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A System Dynamics Model of Socio-Economic Development of Harbin in China

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ABSTRACT

A system dynamics model of socio-economic development of Harbin in China has been presented in the framework of the integrated economy-energy-environment system planning.

The model simulates the activity mechanism of national economy of Harbin by taking the fixed capital of each industrial sectors as a major variable and controls the system behaviour by taking the gap of energy supply and the gap of energy investment as feedback signals. Therefore the pre-established development targets of national economy can be reached by readjusting the investment allocation and production structure towards elimination of the energy and investment gaps.

Through a series of policy simulation, several socio-economic development planning scenarios of Harbin for year 2000 have been compared with each other by examining some key issues, such as growth rate, investment ratio, investment allocation tenency and production structure readjustment as well as improvement of scientific, technical and managemental level, etc. The resulted policy suggestions were proposed with much attention being paid by dicision maker authority.

This model can run on the personal computer under the support of the Professional DYNAMO Plus software, and try to connect SD model to other technical model, such as energy forecasting model, multi-object optimun energy supple model, etc. An idea which is about SD co-operated with other methods has been presented and that is the direction of the system dynamics method development.

1. Socio-Economic System Analysis in Harbin

General situation:

. Geographic location: Harbin is situated in the Southern part of Heilongjiang province, the northernmost province in China, on the middle reaches of the main stream of the Songhuajiang River. Harbin covers an area of 7000 square kilometres, which include 7 administrative districts named Dao Li, Dao wai, Tai Ping, Dong Li, Xiang Fang, Nan Gang and 2 counties named Hulan, Acheng.

. Political position: Harbin is the provincial capital of Heilongjiang province. Harbin is also the economic, transportation and cultural centre of the province.

. Natural condition: Although Harbin as an industrial center, has no own natural resources, the area around the city is rich in natural resources, such as petroleum, natural gas, coal, iron, forest and agricultural products. These natural conditions are very favourable for economy development in Harbin.

Social and Economic Situation in Harbin

In 1985 Harbin has 3.81 million of population, of which 2.63 million are in urban area. With the rapid growth rate of 11.1% in industrial and agricultural production, as an industrial city where there are 3632 industrial enterprises, its gross output value of national product per capita is 1400 Yuan in 1985, and 1925 Yuan in 1987, which are much higher than national average level (793 Yuan in 1985 and 1023 Yuan in 1987). Similar to the "overheat" of economy growth over the country the growth rate of industry in Harbin is also too fast, as to cause much unfavorable consequences such as over large scale of investment in capital construction beyond allowed level financially, tight shortage of energy, raw material and extremely heavy burden of railway traffic investment, as well as inflation.

The main characteristics and problems existed in the current economic system of Harbin.

. Industry structure

The composition of industry product value by sector in Harbin is shown in Table 1, it can be seen that mechanical industry, the core of which are three large scale well-known power equipment manufacture plants (Electric generator, Boiler and Turbine), forms the "pillar" of the whole economy of Harbin.

For machinery industry its output value amounted to 40.9%, much higher than national level (about 22.5%). As an important energy equipment manufacture base in China, the amount of the electric equipment produced in the city account for one-third of the total production in China. However on other hand, this heavy industry- dominated industrial structure causes higher demand for energy and raw material, but lower net output, and there are much potentials to be brought into play for light industry.

. Aged equipment with low production efficiency

Most key industrial enterprises, equiped during 50's-60's year have already aged without renewal. The technical backward equipments are still in production line with low efficiency. This situation becomes worse for those middle and small scale factories. The extent of equipment aging can be measured by ratio of net value after depreciation to original value of fixed assets in industrial sectors, as shown in Table 2.

From the table, it can be seen that due to depreciation the net fixed assets remained for some industrial sector are only 57.6%. As a result, their productive efficiency are lower than average level over the whole China.

