

Introduction of System Dynamics in Urban(Regional)Coordinated Development Planning

Wei Hongsen (Tsinghua University, Beijing, China)

Abstract

This article presenting a summary and analysis of the theory and method of System Dynamics on the author's experience in planning of the coordinated development of science, Technology, economy and social advancement in such cities as Beijing, Harbin, Anshan and Baotou, is aimed to find out the advantage disadvantage of the S.D approach to urban planning as well as to improve upon it.

System Dynamics which is considered in this article to draw on system theory, information science and cybernetics, especially the feedback control principle and computer simulation, is a scientific theory and method that can find an effective application to improving and planning a multi-factor, non-linear, dynamic and/or complex system, and also a laboratory that can verify the social economic policy or strategy. In actual planning of coordinated development of the Chinese cities and regions, S.D is found superior in six(6) points while left five(5) respects to be desired, so the idea of establishing the S.D.-dominated comprehensive model system is thus developed to enhance and strengthen the above planning process.

I. General Principle Of System Dynamics (S.D) In Regional Planning

S.D is mainly applied to modeling and simulating process, Through analysis of which the feasible program and advice for policy are provided. The following principles should be observed in practice.

1. Actual problems should be stressed.

The establishment of object and boundary must take into account urgent problem involved in the regional planning. To facilitate modeling those necessary important points must be stressed and specified.

2. Combination of qualitative analysis with quantitative study

It is positive to set up the proper relationship between qualitative analysis and quantitative study. Qualitative analysis is the basis of quantitative study while the latter makes the former stand well-ground, thus making qualitative analysis much more conform to actual conditions. They are dialectically related.

We must be fully aware that quantitative study is more accurate and correct than qualitative analysis in exposing real problems. Because qualitative analysis is characterised

by intuition and completion and fussy knowledge when applying is a multi-factor dynamic and complex system. If so, subjectivism will prevail. On the contrary S.D approach which features problem-oriented gives various hypotheses and simulate the real process through modeling by means of computer-aided facility. This method can make complex system clear and reflect real conditions, also can change policy or parameter through decision-maker to computer communication, thus having the qualitative analysis and qualitative study well connected and combined to effectively solve the actual problems, free of those errors caused by subjectivism, intuition or sensational change.

But we should not deny the function of qualitative analysis on modeling in regional planning. On establishing S.D model, we must fully attach importance to the method of holding the law of things by experience intuition and object. But for, we should not correctly establish the better model of system analysis. on modeling, we should at first have a rough dim and un-quantitative logical model in brain. Secondly we should make this as reference-point and dynamic guide thinking so that we can the problems much clearer and formal quantitative-studying model.

3. System structure determine system function

system constructure is in mutual relations and mode in space time among every element of system; it is a internal ground that makes system be a entirety and have some function; it is a essential mask that makes a system different from other system. function is system's order and ability that system exchanges matter energy and information form environment. It is exterior manifestation of system constructure. So system construction is the order of mutual effect of elements in system, is interior description of system. Function is the order of system process acted on surroundings, and is system exterior description. A structure has a function. If a system will have a special function, we must design and construct a special constructure that can produce the function. To some degree, regional planning is to find a optimum constructure, and to obtain the best effect. That is to say, according to regional condition, in order to achieve better effect, better function, we should adjust new relations between every element so that it could be the better in space and time state and could find the better economic constructure. It is regional planning that draws up concrete programme for the optimum constructure that can give full play to the best function.

4. Objective reality system is main basis that tests truth and effectiveness of model

On establishing model it should approximate to real system behavior at best. When setting up parameter constant and dimension, it should reflect and approximate to real system. We must not preoccupy supposition linear and stability for the real system does not have the nature. On collecting and dealing with the data we should have real and reliable data. On establishing model, we should test it with real system behavior and develop and perfect it in practice to make it solve correctly the real behavior of objective system.

Features system dynamics on regional planning

On regional planning, we find that because of various reasons the history statistics data is brought about in fragments and because it is on the course of unceasing trade varies and of industrial constructure adjection, it can not make statistics meet the requirement. It has the more difficult in obtaining specimen or sample and data of the longer term especially in manufacture's economic, science-technology, social well coordinating problem for it involves all trades and professions and various factors that are complex and different in dimension and have many difficulty in converting them. In these fields we must deal with a large number of un-linear problems. If it is solved by economic and Input-Output analysis, there are many difficulties that could not be exceeded. On dealing with this kind of multi-factor, dynamics, non-linear complex system problems, system dynamics as to the above method.

