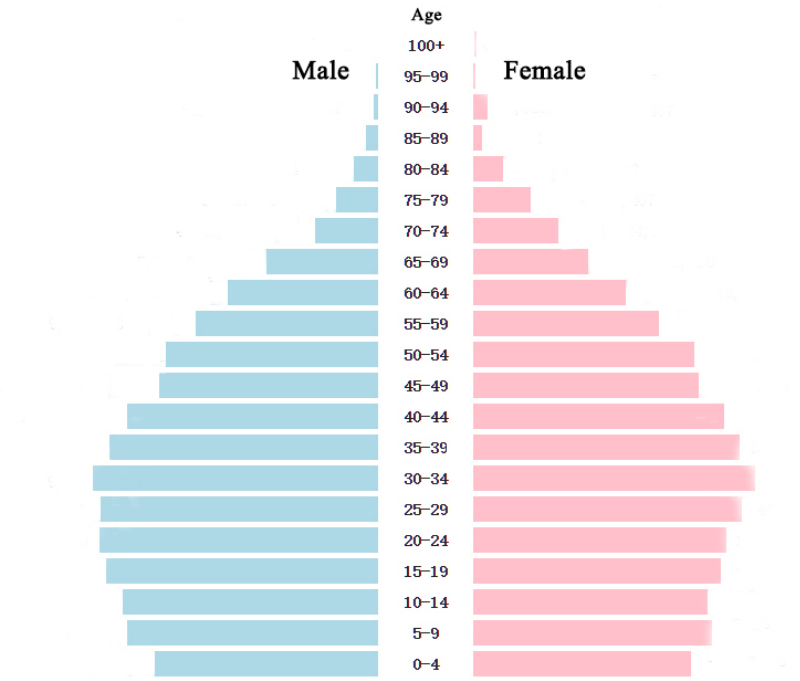

Figure 5: Age and gender distribution

The rates of the two genders are nearly equal, and the distribution of age is shown relatively.

5 Model Construction

5.1 Multiplex human social relationship network

Learning from the Local-world evolving network, describing the economic communication between counties, a multiplex network is utilized in the description of mutual relations. Then, we establish a multiplex human social relationship network based on the existing model. In the network, each node represents a person, and the sides between nodes show that there is some relation between the two persons, which can be relatives, friends, workmates and so on. In addition, everyone in the network lives not only in the complex world, but also in some local area, which is recognized to be formed by those nodes connecting with it. The algorithm building the network is that:

(1) Set 300 nodes and 1000 sides in the initial state.

(2) At the t_{th} step, a new node is inserted in the network. M nodes are chosen in the exiting network, which consist of the local area of the new node, connected to m sides ($m \leq M$). The ratio of prior connection is shown in the equation (13)

$$p(k_j) = \frac{M}{m_0 + t} \frac{k_j}{\sum\limits_{v_j \in LW} k_j} \tag{13}$$

There are some special characters of the network that are of great value in the extension of the multiplex model.

(1) ***Worldlet:*** Similar to 'Six Degree of Separation', the distance between two arbitrary nodes is finite.

(2) ***Node degree:*** Degree, describing how the node influences the whole network, is a basic parameter in the network topology. In this network, the degree implies relationships among the living circle.

$$C_d(v_j) = k_j$$

Where k_j is on behalf of the amount of nodes that connect with node v_j, which is called the degree of node v_j.

(3) ***Scale-free:*** As to scale-free network, the amount of some node degree is large, while some is small.

(4) ***Mediacy:*** It is the mediacy that measures how one node affects the information flow, on the basis of shortest path model. With the assumption that the network is made up with N nodes, then the mediacy of the network can be shown by the equation (14)

$$C_b(v_j) = \sum_{s<t} \frac{g_{st}(v_j)}{n_{st}} \tag{14}$$

In which, $g_{st}(v_j)$ symbolizes the number of the shortest paths between node v_s and v_t that pass the node v_j, and v_{st} represents the total number of the the shortest paths between node v_s and v_t.