Table 1 The Composition of Industrial Product Value in Harbin 1985 (in 100 million Yuan)

Code	Sector	Output value	%
1	Food, Drinks & tobacco	11.33	12.8
2	Textile (incld.synthetic fabric)	5.70	6.4
3	Electric and thermal power	1.50	1.7
4	Petroleum Processing	1.81	2.0
5	Coking, gas etc.	0.13	0.1
6	Chemicals	3.30	3.7
7	Medicine	3.10	3.5
8	Building Materials	3.35	3.8
9	Machinery manufacture (incld. Electrical Equipment)	36.20	40.9
10	Electronic products	0.77	0.9
11	Other	21.37	24.1
	Total	88.56	100

Table 2 The Ratio of Net Value to Original Fixed Assets in Industrial Sectors in Harbin (in 100 million Yuan) 1985

Sector	Net value	Original value	Ratio %
Food, Drinks & tobacco	305	398	76.6
Textile (incld.synthetic fabric)	264	374	70.6
Electric and thermal power	300	510	58.8
Petroleum Processing	66	100	66.0
Coking, gas etc.	32	39	82.1
Chemical	134	216	62.0
Medicine	97	137	70.8
Building Materials	303	420	72.1
Mechanical manufacture (incld. Electrical Equipment)	2007	3483	57.6
Electronic products	39	59	66.1
Other	818	1443	56.7
Total	4365	7179	60.8

. Lower investment effect

To improve the aging problem of industrial equipment, much investment have been input to increase the fixed assets in Harbin during recent years. But many advanced production lines introduced with the investment do not bring obvious economic return as much as expected for some reasons such as lower management level,poor technical skill, shortage of energy and raw material supply, and their prices rising. Table 3 illustrate the investment effect indicated with the output rate of per unit value of fixed assets, and as a whole industry.

. High expense during productive process and low net output

Table 4 gives the comparison between gross output value and net output value in industrial sector in Harbin in 1985. Inspite of the rapid growth

rate in gross output value these years, the growth rate in net output value, in comparison, is lower than the former. It means during productive process the expense increase over time resulting lower value-added.

Table 3 The Output Rate of Per Unit Value of Fixed Assets in Industrial Sectors in Harbin (in 100 Yuan 1987)

Sector	Output rate in Harbin	Output rate in average in China
Food	154	235
Textile	127	200
Electric and thermal power	30	33
Petroleum Refinary	171	212
Coking, gas etc.	22	71
Chemical	170	115
Medicine	292	--
Building Materials	79	89
Machinery manufacture	91	106
Electronic products	144	172
Other	--	--
Industry Total	94	104

Table 4 The Comparison Between Gross Output Value and Net Value in Industry in Harbin, 1985 in real price

Sector	(in 100 million Yuan) Gross output value	Net output value	Ratio %
Food, Drinks & tobacco	1084	272	25.1
Textile (incld. synthetic fabric)	477	139	29.1
Electric and thermal power	149	69	46.3
Petroleum Processing	216	69	31.9
Coking, gas etc.	18	2	11.1
Chemical	301	77	25.6
Medicine	257	78	30.4
Building Materials	276	96	34.8
Machinery manufacture (incld. Electrical Equipment)	3334	1057	31.7
Electronic products	51	18	35.9
Total	8159	2423	29.7

The reason for that is related with technical processing condition and unreasonable price system.

. Shortage of energy supply

A great amount of coal are needed in Harbin for space heating in winter season which lasts longer than six months. In 1985, the fuel consumption for space heating was: coal 370.5 10KTon and fuel oil 46.22 10KTon, that accounted to 60% total fuel consumed in Harbin. This additional energy

consumption, which is not the case in southern China, aggravate the existed shortage of energy supply, which has occured with dramatic growth of economy. In winter many factories have to stop productive activities in order to keep space heating. The estimated economic losses would be 6 billion Yuan during the 6th Five-year-plan period (1981-1985).

Summary: Although a great progress in economy has been achieved during past ten years, the economy system of Harbin appears relatively somehow "heavier", "elder", "slower", comparing with several other large cities. So the municipal government has been finding ways to make the economy system full of activity and steady growth.

2. Model Introduction

The system dynamics method is selected for modeling of social economic development, which could simulate the economic development and comprehensive analyze the relationship between social economy and the energy demand, in macro-level.