1. Supporting system model is not only data. It is at first its structure system interior causality.

Based on the principle of system constructure deciding on function, the behavior of real system is all defined by its constructure of mutual reaction and mutual connection among system elements. By means of this, we can conveniently obtain the most mainly information from complex dynamics behavior system, and make study approximate to objective reality. While the traditional quantitative model is supported by data. In Harbin Economic-Energy-Surroundings Model research, apart from data to be insufficient, unfull and incorrect, we also find that data laging phenomenon is not excluded, especially high-grade system such as economic and ecosystem that data-shortage largely limits applying scope and applying effect of general quantitative modeling method so that it the applying of quantitative economic and Input-Output analysis impossible. On applying S.D, we can obtain necessary information from causality-feed back relationship and establish model and find out the constructure that reflects in interior relation of real system. This can largely reduce the requirement for data and can conclude quantitative study result or practice conclusion that is obtained by the combination of qualitative analysis into quantitative study, we call this feature as structure. It is very important to city and regional planning at the present statics and data information level of my country for it can largely save time and cost.

2. By simulation method, to better solve non-linear problems

The man who establishes model to solve actual problems has realized the actual system is mostly non-linear, especially gigantic complex system such as Social Economic Ecosystem. Because we have not found out the more effective method in mathematics that can deal with these non-linear problems, we have to make these problems change into linear problems to be solved. The concession of method result in corresponding concession of truth accuracy reliability. This concession can inadequately keep to the simple system. But if we should still apply this simple method, it should bring about the more harmful result to the solving of gigantic system such as Social Economic Ecosystem. We often consider coordination developing problem of gigantic system such as science and technology. Economic, Social and Surroundings, now we are faced by real task of coordination

development of Economic, Energy and Surroundings. We do not make a detour of non-linear stage entirety dealing with the complex non-linear system. This has led to much trouble to quantitative economic and Input-Output Analysis. By means of S.D, the actual system can be defined as the combining system of multistage feedback loop. With the combining of qualitative analysis into quantitative study, we can easily handle this kind of non-linear problems. Instead of being solved by mathematics calculating but by simulation we can make this kind of problems more appropriate handling as effective to solve non-linear problems.

3. Intuition and image when solving problem

With S.D, the problem to be solved can be formular. According to feature of problem, its elements can be respectively represented by information flow and matter flow and currency flow, and can be consisted to a organic entirety by system interior mutual connection. This can avoid shortage in the past by dealing with the problem with isolating these systems. While by the other middle methods, it can solve the difficulty of the transformation of different elements when applying general methods. Compared to Input-Output analysis, it has a peculiar advantage. Based on this advantage, it could make the research man listen to suggests extensively, make logical model approximate to real system. At the same time, when we have converted logical system into the special purpose flow model of S.D, the concept of the original large extension, elements is further distinct and we have decided that every element is which kind of variable such as level variable such as level variable, rate variable, assistant variable and so on. Up to now, the relationship pattern between elements is further distinct. The limited factors of logical model now could be considered and unnecessary factors could be removed. When we have written DYNAMO Language procedure model based on flow-picture, this language itself has the function of looking for error, so it can make us eliminate every kind of error in form. When the procedure model has been passed translating and editing function we can most intuitively, imaginably see how the model approach to the property of the real system.

4. Have policy-test and social-test and could give full play to the people's subjective activity

Because system dynamics has adopted the method of information and feedback method, it easily brings into desire value information of state variable on establish model. The different desire value has different result. This opens up the way to make science experiment like science on solving economic and social problems. Compared to the input of different policy to desired value. We could adjust policy to achieve a certain aim. The problems of being destructive and risk that are inconveniently tested can be tested by system Dynamics model. We call this character as experiment. This is the most important character compared to any other methods. New printed DYNAMO software (for example PD-PLUS) also has the functions of two parameters of value-modifying and picture-modifying and has provided as advantage to do lots of simulation tests and give play to our subjective activity. For we can depend on the form of "if-then" by S.D method to give full play to researcher's imagination to study the system behavior in different states and can systematically attain different results to find out the better policy and

policy making programme and to forecast the result of the carrying of the programmes.

5. S.D is deep and broad in analysis of middle- and long-term strategy

S.D is not only applied to solving the problems involved in science and technology, economy and society in a macro way, e.g the general trend of macro-economy, the proportional relation between accumulation and consumption relation between accumulation and consumption, population, the changing trend of labour, but also employed to study the production in an enterprise, inventory, sales in a micro way.