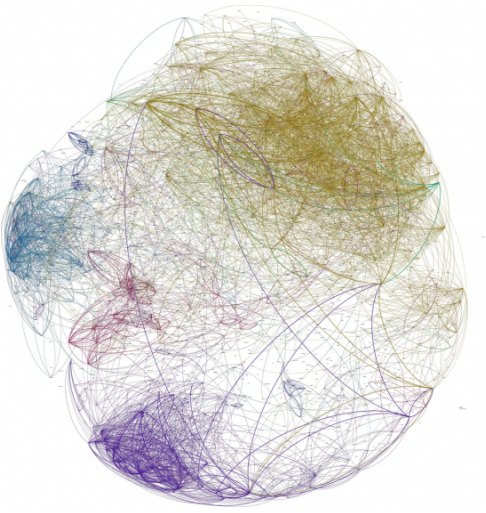

Figure 6: Structure of the network

Integrating attributes of the network, we assume that the larger the node degree is, the more contribution one makes to the society, and the condition of mediacy is the same as node degree. The contribution function is structured:

$$f(j) = \varpi_{j1} C_b(v_j) + \varpi_{j2} C_d(v_j) \tag{15}$$

The Entropy method is used to figure out the coefficient ϖ_{j1} and ϖ_{j2}.

5.2 Feature extraction of individual attributes based on the Deep Learning

We set up one-dimensional convolutional neural network, whose construction is shown in Figure(6). The first layer works as input terminal, and the following are convolutional layer-pooling layer-convolutional layer-pooling layer. Different convolution kernels are connected by vectors, and there is only one-dimensional output terminal linking totally. We select 30,000,000 data as examples from the dataset, and cut down some of the dimensions. After that, the useful data is of 160 dimensions.

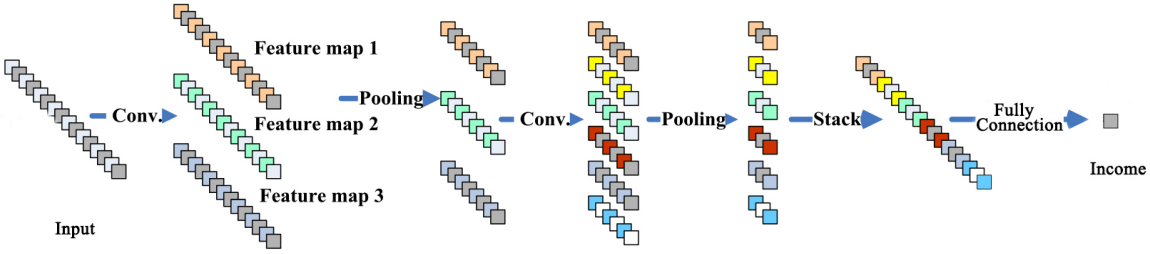

Figure 7: Process of convolution

A complete CNN stage contains a convolution layer and a pooling layer:

Convolution: The convolutional layer is introduced first. The value of a neuron at position x of the j_th feature map in the i_th layer is denoted as follows:

$$v_{ij}^{x} = g(b_{ij} + \sum_{m} \sum_{p=0}^{p_i - 1} w_{ijm}^{p} v_{(i-1)m}^{x-1-p}) \tag{16}$$

$$g(x) = \tanh(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \tag{17}$$

where m indexes the feature map in the previous layer ($(i_1)t_h$ layer) connected to the current feature map, w_pijm is the weight of position p connected to the m_th feature map, P_i is the width of the kernel toward the spectral dimension, and b_ij is the bias of j_th feature map in the i_th layer.

Pooling: Pooling can offer invariance by reducing the resolution of the feature maps. Each pooling layer corresponds to the previous convolutional layer. The neuron in the pooling layer combines a small patch of the convolution layer. The most common pooling operation is max pooling, which is used throughout this paper. The max pooling is as follows:

$$a_j = \max_{N \times 1}(a_i^{n \times 1} u(n, 1)) \tag{18}$$

where u(n,1) is a window function to the patch of the convolution layer, and a_j is the maximum in the neighborhood.

The training is consisted of forward propagation and back propagation.

As to the former, we select a sample from the sample set and calculate the predicted values. At this stage, the high-dimensional information is transported from the input layer to the output layer.

