Some Applications of
The Macro-socioeconomic Model-SD to a Province of China

Jien-Chung Wu Huan-Chen Wang Mao-Kang Su
Institute of Systems Engineering
Shanghai Jiao Tong University

ABSTRACT

Northwest will be a strategically key region for the economic development of China in the early next century. The Macro-socioeconimic Model-SD for a northwestern province (abbreviated to MASEM-SD) has been built. The main purpose of the model is to research into the internal and external conditions and the proper policies which are necessary to realize the great goal in 2000 set by the People's Government of the province. The model further exhibits prospects for the province in the next century and put forth some potential problems that should be paid attention to.

INTRODUCTION

Strategic shift in China's economic construction to Northwest will start in the early next century. The Institute of Systems Engineering of Shanghai Jiao Tong University has taken the responsibility for giving opinions in an advisory capacity on the socioeconomic development of a northwestern province by 2000. In order to complete this important and glorious task, we have built the MASEM-SD. System Dynamics method is suitable for secular, dynamic and strategic analysis and research. There have been many successful SD models in the world. But in China the method is in its infancy and there is no precedent to go by. We have made serious preparations in three aspects for the model. First of all, we probed the theoretical basis and methodology of SD, studied some world-famous SD models and made a program for the model with Fortran-77. Secondly, we studied macroeconomic theory. Thirdly, we gathered data about the province. We have been to the province four times and visited a lot of places of the province, so we had much first-hand information. Using Delphi method, we asked many noted specialists and professors on the development of the province. Only through hard work have we basically found out about the history, the current situation and the goal in 2000 of the province. We have also made out the present status and its evolution of the province's population, geographical environment, resources and climate etc., especially we have grasped the six major factors restricting the development of the province. They are 1) the lack of capital in construction, 2) the long transport distance caused by the large area, 3) the irrational distribution of water resources over regions and seasons, 4) the poor infrastructure, 5) the shortage of scientific and tichnical workers, 6) the uncertainty of workable reserves of resources.

THE PURPOSES OF THE MODEL

There are two main purposes for the model. One is to research into the internal and external conditions and the proper policies which are necessary to realize the great goal in 2000 set by the People's Government of the province. The other is to look ahead to the next century and to indicate some potential problems that should be paid attention to. In the long run, the province's economic construction before 2000 is in preparation for the rapid development at the beginning of the next century. Therefore the second purpose of the model is not only natural, but also necessary.

According to the purposes of the model, we use the model for solving the following problems, taking account of the six major restricting factors:
--- to probe the demand for capital in developing the province's economy,
--- to probe the rational scale in developing transportation and the proper proportion of the investment in transportation to the total investment,
--- to probe the influence of the limitation in water resources upon the province's economic development and analyse the effect of raising water utilization coefficient,
--- to predict the time-varying trajectories of the province's main socioeconomic variables under different alternatives,
--- to evaluate various policies and measures by testing them on the model,
--- to discuss the population problem in the next century,
--- to probe the influences of the limitation of resources on the province's development in the next century.

THE GENERAL STRUCTURE OF THE MODEL AND THE STAGES OF SIMULATION

A model can never solve all problems at different levels in a socioeconomic hierarchy. The MASEM-SD, as a province-level model, deals with only the province's macrocosmic socioeconomic barometers. A great amount of detailed information about the problems at the lower levels are omitted. Only when we have grasped the general trend in socioeconomic development and the concrete values of main variables, can we better study and solve various concrete problems at the lower levels.

Our model consists of five subsystems. They are industry subsystem, agriculture subsystem, transportation subsystem, population subsystem and resources subsystem. The five subsystems are indispensable to the model with the above functions. The strategic goal of the province in the last two decades of this century is to raise gross industrial and agricultural output value 6-fold and per capita gross industrial and agricultural output value to the medium level of China. Therefore the model includes both industry subsystem and agriculture subsystem. Because the long transport distance is one of the important restricting factors, transportation subsystem is included. Since people are the main element of society, population subsystem appears in the model. Seeing that resources are the base of economic development, resources subsystem is taken into account. In the five subsystems exist one hundred and forty variables, including eleven level variables.

The whole process of simulation on the model is divided into three stages.