S.D is found to be much effective to analyse macro-economy. Science-technology and society, especially the general trend of the system behavior in the middle- or long-term period. It can also be used for analysis of short-term behavior (3-5 years), middle-term behavior (10-15 years) long-term behavior (more than 60 years). The longer the term is, the more accurate the result is, e.g the Globe Strategy Study made by Dennis Meadows.

6. Person-to-computer connection is easy for communication

As S.D is a set of systematic methods and equipped with a set of formative graphs, specialised advanced language and other software, the real problem program is found to well conform to the dialectically-meditated law and very easy to use. This method also featured intuition, free of mathematical formula or inductive inference, it is easy to conduct person-computer communication, thus making it no difficulty in communicating of the researcher with the enduser, because the cultural quality of the chinese users have been well considered. This method is worth popularizing.

The limitations of S.D Method in Regional Planning

When practically applied, S.D is also found to be limited in some respects as other methods will, so this approach is left to be improved. Some limitations are given below.

1. Mathematical and Economic Theories are not provided in Regional Planning

If S.D is economy-science and technology-society-oriented, mathematical or economic theories must be provided to guide. But S.D is found to fail to give them. As we know, theory varies according to different model-makers, so there is sure to appear subjectivism. Further-more, when studying the co-ordinated development of a nation, some economic policies must be involved. While mediating economic. Science-technology, society model, the nature of feed-back ring is difficult to determine. We must be aware that the special aspect of a real fact should be well-analysed, otherwise there is no reliability.

2. lack of a set of scientific and all-round standard system

When considering the co-ordinated development of a nation in economic, science-technology and society, there must be a set of scientific and all-round standard, by now we have not worked out such effective standard system, and S.D itself can't give either. So the result obtained by S.D lack of such assessment standard which means in this two aspects: a) whether a region is in co-ordinated development in economy, science-technology and society; b) whether the measure given by S.D is correct. Thus, we have seen that the objective system established by S.D often lack "co-ordinated", this is a

vital weakness and difficulty. Under such condition we have to stay at the level of "objective study" or "imaginary experiment".

3. Subjectivism involved in the description of system structure

One basic point for S.D is "system determine the function". S.D is used to study the input-output function by describing the economy-science and technology-society. If the description is found to be wrong, then it means the basis is destroyed.

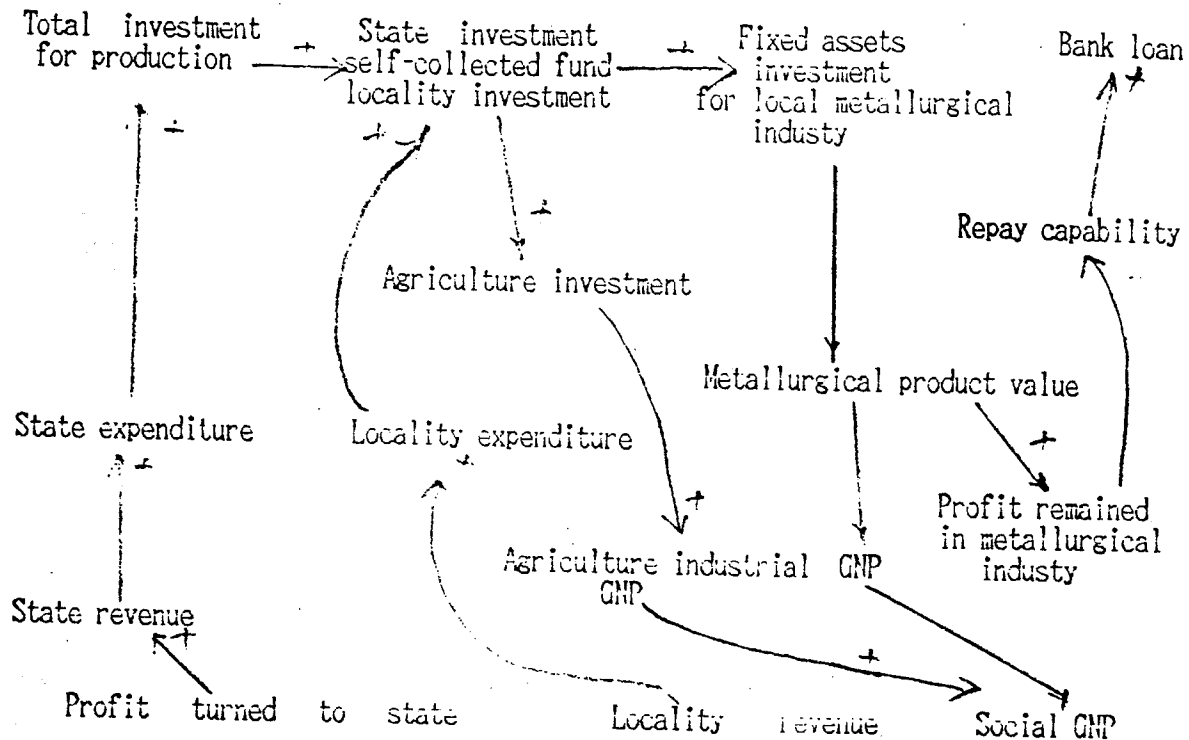
The subjectivism involved seems to exist in two ways: one is that different description of one system may appear due to different model-maker, the other is that subjectivism may be involved in determination of parameter.