A cost function is necessary to construct the back propagation, which is computed on a mini-batch of inputs:

$$c_0 = -\frac{1}{m}\sum_{i=1}^{m}[x_i \log(z_i) + (1 - x_i)\log(1 - z_i)] \tag{19}$$

Here, m denotes the mini-batch size. Two variables x_i and z_i denote the $i_t h$ predicted label and the label in the minibatch, respectively. The i summation is done over the whole mini-batch. The ultimate goal is minimize c_0, which is achieved by mini-batch stochastic gradient descent. In this case, if c_0 is below the threshold, the network is recognized to be accessible.

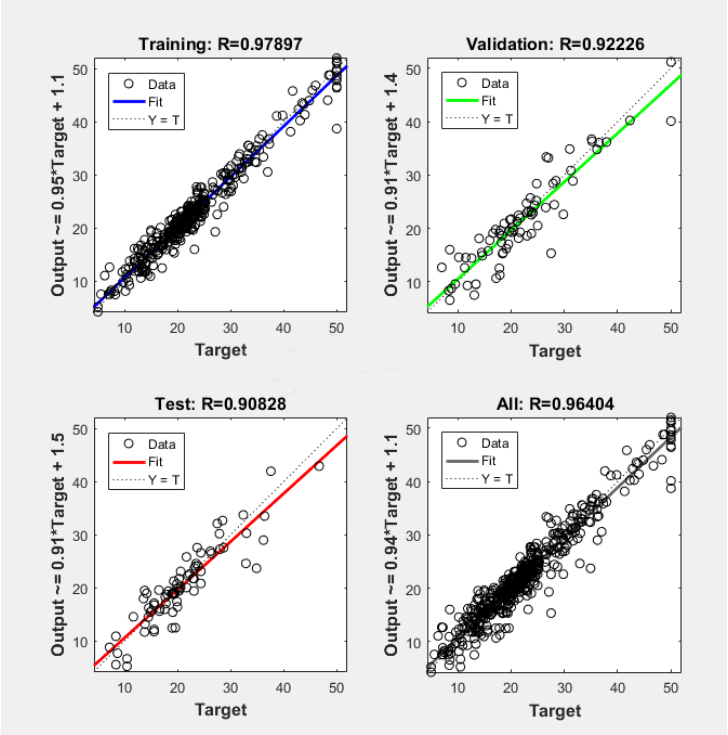

Figure 8: Regression curve

According to the theoretical analysis, when the points distribute among the straight line, the network is trained well. Combining the two pictures in the first column, the outcome is over fitting.

5.3 Social network partitioning based on Spectral Bisection Method

Spectral bisection method is a classic method for sectionalization. In our model, it is utilized to divided the population into two parts G_1 and G_2: one is made up of unskilled labor force, and the other is skilled labor force. The concrete flow of the method is stated:

Theoretical basis

For dividing the network into several parts on the basis of comprehensive factors, the Spectral bisection method comes into service. What we need to do is to build a Symmetric Laplace matrix L for undirected networks of N nodes, whose diagonal elements l_{ii} is the degree of node v_i, and other elements represents the relationship between node v_i and node v_j: if there is a side between two nodes, then $I_q = 1$, otherwise, the value is 0. The minimum eigenvalues of matrix is 0, and the feature vector corresponding to the value is $l = [1, 1, \ldots, 1]^T$. Meanwhile, other eigenvalues are equal approximately, which is the basis of Spectral bisection method.

Two general cases

As to one case, a network is made up of c independent communities, which have nothing to do with the others. Only among the community does the sides exit, and further, the matrix L is of c block diagonal matrixes. Each one of these is related to a community, and the minimum eigenvalues of it is 0.

As to the other case, there are a few sides between two communities, which hardly influence the distinction of different groups. The eigenvalues, whose value is 0, is little or no. It is obvious to choose some close to 0. The linear combination of feature vectors is utilized to find the diagonal matrix blocks.

5.4 Analysis of the model

5.4.1 Task 3: The best strategies

It is the income distribution and social welfare that the government get command of to maintain the equality. Through analysis, with the foregoing method for contribution, a fraction of people is of great contribution and a portion of people is of a little contribution, which may lead to income polarization. Thus, adjustment strategies following arise with the purpose of weakening the polarization. Our idea is to divide the social wealth into two parts. One part is used to ensure income distribution according to work, which means that one making more contributions deserves more income, and the other part is utilized to increase the support on those earns a little, who is likely to be of low labor capacity.