The purpose of the first stage is to test model utility. The time horizon is the 1950-1982 period. The purpose of the second stage is to probe the conditions and policies indispensable to the province's great goal in 2000. The time horizon is from 1950 to 2000. The purpose of the third stage is to exhibit the outlook of the province in the next century and put forward some potential problems. The time horizon is from 1950 to 2100.

THE MODEL UTILITY TEST (STAGE 1)

The model's behavior over the 1950-1982 period can be compared with the historical behavior as a test of model utility. As regards eight major socioeconomic variables, such as gross industrial and agricultural output value etc., the output of the model coincides with the historical data. Of the 168 coupled data, the relative errors of 87% are less than 5%. Thus the utility of the model has been proved.

THE REALIZATION OF THE PROVINCE'S GREAT GOAL (STAGE 2)

We are of the opinion that the key to the province's development is to break through its six major restricting factors. Although there are many elements which will influence the future of the province, elements, dominative and fit for control, are limited. Various combinations can be formed from these elements. Each combination is an alternative assumption, corresponds to a possible future situation. It is very important to test numerous alternative assumptions on the model and analyse the changes in the results of the simulation. Now only three examples are briefed.

1) Funds Problem
One of the most important restricting factors for the province's development is the lack of capital in construction. Using the mechanism of Harrod-Domar formula about economic growth, the funds condiction to realize the province's great goal has been probed. In consideration of imported overseas capital, Harrod-Domar formula about economic growth is as follows.

$$\frac{\triangle Y}{Y} = \left(\frac{S_d}{Y} + \frac{S_f}{Y}\right)\left(\frac{\triangle Y}{S_d+S_f}\right)$$

Here Y is the annual economic output value, $\triangle Y$ is the annual increment of Y, so $\triangle Y/Y$ represents the growth rate of the economic output value. S_d is the annual domestic investment, S_f the annual imported overseas investment.

Let $\alpha = \frac{S_d}{Y}$, $\beta = \frac{S_f}{Y}$, $C = \frac{\triangle Y}{S_d+S_f}$

then the formula can be simplified to

$$\frac{\triangle Y}{Y} = (\alpha + \beta) \cdot C$$

where α , β and C have their economic definitions.
Suppose that I is the accumulated investment, R is the total annual investment. Then the relationship of the above economic variables can be shown in Figure 1. The corresponding equations are

$$\begin{cases} Y = C \cdot I \\ R = S_d + S_f = \alpha Y + \beta Y = (\alpha+\beta)Y \\ \dot{I} = R \end{cases}$$

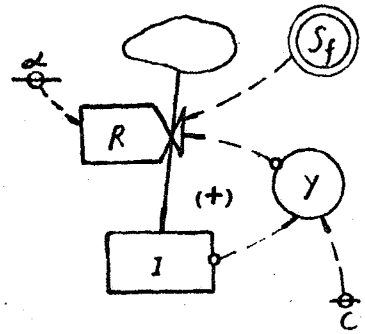

Figure 1

From the above three equations, we can easily obtain

$$\dot{Y} = C(\alpha+\beta)Y$$

Obviously, Y will grow exponentially, its growth rate can be expressed approximatively as

$$\frac{\triangle Y}{Y} = C(\alpha+\beta)$$

Taking account of the domestic situation, we have revised the formula slightly. This time suppose that I is the fixed capital, C the output value per unit fixed capital, γ the fixed capital formation rate of investment. Then Figure 2 can be easily obtained from Figure 1 by adding a variable. Corresponding equations are

$$\begin{cases} Y = C \cdot I \\ R = (S_d+S_f)\cdot\gamma = (\alpha+\beta)\cdot\gamma\cdot Y \\ \dot{I} = R \end{cases}$$

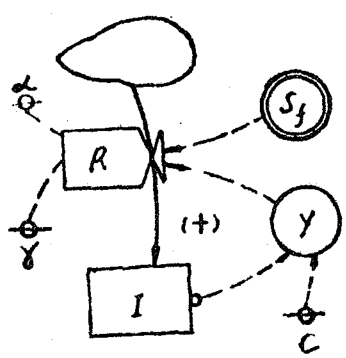

Figure 2

In the same way, we obtain

$$\dot{Y} = C\cdot(\alpha+\beta)\cdot\gamma\cdot Y$$

Therefore the economic growth rate approximatively is

$$\frac{\triangle Y}{Y} = C\cdot(\alpha+\beta)\cdot\gamma \qquad \ldots\ldots (1)$$

From (1), we can see that to raise accumulation rate adequately, to import overseas capital (including other provinces' capital) boldly, to pay attention to investment direction and fixed capital allocation for raising the output per unit fixed capital, to subtract the building cycle of large projects for raising the fixed capital formation rate of investment, all of which are the key measures to raise the economic growth rate. Formula (1) lays a foundation for quantitative analysing the funds condition to realize the province's great goal. From the above demonstration, we notice that the mechanism of the formula is suitable not only to countries, but also to provinces and that the economic output can be either national income or gross industrial and agricultural output value. Of course, under different occasions, α , β and C have their different definitions and dimensions.