. Why I select SD method

Comparing to econometrics and mathematical programming the SD method has its own advantages:

First of all, SD method has directly perceptible sense to describe the system, and has strong capacity to present the insight of the systrm structure. So it is more suitable for studying the system which have complex structures and much coupling relationship. The economic development of such larger industrial cities as Harbin is not only restrained by the energy supply and the environment pollution, but also connected with such factors as scientific technology, education, population, etc. As to the internal of economic system, it has the relationship of complex restraint and influences among various branches. The economic structure and relation among various factors determine the overall behaviour of the system of Harbin. From methodlogy point of view, the way of thinking that SD provides for system analysis, make it selves much suitable as a powerful means to simulate the structure of system distinctly.

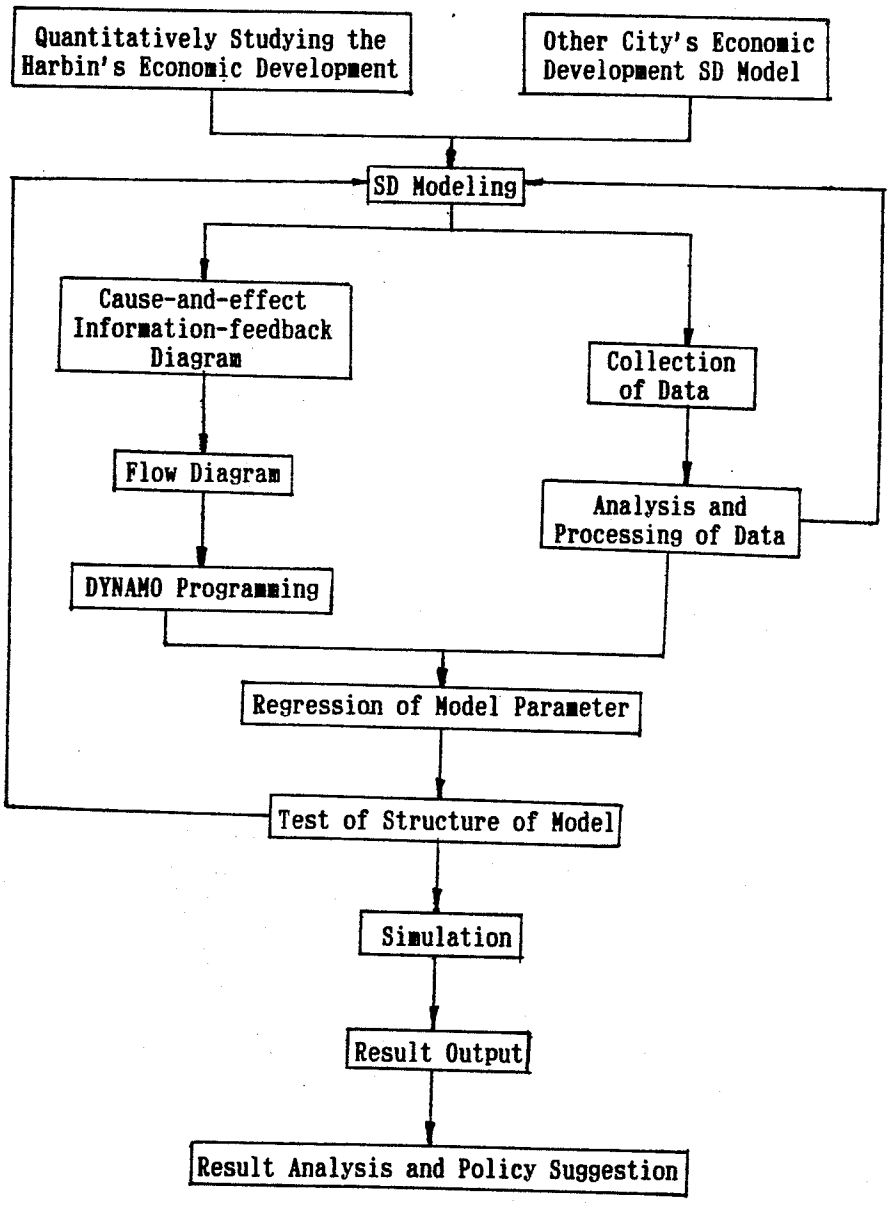
The second, the model established by using SD method is a structure simulated model. Once the model can more accurately represents the structure of actual system, many kinds of policy testing can be done with the SD model, and it can offer convenient means to search for the better ways of the city development and the policy of energy and environment.