Population Development Model Based on Differential Equation

The Utopia is similar to a country, in which the population changes over time. It is apposite to establish a continuous model on birth and death in the approach of time. In order to study the population of different ages, the distribution function $F(r, t)$ is continuous and differential. And the population density function is defined on the foundation of $F(r, t)$.

$$p(r, t) = \frac{\partial F}{\partial t}$$

And $p(r, t)dr$ symbolizes the amount of people whose ages are among the interval $[r, r + dr]$. Similarly, the mortality rate is defined as $\mu(r, t)$. After theoretical deduc-

tion, the first-order partial differential equation of population density is affirmatory.

$$\frac{\partial p}{\partial r}+\frac{\partial p}{\partial t}=-\mu(r,t)p(r,t) \tag{20}$$

In the equation (20), there are two knowable factors, birth rate $p(0,t)$ and mortality rate$\mu(r,t)$, that can be found by analyzing the Population Zero. Substituting the two factors into the equation, the solution is :

$$p(r,t)=\begin{cases} p_0(r,t)e^{-\int_{r-t}^{r}\mu(s)ds} & 0\le t<5 \\ f(t-r)e^{-\int_{0}^{r}\mu(s)ds} & t>r \end{cases} \tag{21}$$

In the process, we set a time frame, where we start to track the transformation of population distribution. t years later, the value of population density differs in the ages: the value is determined by the initial density of population as to the older, while the value is influenced by fertility status and mortality rate.

No.1: Minimum wage and salary distribution

To build one-to-one correspondence between the node in the network and the individuality in Population Zero, the nodes are sorted by the value, and the individualities are by it. After that, we endow the nodes in the network with concrete attributes of population. Broadly speaking, the revenue and the contribution are positively correlated. Paying attention to the fact that that one making more contributions deserves more income, an adjustment factor $d(i)$ is added in the model, with which if one contributes little, his income will be lower than the value he deserves; and if one contributes a lot, his revenue will match the value he deserves.

$$d(i_1)=\begin{cases} 2-e^{-0.3i} & 0\le i\le 1 \\ 0 & others \end{cases}$$

$$d(i_2)=\begin{cases} 2-e^{0.693i} & 0\le i\le 1 \\ 0 & others \end{cases}$$

Normalization processing is needed:

$$f_1(j)=\frac{f(j)-\min f(j)}{\max f(j)+\min f(j)} \tag{22}$$

The social welfare which is utilized for primary distribution and redistribution isčž

$$I_1=(1-\nu\%)\sum_j I_0(j) \tag{23}$$

$$I_2=v\%\sum_j I_0(j) \tag{24}$$

The regulation factor on income regulation and control the total social wealth unchanged, which can be stated:

$$I_1(j)=I_1\frac{I_0(j)d_1[f_1(j)]}{\sum\limits_j I_0(j)d_1[f_1(j)]} \tag{25}$$

$$I_2(j) = I_2 \frac{I_0(j) d_2[f_2(j)]}{\sum_j I_0(j) d_2[f_2(j)]} \tag{26}$$

$$I(j) = I_1(j) + I_2(j) \tag{27}$$

When the value of v is between 5% and 40%, we can figure out the optimal value of v where the middle class account for the biggest proportion.

By computation, the minimum wage is 2,000 dollars and the each person's salary is figured out. Integrating the individualities, the distribution of income is depicted.