Subjectivism involved is owing to the fact that the model-maker adopted different scientific method to different problems. So we say scientific feature still prevails the subjectivism.

4. Multi-stage feed-back is not solved in practical process

As we know economy-science and technology-society is characterised by multi-variable, non-linear, dynamic, multi-stage feed-back, time-lag etc. But, S.D approach by now have been found to fail to solve these problem, sometimes many multi-stage feed-back problem can't be well solved in practical process.

In fact, we have noticed that it is impossible to study such multi-stage feed-back problem, due to the fact the investment contributed by the state is not determined by the amount of profit turned to the state, this is because the economy in China is dominantly a planned one, the market-oriented economy is imbalanced, the effect of "lever" is not tangible, and even sometimes just on the contrary. This means the investment is of "random" quality. So we think it may be feasible and suitable to well apply this S.D approach in the western countries. While in a country with planned economy, such problems can't be solved by considering the feed-back ring.



5. S.D can't give the optimal solution

One advantage of S.D is that it can simulate the social giant system, i.e, it can actually imagine the future development economy, science-technology and society, e.g, if we want to make simulation experiment of the development of economy, science-technology and society in 2000, we must before hand determine the future system structure in 2000, and decide on the input into the system in 2000. To meet these must be some "pre-policy" as a reference and some knowledge of structure parameter. These two requirements mean that S.D shall be applied in combination with other quantitative method. Even though these two requirements are met, S.D itself can't provide the optimal solution in the sense of theory.

S.D can give many results for us to make choice, so the decision maker is the master.

6. S.D gives strategic guide instead of specific advice

Regional Planning is a general behavior, S.D can only give strategic guide and policy advice. But macrocosmic behavior is never isolated. So in practice work, we should not only

study the past, present and future of the social macrocosmic behavior, but also consider the environmental macrocosm and micro-mechanism. S.D is theoretically possible, but no precedent has been set by now to study and connect the above three factors. Here we can conclude that S.D theory is at variance with practice.

When S.D is applied in the analysis of economy, science-technology and society, we, in fact, needn't consider what product is to be made in the economic subsystem, nor consider the fluctuation of the demand and supply of markets, instead, we regulate the investment policy to adapt to the actual conditions. In the same way what we need to do in the science-technology sub-system is to analyse the researcher proportion in total numbers and research result and comprehensive factor.

Practically, science and technology can be improved by introduction of technology or development of technology, or by both, but the proportion of the two elements is not well analysed, because it is difficult to give a proper standard system. If so, a question will arise, what is the best standard system? How to make the best use of the local resource? We think that technical economy revolution as well as economic theory guide is importantly needed when S.D is applied in tapping and developing resources, it is found to be a weak method, but it can be complemented by regional CDESS.

7. S.D is impossible to solve the chaos and mutant matters in economy, science and technology and society system.

Although S.D is effectively applied to studying non linear, dynamic, multi-stage feedback, it is found to be weak in solving chaos and mutant matters in social giant system, e.g, sharp price-rise buying spree, bank run railway accident, and social riot etc. As we know that there must exist some pre-conditions for chaos i.e non-linear system, entropy increase and fluctuations, etc. So S.D is ineffectual in determination of social entropy. Some complex phenomenon may exist in economy-science and technology-society system, but the complex reason may go beyond this system. Superficially, this problem is not within the CDESS, in fact, we have to face a new challenge. We should see the problem in a view of openness. In this circumstance, the result is only an approximation to the real complex social giant system.