The third, SD method put emphasize on description the of system. Of cause the data also plays a very important role in the model, but the requirement for data accuracy and data sample length is far less strict than other methods. Therefore it is more suitable for the area where the statistical work is not perfect, especially where the statistical standards changes frequently.

The fourth, the SD method is convenient for making dialogues between the model and decision makers.

The logical flow chart of SD model is shown as Fig. 1.

Fig. 1. Logical flow chart of SD model



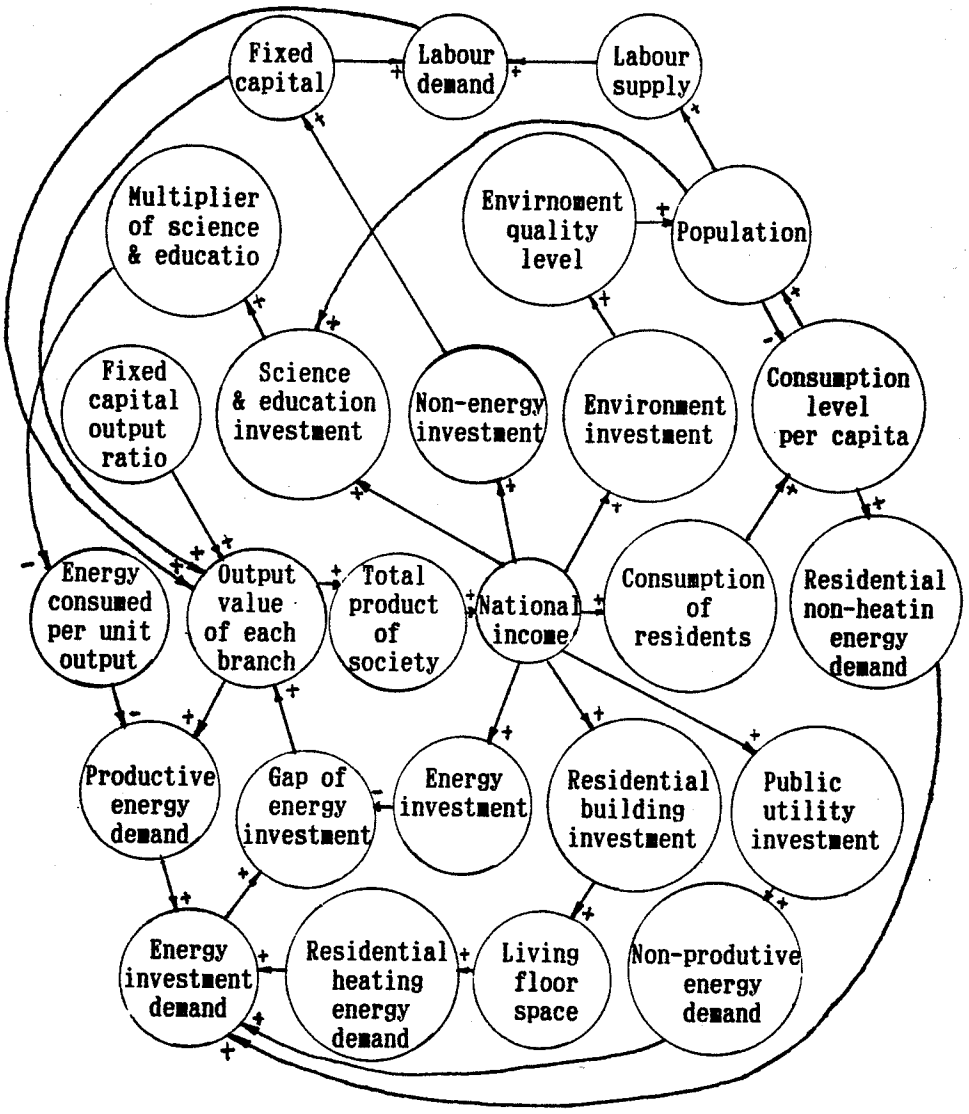
. The thinking of model designing

The feedback loop structure of socio-economic system in Harbin is shown in Fig. 2.