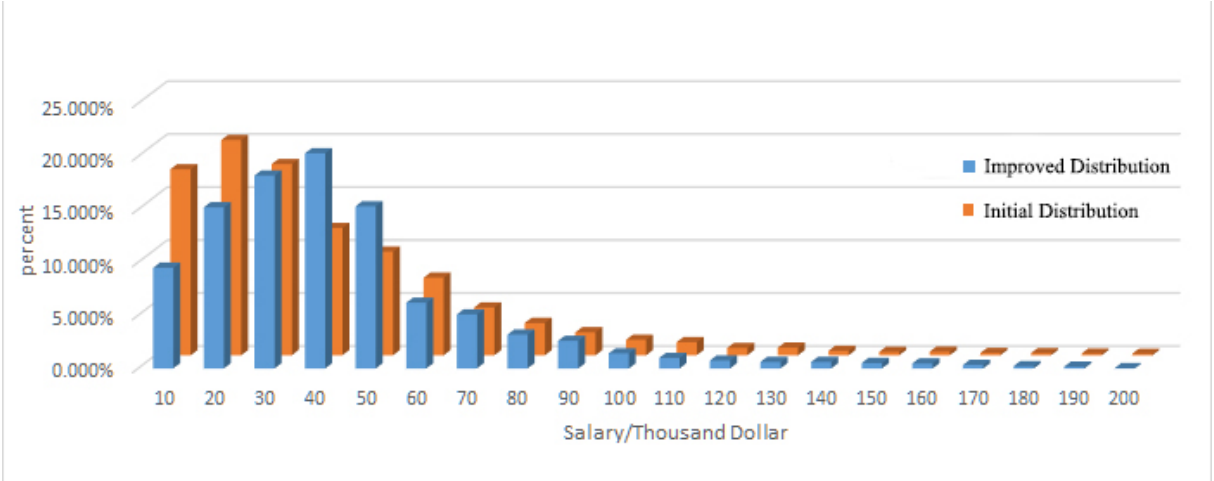

Figure 9: Comparison between initial and improved distribution of income

No.2: Paternity/maternity leave

Paternity/maternity leave influence not only the happiness of women practitioner but also the sustainability of the whole human society. With the combination of equation(7), birth rate, which has close connection with the happiness of women, is paid attention to attention. When the female is willing to have children, the birth rate increases; if not, the rate decreases.

$$h(d_w, d_m) = \alpha(p(0,t))[\varpi_{11} h(d_w) + \varpi_{12} h(d_w) h(d_m)] - [\varpi_{21} p(d_w) + \varpi_{22} p(d_m)] \tag{28}$$

Here, the value of α is defined as 1.3. By calculating the maximum value of the function, the best length of maternity is solved as 130 days, and the paternity leave is 20 days.

No.3: Childcare

When it comes to childcare, the government serves in two ways: one is the level of free education, and the other is the allowance for the growth of person. The total subsidy is composed by the expenses that the government cost for the free education and the allowance for the birth of baby. Assuming that the compensation for a newborn is A dollars, the number of the newborn is n_c and the birth rate is α, the government compensates An_c dollars for the fertility.

In addition, educational background has been divided into 5 levels in Task 1, and the relative injectant differs from each other: the free education for primary school is

E_1, similarly, the secondary school, university and the higher is E_2, E_3 and E_4. The total compensation for a person is $(A + E_i)n_c$ dollars, and the average compensation in each year educated is $(A + E_i)n_c/e_l$. As to the subsidy, people's happiness of it is similar to the income evaluating function, which is expressed in equation (1).

We assume that, if the free education advances for one level above, there are n_c persons whose educational background improves one level. Then, the income is figured out by the neural networks, comparing with the value which is worked out without improving the level of free education. By comparing the difference between the values and the average compensation, the worth of allowance is clear.

Taking the data in 2015 for numeration, the best strategy of childcare is that the government compensates 20480.4 dollars, and the level of free education provided by the government is elementary which represents the senior high school degree.

No.4: Relationship among the three identified factors

In a word, the three factors(income, education and equality) restrict each other in separate cases.