The People's Government of the province puts forward the great goal to raise gross industrial and agricultural output 6-fold by 2000. That is to say, the province's gross industrial and agricultural output value ought to increase by an average of 9.2% a year. Using (1), quantitative analysis can be made on various assumptions. But we didn't adopt (1) directly. Rather, we enriched it, then melted it into the MASEM-SD. This is because:
(1) Harrod-Domar formula only reflects the most important positive feedback loop in the economic development, as shown in Figure 1. In fact, there are also several negative feedback loops which represent the influences of the restricting factors and suppress the further increase in the economy.
(2) The depreciation of fixed capital is not considered in the formula. Really, both the investment and the depreciation of fixed capital ought to be taken into account in the macrocosmic presentation of a long-term economic process.
(3) In the formula, C (output-capital ratio) is a constant. In addition, this comprehensive index doesn't distinguish industry from agriculture etc. Therefore it doesn't meet our need.
In the above three points the MASEM-SD enriches (1). The investment is divided into three parts: the investment in industry, the investment in agriculture and the investment in transportation. The output per unit fixed capital in industry is a variable, influenced by the conditions of the model system. Thus, the restricting effect of negative feedback loops is represented in the model. In spite of this, the mechanism and elements in (1) are all included in the model. For example,
the self-financing coefficient (the proportion of self-financing investment in the province's gross industrial and agricultural output value) corresponds to α in (1);
the annual investment from the outside (including the investment from the central government, the overseas investment and the investment from the other provinces of China) corresponds to S_f in (1);
the industrial fixed capital formation rate of investment corresponds to γ in (1);
the output value for unit industrial fixed capital corresponds to C in (1).
Because of a lot of multi-feedback-loops and nonlinear relationships in the model, such analytic formula, as (1) can not be obtained. Fortunately, the computer simulation can tell us the time-varying trajectory of the economic development for given self-financing coefficient, annual investment from the outside and fixed capital formation rate of investment in industry. As regards the self-financing coefficient, three possible curves are assumed. According to the curves, the self-financing coefficient will increase along with the steady growth of per capita gross industrial and agricultural output value. As regards the fixed capital formation rate of investment, two possibilities are assumed. In the first case, it will maintain the province's average level in the past thirty-odd years. In the second case, it will increase to the current average level of China by 1990, then maintain a constant.
As to the investment from the outside, several amounts in time series are assumed.

Because the output value per unit fixed capital in industry is a variable, nine combinations of the above three elements are assumed. As an alternative, every combination is tested on the model without any change of the other conditions in the model. By analysing the changes in the model outputs, the following conclusion can be drawn.
(1) In order to guarantee that gross industrial and agricultural output value can be increased 6-fold by 2000, the accumulated investment in the province within the last two decades of this century must be higher than a lower limit. For the sake of raising funds to develop the economy, the province can tap many-sided financial resources. For instance, the province can
—— strive for the support of the central government,
—— open to the entire country as well as to the outside world so as to import overseas investment and the other provinces' investment,
—— raise funds from the community's idle money,
—— set up such kind of enterprises which can bring about more profit in order to strengthen the self-financing capicity.
(2) Great importance should be attached to the raising of economic benefit and the taping of the latend power of existing enterprises. For example, when we keep the gross industrial and agricultural output value in 2000 unchanged, and alter the fixed capital formation rate of investment from the first case to the second case, the model output indicates that the accumulated investment within the twenty years can be cut down nearly by four billion yuan.