Some knowledge gained in comparison

1. Qualitative analysis must be combined with quantitative analysis

Regional planning is associated with the co-ordinated development of science and technology, economy and society, and there are many sub-systems in the system concerned. So there is no specified quantitative method that is available. Practically, we must employ qualitative method which is the basis of quantitative method to ascertain the actual condition. Because only to the bottom can the model reflect the system behavior. For the co-ordinated development of science-technology, economy and society, qualitative analysis is considered as an very important way to accurately make the planning model and to correctly reflect the system features. As is known, quantitative method is only a mathematical approach in the abstract, when practically used, it has been simplified to

approximately reflect the object system so, this method is not sound or perfect.

As a matter of fact, qualitative method can be a complement. qualitative method which is of intuition may be practised upon to make rough estimation and analysis. In the case that there is much difficult to study by quantitative method, qualitative approach is found to be effective. But quantitative method is systematic, comprehensive, accurate to reflect the inter-relationship among all elements. And the modeling process can deeply reveal the potential contradiction and system behavior to make people well understand the system.

As is stated above, we can conclude that quantitative and qualitative approach should complement each other.

II. Select a proper model method according to the characters, conditions, necessities and goals of different regions

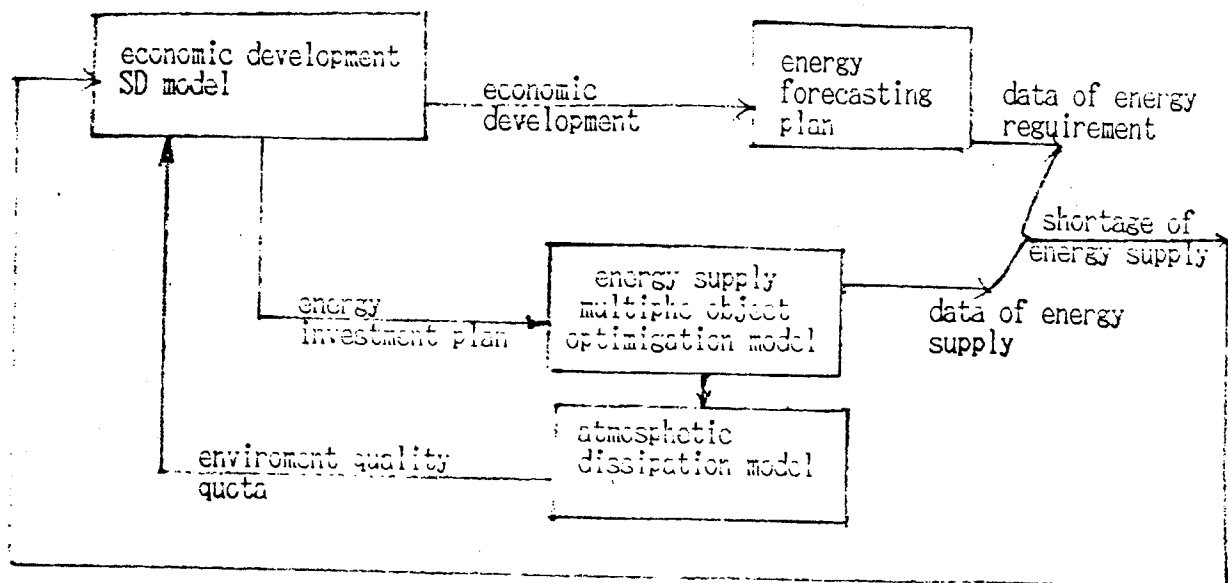
model method is a quantitative method applied more widely in regional planning today. I have analysed and compared several methods above, which have applying conditions and advantages. We must select it according to the characters, conditions, necessities and goals. If we want to study the economic action in the near future, the data being completed and accurate, we can select a quantitative economic model. We have the knowledge from studying Harbin economy-energy-environment model. Harbin is a older industrial city. Industry is of vital importance. Enterprises have been lead by government but industry. Project study requires division of industry in Harbin according to the state standard. But the obtained data is not fit to the state standard which have a great restriction on selecting quantitative economic model. System dynamic method, which has advantage of representing system structure, is lower in accuracy of data and effectiveness of sample term. So we select it. Practice demonstrates it available. We realize that most cities in china, especially heavy industry cities, are changing from government administration to industry administration. It makes the requirement of production statistics change greatly. It is difficult to get statistic data conform to the state standard in long term. This limits the application of Mathematic Programming and Quantitative Economy. So we select system dynamic method in planning Anshan city and Baotou city. System dynamic must not be selected in any situation because it has some limitations. It is not accurate in short term planning. It is no more accurate than others in middle and long term planning. So we can select it according to region, time, and condition. We think that we had better select Input-Output Analysis to make planning of a province or a city. It can help to collect a lot of basic data which lay foundation of the planning in the future. Then, it is more accurate and effective to use System Dynamic to study science and technology, economy and society coordinated development. Input-Output Analysis is widely applied in regional planning in these aspects:

1. To analysis regional economy
2. To forecast and planning the development of Macroeconomy
3. To simulate a complicated policy

III. Make the comprehensive model system to bring the function of every model method into full play in regional planning

Regional planning deals with a wide range of actual issues. Different problems are solved depends on the use of differeny qualitative and quantitative method. Form the content, it should include economic model, science and technology model, social developmant model, population model, ecology model, enviroment quality model, education model, labour force model, living quality model, etc. In a word, it is a social system engineering related to the region. It is required to reveal the mechanism and rule of development of social giant system. An effectire theory and method has not been given. Different model method is used to satisfy the requirment of different regional planning in the practice. As mentioned above, an Input-Output model is used to make sure the economic proportion in all sectors of the region. A quantitative economic model is used to represent the development quantitative relations of all nation economic sectors. A optimal control model is used to optimize some economic problems. A system dynamic model is used to solve middle and long term development tendency and to do the test of science and technology, economy and society coordinated development. A system evaluation model is used to evaluate objection, etc. In order to overcome the short coming of different method, we should use all methods comprehensively to bring the advantages of all methods into full play. So we can study the mutual relationamong science and technology, economy and society and represent their internal operation mechanism. We use these kinds of msthods to solve three kinds of problems in Harbin economy, energy and enviroment coordinated development. then, we have three methods combined to form what is called the comprehensive integrated model system, i.e. We use system dynamic model to solve the problem of economic system, use energy-supply-multiple-object-optimigation model to solve the problem of energy, use atmosphetic dissipation model to solve the problem of enviromental quality.

We do the first attempt to link the system dynamic model and others in the study of Harbin economy-energy-enviroment coordinated development. Professnal DYNAMO Plus gives the necessasy technical means to complete linking, The sketch for model linking indicated as below:



We think there are some advantage to select model linking:

1. Because it forms big feed back ring between models, we can use it to make system to obtain the function of stable state automatically. An feasible development planning can be found through the operation of model.
2. We can raise efficiency of research by taking full advantage of the high calculating function of computer.
3. Learning form other model's advantage to make up for a deficit of system dynamic in dealing with some problems, we can make the whole research be more scientific and accurate.

Many scholars in China have done a lot in this field to give many good experiences which are worth spreading. Typical examples are three model combination which are belong to the comprehensive integrated models, i.e. Zhuzhou model combination made by Wang Yuji and Xiang Yuanwang, Xinjiang model combination made by Wu Jianzhong, Hua Luogen model combination made by Li Baojian. The radical difference among the three model is the different model selected by leading model. Zhuzhou model make quantitative economic model as its leading model and includes SD model as its system simulate model. Xinjiang model makes SD model as its leading model. Hua Luogeng model makes itself as leading model.

This model system should be gradually standardized. Five bases should be established to suit the need of regional Planning research. That is

1. Model base

Model base is established with the input-output model, quantitative economic model, system dynamic model, economic control model, optimization control model as its main part to make all models' software language change each other. The model base also should

include some assistant models. For example, network technic model, data process model, decision model (multiple object decision, fuzzy decision) etc.

2. Strategy base

As to a region, it should make strategy and planning of all industries and sectors. A regional strategy base should be formed after the regional comprehensive development strategy is made. It is a dynamic development strategy base.

3. Data base

We should establish a data base which can be used by all kinds of models. It includes the data of history and present in the fields of economy, science and technology, society, policy, culture, natural resources, geography.

4. Standard base

As to a region, it should establish a base while includes the newest economy, science and technology and society standard system in the same kind of region.

5. Technological economy analysis base for important item

This work should combine the technological economy plans of the important items to be developed to form a network with multiple levels.

The establishment of these bases can be finished with the work of calculation center in region. It should be a necessary job completed by calculation center. It is economical and feasible to do that.