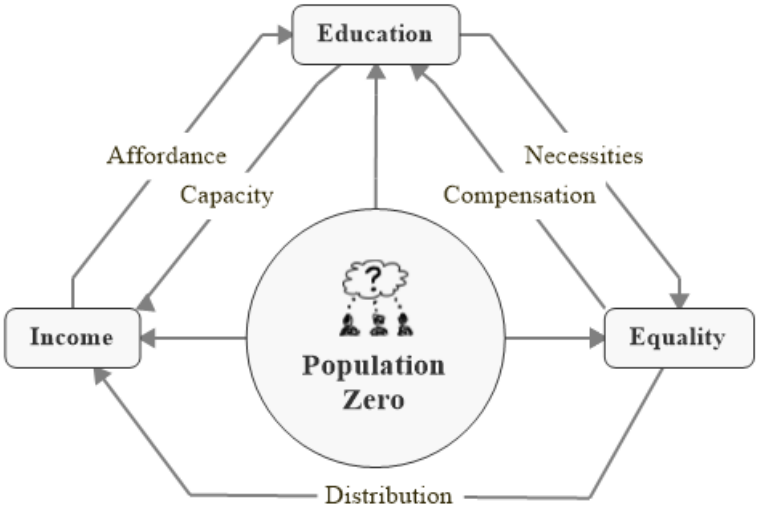

Figure 10: Critical independencies among the three parameters

5.4.2 Task 4: Operations of subgroups

Evaluation of individuality and subgroup

After the population has been sectionalized into two groups, we establish a satisfaction model, of some new parameters which evaluate the priority in their life, to appraise the happiness of lives. Focused on one individual person, five attributes(income, educational background, childcare expenses, level of free education and maternity/-paternity leave) are involved in the satisfaction model. To unify the dimension, each

parameter ought to be normalized.

$$\begin{cases} x_{n1} = [I(j) - I(j)_{\min}]/[I(j)_{\max} - I(j)_{\min}] \\ x_{n2} = [l_e(j) - l_e(j)_{\min}]/[l_e(j)_{\max} - l_e(j)_{\min}] \\ x_{n3} = A \Big/ (1/5) \cdot \widetilde{I(j)} \\ x_{n4} = [i - i_{\min}]/[i_{\max} - i_{\min}] \\ x_{n5} = \varpi_{11} h(d_w) + \varpi_{12} h(d_w) h(d_m) \end{cases} \tag{29}$$

How much each parameter works on the satisfaction of one person is reflected from the weight separately. Meanwhile, the rank of the weights are regarded as the priority of the parameters. Based on the social psychology that human live in groups and the attribute of his group affect his acknowledge, when a person lives in the environment where others earn a lot of money, he is hardly content with limited revenue. When it comes to the other parameters, the thought is a basis guiding the elementary establishment of the model.

$$\begin{cases} w_{k1} = \dfrac{\frac{1}{N_1} \sum\limits_{j \in G_1} f(j) + \frac{1}{N_2} \sum\limits_{j \in G_2} f(j)}{\frac{1}{N_k} \sum\limits_{j \in G_1} f(j)} \\ w_{k2} = \dfrac{\frac{1}{N_1} \sum\limits_{j \in G_1} l_e(j) + \frac{1}{N_2} \sum\limits_{j \in G_2} l_e(j)}{\frac{1}{N_k} \sum\limits_{j \in G_1} l_e(j)} \\ w_{k3} = \dfrac{I(j)_{\min} + I(j)_{\max}}{I(j) - I(j)_{\min}} \\ w_{k4} = \dfrac{l_e(j)_{\max} - l_e(j)_{\min}}{l_e(j) - l_e(j)_{\min}} \\ w_{k5} = \dfrac{I(j)}{I(j)_{\max} - I(j)_{\min}} \end{cases} \tag{30}$$

Then, the satisfaction of one resident is defined as:

$$S(j) = v_{k1} x_{n1} + v_{k2} x_{n2} + v_{k3} x_{n3} + v_{k4} x_{n4} + v_{k5} x_{n5} \tag{31}$$

In which, the weights are normalized by the equation $v_{ki} = \frac{w_i}{\sum\limits_z w_z}$. The satisfaction of the group is defined as the average of the individualities'.

$$S_k = \frac{1}{N_k} \sum_{j \in G_k} S(j) \tag{32}$$

Majorization design for the greatest outcome

According to the foregone model, unskilled workforce is not satisfied with the income, meanwhile, the skilled practitioners pay more attention to the maternity and paternity leave.

To improve the satisfaction of the former, we decide to slightly enlarge the proportion of redistribution among the social wealth.

To ameliorate the latter, a method called 'partial paid maternity' is built. In which, if the length is shorter than the threshold, the holiday is paid by the company; however, when the length is longer, the original revenue of the work is deducted, and the amount is ζ times as many as the earnings. ζ is a function of time t:

$$\zeta = \begin{cases} 0 & 0 < t < a \\ \frac{1}{m-a}(t-a) & a \leq t < m \end{cases}$$

Where a represents the maximum length of the paid holiday. There are two extreme conditions as to the distribution of ζ: one is that the maternity is considered as paid-leave when the length is shorter than a, and the other is that the deduction of earnings is up to original income. Without significantly reducing the global outcomes, traversal method is utilized to achieve the maximum gross national income after the trial of all the combination of a and m, where we assume that the concrete gross national income is higher than 99 percentage of the original value.