2) Transportation Problem
Transportation system has long been known as economic arteries. Transportation, industry and agriculture are interdependent. The long transport distance caused by the large area is a conspicuous restricting factor for developing the province's economy. At present the development of industrial and agricultural production is suppressed by the existing transport capacity. Therefore, the developing transportation will certainly promote the development of industry and agriculture. Is the more investment in transportation the better? Obviously not. Because the funds for construction are limited, both the surplus and the insuffciency of transport capacity are not expected. For the sake of probing the proper proportion of the investment in transportation in the total investment, several proportions are assumed and tested on the model. The outcome shows that with the increase of the proportion, the transport capacity will increase, but only when the proportion goes up 1.8 times compared with the average in the past 30-odd years, does the gross industrial and agricultural output value in 2000 achieve its maximum. Thus a proper proportion has been found.

3) Water Resources Problem
Water resources has long been known as economic lifeline. The production of industry and agriculture and the people's daily life are all dependent on water. What extent will the provice develop to? How much wealth can be created? The first decisive factor for this is the province's water conservancy. The water resources in the province are limited. It is their characteristics that they are rich in population, but poor in area; their distribution over the seasons is not even, in spring the shortage of water is serious. Many barren lands exist in the province. Whether they can be opened up depends mainly on water. There are two ways to solve the water

problem. One is to develop new sources of water. The other is to economize on water and make rational use of water. But there is not much room for developing new sources of water. In addition, the water utilization coefficient is comparatively low. Therefore, the second way is obviously more important than the first way. Now 95% of developed water resources is used in agriculture. In view of the above reason, the effect of raising water utilization coefficient on the province's agriculture is emphasized in the model. The simulation tests point out that if the coefficient can be gradually raised 1.5-fold by 2000 from the current value, then the province's cultivated area in 2000 can be expanded 1.4-fold and the gross agricultural output in 2000 can be increased 1.3-fold as compared with those in 2000 under the present constant coefficient.

The three main restricting factors have been discussed. In fact, as to every restricting factor, measures can be found to break it through. Many alternatives are formed by combining these measures. A recommendable alternative has been found by means of tests on the model. By contrasting and analysing the model outputs under different alternatives, it can be discovered that the great goal in 2000 set by the People's Government of the province is neither too high to reach, nor easy to realize. It is attainable under certain conditions. The main conditions are as follows.

(1) The provice should open to the entire country as well as to the outside world and reform the existing economic management system.

(2) The provice should bring the population under control and make the growth rate of population lower than 15‰.

(3) The accumulated investment within the last two decades of this century should exceed the above minimum.

(4) The proportion of the investment in transportation should be raised about 1.8-fold as compared with the average in the past thirty-odd years.

(5) The developed water resources should be increased 1.25-fold and the water utilization coefficient should be raised 1.5-fold compared with their present values.

(6) The province should make great efforts to develop education so that in 2000 the scientific and technical workers will increase 5.4-fold compared with those at present.

Figure 3 shows the simulation output under the recommendable alternative.

The definitions of the letters used to identify variables in Figure 3 are as follows.

W developed water resources (water units/year)
P population (population units)
L cultivated area (area units)
* gross industrial and agricultural output value (output value units/year)
# per capita gross industrial and agricultural output value (output value units/person/year)
N annual extraction yield of nonrenewable energy resources (energy resources units/year)
T transport capacity (transport capacity units/year)
S scienrific and technical workers (population units)