As to the 'the best strategy' formulated in Task 3, the score of satisfaction that unskilled labor force made is 0.56, while the skilled group is 0.87. Based on this outcome, the satisfaction of skilled labor force is greater than the unskilled, which meets the reality. Taking each factor into consideration, the unskilled labor force is the least satisfied with income, the value of which is 0.12; the skilled labor force pay more attention to the maternity and paternity leave, the value of which is 0.26. Thus, the model built in the Task 3 need modification for different groups.

6 Sensitivity Analysis

6.1 Task 5: Additional migration

Sensitivity to population demographic

The demographic distribution of this population is changed by the new migration in a sudden, particularly in the distribution of education. We construct the several distributions of educational condition, whose Pearson correlation coefficients with the ideal distribution is separate. Then, the average satisfaction can be quantificat. Due to the average level of education influencing the satisfaction, we analyse the two situations dividually.

Table 1: Satisfaction under the condition that educational level higher than ideal value

Correlation coefficient	0.93	0.7	0.5	0.3	0.1
Satisfaction	0.78	0.73	0.69	0.55	0.21

Table 2: Satisfaction under the condition that educational level lower than ideal value

Correlation coefficient	0.93	0.7	0.5	0.3	0.1
Satisfaction	0.78	0.80	0.81	0.78	0.77

In the two tables, as to the group whose average educational level lower than ideal value, the group's satisfaction is influenced seriously by the correlation coefficients. The lower the correlation coefficient is, the less content the group is. However, regarding to the group whose average educational level higher than ideal value, the group's satisfaction is influenced slightly by the correlation coefficients.

Transformation of the model

As to age, when the immigrants arriving, some changes take place on the distribution of age. However, two requirements are needed to meet:

(1) **Avoiding the aging of the population:** The percentage of those whose age is greater than 60 years old account for 10% and those elder than 65 years old occupy 7%.

(2) **Guaranteeing adequate workforce:** The number of the youth whose age is between 25 to 45 years old is enough to create sufficient fortune in order to ensure the operation of the society.

The population development equation is used to predict the distribution of age among the population. We assume that three migrations come up during 2100 to 2200 which is in 2130,2160 and 2190. Take the migration in 2130 as an example, the distribution of age is figured out on the basis of Equation(21).

The outcome shows that the aging of the population occur. The LIFE ought to encourage the birth of babies by improving the compensation for newborn and extend the maternity and paternity leave.

Sustainability of the project

In the population development model, the mortality rate is regarded invariable in a short time. To adjust the parameter, we set up a prediction model based on the Time series analysis, in which we figure out the actual mortality rate every ten years. While the forecast period does not exceed ten years, the value of prediction is given directly; On the contrary, while the period is more than ten years, the process of prediction is divided into several steps, and each of the step is less than ten years.

Besides, the average level of educational background improves with the development of society. Considering the influence from the approach of time, the distribution of education turns into a dynamic process.

6.2 Task 6: A much larger scale migration

When it comes to a much lager scale migration, they are likely to immigrate at one time or at several times. The two conditions have different effects on the society and the individualities.

Regard to the former, we exceed the amount of the population up to 50,000, 200,000, and 500,000. Referring to the process of solutions in Task 4, the influence that brings by the changes of scale is figured out at the aspect of integration and individuality. The information that we learn from the table is that our algorithm for sampling is of great

Table 3: Satisfaction of different scales

Scale	10000	15000	20000	25000	30000	100000	200000
Satisfaction	0.78	0.75	0.82	0.82	0.77	0.76	0.74

robustness. With the extension of the migration scale, the score of satisfaction changes slightly. Due to the limit of time, the maximum scale we study is of 20,000 population.

For the latter, the process in Task 4 is repeated after making bold assumption that the initial migration happens in 2100, and the next migration may come up in 2130 or 2160 or 2190. Taking the three conditions into consideration, the weaknesses and strengthes implicit in the evaluating parameters.

Table 4: Satisfaction of different process of migration

Year	No	2130	2160	2190
Satisfaction	0.78	0.75	0.79	0.73

What we can see in the table is that different stages of processes almost have nothing to do with the satisfaction, which indicates that our model is not of great sensibility and it can be utilized under varieties of background.