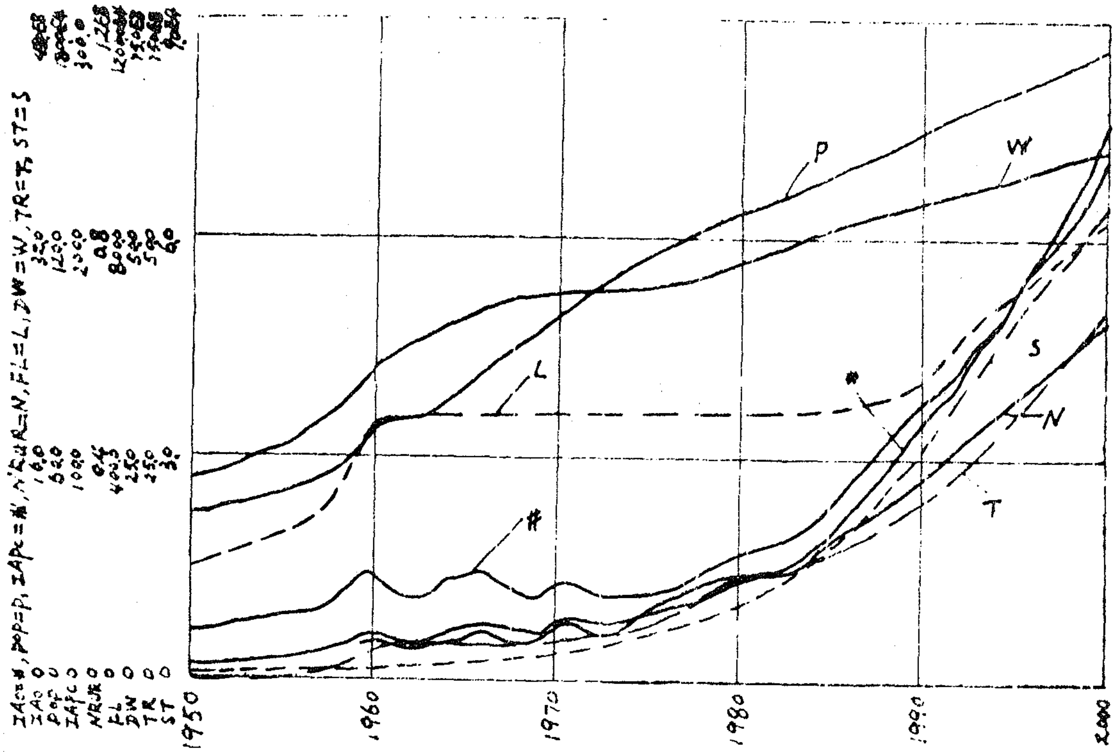

Figure 3

PROSPECTS FOR THE NEXT CENTURY (STAGE 3)

Forecasts are usually needed in making a long-term program for socioeconomic development. Because great inertia exists in socioeconomic systems, a long-term program should be made in advance. If controls are never applied until some harms can be perceived, then the situation probably will be worse before its turning point. The simulation in the third stage is based on this point of view. Socioeconomic systems are known as "soft systems" due to their great uncertainty. The longer the time, the great will be the uncertainty. Therefore, it is impossible to predict the accurate values of socioeconomic variables in the next century. But it is possible to study that what results are produced under certain conditions and changes. In the third stage, the way of "if ..., then ..." is repeatedly used in studying some potential problems in the province's development during the next century. Now only two important and interconnected problems, population problem and resources problem, are reviewed.

1) Population Problem

In the whole country, the population problem has been paid special attention to, and a series of powerful measures have been taken. But the province is the region inhabited by the minority nationalities. Therefore the province's population problem has its specific characteristics. In the past thirty-odd years, the province's annual population growth rate was higher than double that of the whole country within the same period. In these years the province's economy has been greatly developed, but the population growth was too fast, the economic growth was greatly offset by the population growth, the living standard of the people was increased slowly.

The population problem is a major problem which affects the overall socio-economic situation. In addition, there is a delay in the population control. So it is especially necessary to make a plan for the total population and control over the population. To have control over the total population is no more than to have control over the crude growth rate of population and the annual net immigrants. As regards the crude growth rate of the province's population in the next century, three possibilities, 14.1‰, 10.0‰ and 7.0‰, are assumed. It is another major characteristic in the province's population history that average annual net immigrants were numerous. Therefore, as to the annual net immigrants in the next century, four possibilities, zero, one hundred thousand, two hundred thousand and three hundred thousand are assumed. The time-varying trajectories of the province's population in the next century under different conbinations of the above two control elements can be obtained from the MASEM-SD. The following is a list of the province's population in 2100 under all possible conbinations.

the population in 2100 (population units) / the net annual immigrants / the crud growth rate	0	100,000	200,000	300,000
14.1‰	7.021	9.249	11.443	13.637
10.0‰	4.695	6.405	8.123	9.809
7.0‰	3.496	4.933	6.372	7.812

These results of simulation can be provided for reference in making the population plan and policies.

2) Resources Problem

Natural resources are a congenital foundation of a country. According to the total reserve, China abounds in natural resources, but according to the reserve per capita, China is poor in natural resources. It can be said that China will be faced with a serious situation on the resources problem. Under such a background, the influences of the limitation of resources upon the province's socioeconomic development in the next century are probed. The growth of material wealth is promoted by social progress and technical development, at the same time it will be certainly suppressed by the physical limits of resources, such as nonrenewable energy resources, water resources and cultivable area etc. Now the developed water resources are making up 56% of the total water resources, the cultivated area 32% of the whole cultivable area. The total reserve of nonrenewable energy resources is uncertain, but its series of annual extraction yield obviously coincide with certain exponential growth.