7 Model Extension

In African Savannah, there are a variety of animals which constitute a splendid animal society. It is interesting to study the animal society with the method used in human society.Now we will introduce the multiplex human social relationship network established by us to describe the animal society.

In an animal population, the connections between most of ordinary animal individuals are much fewer than those between the leaders and other individuals, which result in the scale free phenomena in the corresponding network. Meanwhile, modularity structure also exists because different populations have fewer connections than those within a population. In the network, different communities which correspond to different animal populations can be partitioned by spectral bisection method. The method is also the same as which is used in the human social network. The degree and mediacy also have the ability to distinguish the important animal individualities.

8 Strengths and Weaknesses

8.1 Strengths

(1) The high-dimensional and nonlinear characterization of the data is extracted by Deep learning effectively, and then the accurate prediction result is obtained.

(2) Based on the local world evolution model, the multiplex human social relationship network has the characteristics of locality, small world and scale-free, which can reflect the real society.

(3) The model, of multi-layer structure, has good scalability and dynamism.

8.2 Weaknesses

(1) The network model has higher algorithm complexity than the simple model.

(2) Convolution neural network may lead to overfitting, which is hard to be avoided.

Task 7: Policy Recommendation

As to income, our idea is to divide the social wealth into two parts, and the percentage of them are 90% and 10%. One part is used to ensure income distribution according to work, which means that one making more contributions deserves more income, and the other part is utilized to increase the support on those earning a little, who is likely to be of low labor capacity. The compensation from the government ought to be set to afford the necessities.

When it comes to education, it is the money and the infrastructure that is offered by the government to benefit the society, which evolves into the policy of free education and professional education:

- **Free education:** We suggest that the money is utilized for free education, which is based on the fact that if the free education advances for one level above, the average educational background in society improves one level. In new-built manufactured cities, the development of human society has close connection with the capabilities that the new comers equipped. And the skills for work scarcely get rid of how well he educated. The ideal level of free education under the background is senior high school degree.

- **Professional education:** In addition, the labor force are divided into four parts: those engage in educational work, technological invention, the production of necessities and management.Taking the reality of the city into granted, the infrastructure, which consists of the allowance for project, the construction of the corresponding educational system and so on, is built on the basis of the different attributes of each fields: those taking part in the education work ought to be of high cultural background. Thus, the support of education aimed at this field is superior to those work for production of necessities and management, and among the fields, the most allowance should be put into technological inventor.

Equality is the foundation of social stability. In our opinion, the satisfaction of professional women is the most significant parameter, which should be cared for at several aspects:

- **Avoiding employment discrimination:** In reality, the female is underrepresented or discriminated against in many fields on Earth. Our idea is to reduce the employment discrimination at two aspects. One aspect is to guarantee that the income of the women is even more than the men who do the same work with the female. The other aspect is to impose restrictions that the gender distribution is ideal among the company, particularly in the fields of industry engineering.
- **Providing suitable maternity and paternity leave:** The length of maternity and paternity leave influences the satisfaction of work both in physic and psychologic. Based on the fact that the longer the holiday is, the larger the value of the function is. Two extreme situations must be paid attention to.One is that if the length of the holiday is so short that she is hardly content with the status; the other is that if the paid leave is rich enough to recover and take good care of baby, the length impacts a little on her life. According to the model we establish in the solution, the best length of maternity and paternity leave is 130 days and 15 days.

In order to improve the equality, childcare expenses should not be ignored. When the income of a family is high, they pay little attention to the allowance from the government. On the contrary, if the family earns little, the government is suggested to offer more compensation. We suggest the government to enact the policy on childcare depending on the differences of family.

Broadly speaking, our policy is slightly influenced by the size of Population Zero, which has been verified by our model. The smaller the population is, the slighter the influence is. Meanwhile, the changes of population composition contributes little to the policy as well.

What we want to stress is that the policy is of decent stability, which can be ensured that the new-built city operate healthily. With the help of our suggestion, several outcomes will be seen:

- The unskilled people have the capability to afford the necessities, while skilled people achieve the salary according to his work. The polarization is reduced in a certain extent.
- The average level of educational background is higher than the original situation.
- Women share the similar resources to the men in work, which inspires the enthusiasm among the society.

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