Using "Scenario" method, various conditions, for example, different amounts of the total reserve of nonrenewable energy resources are assumed. Of course, the basic hypothesis in the third stage is that the model of the province's socioeconomic development in the late this century will be maintained in the next century. That is to say, no influences of new technical revolution will be introduced into the MASEM-SD. The following is a specification of the symbols of simulation conditions.

NRI/400 represents that the total reserve of nonrenewable energy resources is assumed to be 400 (reserve units).

ENRR/2% represents that the annual growth rate or the province's supply of nonrenewable energy for the whole country is assumed to be 2%.

IMIR/10.E4 represents that the annual net immigrants in the next century are assumed to be 100,000.

NIC/14.1‰ represents that the crude growth rate of population in the next century is assumed to be 14.1‰ .

Others are on the analogy of this.

Of a lot of simulation outputs, only three scenes are shown below. In these graphs, the ordinate is omitted purposely, because what we want to emphasize is behavior trends, rather than concrete values. In the graphs, letter "R" represents the remaining reserve of nonrenewable energy resources, "A" the gross agricultural output, and "I" the gross industrial output.

Scene 1: NRI/200, ENRR/2%, IMIR/0, NRI/14.1‰

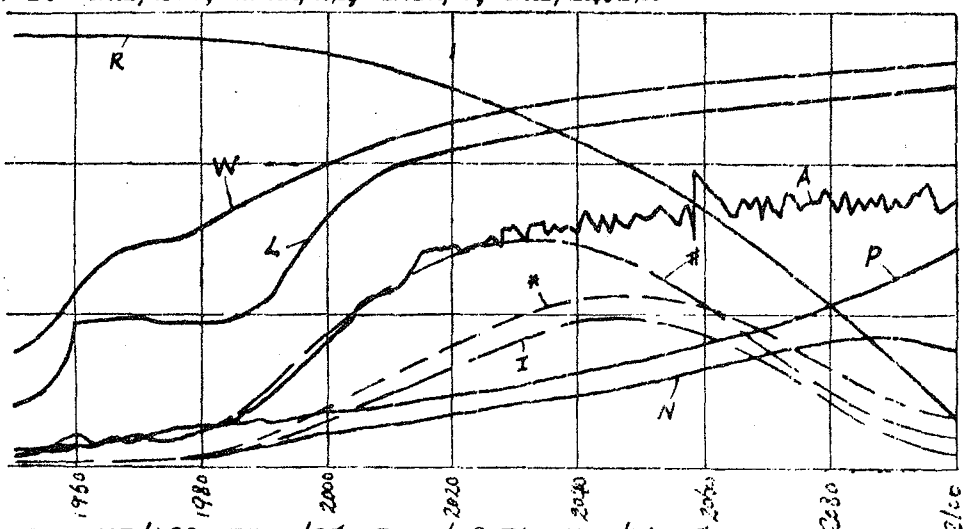

Figure 4

Scene 2: NRI/400, ENRR/2%, IMIR/10.E4, NRC/14.1‰

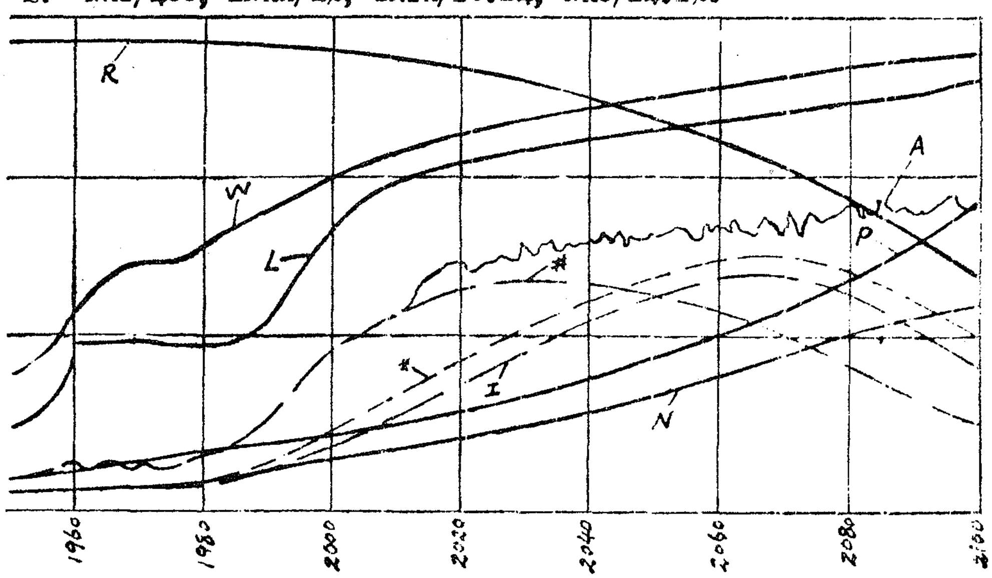

Figure 5

Scene 3: NRI/2000, ENRR/3%, IMIR/30.E4, NIC/14.1%

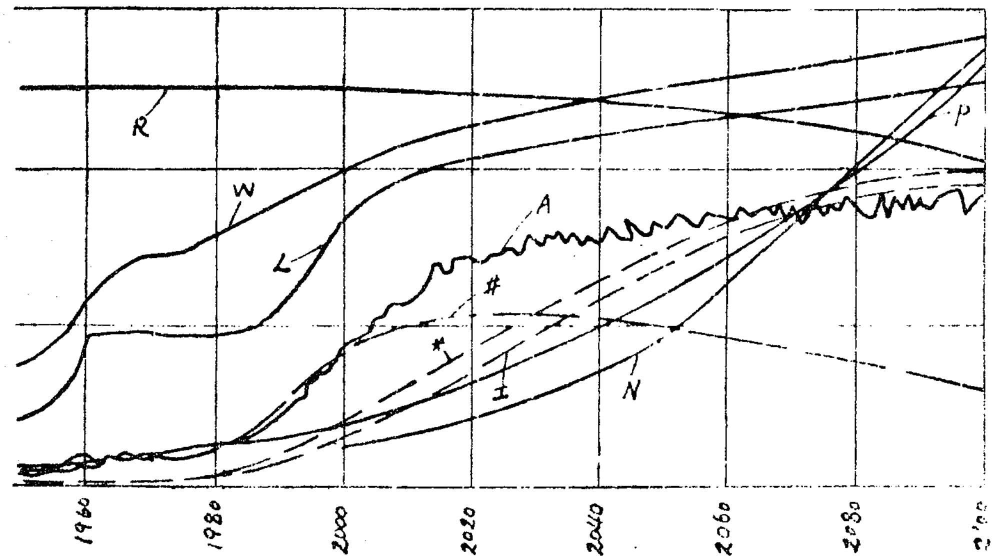

Figure 6

The above three scenes are the results under the basic hypothesis and certain conditions. They may not necessarily turn out in that way. In spite of this, by comparing and analysing them, the following important enlightenment can be obtained.

(1) Without new technical revolution, the limitation of resources will restrain the further growth of the economy. No matter how rich the reserve of resources is, it is still limited. The richness of resources can never change this general trend. What it can do is only to put off the breakout of restraining effect and win a valuable period of time for us to meet the challenge of new technical revolution.

(2) Energy is the important guarantee of the continued growth of the economy. The traditional industry is dependent on energy. With the process of industrialization, the demand for energy will be more and more, but the nonrenewable energy resources will become exhausted. Such a contradiction will be sharper and sharper. If there is no breakthrough in new energy sources, it will certainly restrain the development of industry.

(3) Water resources and cultivable area are limited resources. In the province, the restraining effect of the former will appear earlier than that of the latter. So water will be the first barrier to restrain the development of new farmland. In addition, the yield per unit area can not be increased infinitely. If there is no breakthrough in biogenetic engineering, these factors will suppress the growth of traditional agriculture.

(4) If the growth of population doesn't coordinate with the economic development, the province will follow the same old disastrous road, that is to say, the achievement of economic development will be again offset by the overquick growth of population.

Thus it can be seen that the province's economic construction should be divided into two steps. The first step is to realize industrialization within this century, at the same time keep a close watch over the new technical revolution. The second step is to use the achievements of new technical revolution in the world directly, build a series of developing industrial branches, including biological industry and microelectronic industry etc., make new contributions to bringing about the continued prosperous .

economy in the province and making China join into the ranks of developed countries.

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