Main idea is to guarantee the Harbin's national income (total product of society or gross production value of agriculture and industry) as prerequisite, and refering to the development programme of every department, we adjust the input and output of different department to menimize the gap

of energy supply and the gap of energy investment.

Fig. 2. The feedback loop structure of socio-economic system in Harbin



Harbin, as a system, should achieve its overall goal of development. There are many ways to be chosen to achieve the goal. Economic development faces two important restraint factors. One is investment, the other, energy. So we can take the gap of energy supply and the gap of energy investment as a feedback to control the behaviour of the whole system. On the other hand the ratio of input to output and the energy consumption per unit of product are quite different from each other among defferent branches of industry. So by adjusting the allocation of investment in different branches, we can control the readjustment of production structure that can give negative influentces on the gap of energy supply and gap of energy investment (i.e. elimination), and then, in return, promote the economy

development along this way to its goal.

On other hand, fixed capital and quantity of labour employed can represent the production scale of each department, and the fixed capital per capita reflects the intensity of capital and the intensity of technique. Therefore we use the fixed capital of branches as a main variable in the model. So by increasing the fixed capital transformed from investment and by improving the fixed capital output rate due to scientific technology progress, we can forecast the output value of every branch.

3. Development Targets

As Harbin is a large scale socio-economy system and an urban ecological system, the long term development planning should be formulated base of on correct strategies and policies.

During 1985-1987, the municipal planning authorities proposed a document "Socio-economy development strategy for year 2000 in Harbin", in which the main socio-economic development scenarios can be classified as shown in Table 5.

Table 5 Socio-Economic Scenarios

Item		1985	1990	1992	1995	2000
. Total Product of society (in 100 million Yuan)	A:	105.4	175.6		250.9	380
	B:	105.4		204.2		320
	C:	105.4		175.5		320
. Growth rate of total product of society (%/a)	A:	10.7		7.4	8.9	
	B:		9.91		5.94	
	C:		7.56		7.97	
. Gross output value of industry (in 100 million Yuan)	A:	76.3	131.1		190.8	299
	B:	76.3		153.5		250
	C:	76.3		130.3		250
. Living floor space per capita (sq.m/man)	A:		6.0			8.0
	B:		6.0			8.0
	C:		6.0			8.0

Here scenario A called Economic benefit oriented scenario, means a higher growth rate strategy, at which the total product of society will reach 38.6 billion Yuan in year 2000. Both scenario B and C means lower growth rate strategy. The annual growth rate between 1985-2000 would be 7.77 % lower than 9.02 % of higher one. However, on the other hand, there are difference in the growth rate between scenario B and C in 1992, when the current session of the municipal government will be at the expiration of its term of office. The former scenario tries to pursue a higher growth rate than the latter in 1992 to see what influences would happen on the future.

Of cause there are some other scenarios may be taken into account, such as energy saving oriented scenario, etc.

To realize these ambitious targets that need great efforts to be made, the following strategical factors would be considered:

. Integrated equilibreum: including materials, finance, market, labour, foreign trade and so on.

. Harmonized (coordinated) and synchronized development pattern associated with economy, energy and environment.

. Reasonable growth rate and proportion of consumption to accumulation over the time horizon.

. "Tilted" allocation of limited investment among variety of industrial branches in order to guide the direction of adjustment of industry structure.

. Full use of advantage of industrial base in Harbin. For example, machinery and electric equipment manufacture, food processing, chemical, textile, medicine and building material industry should contribute more to the national economy.

These scenarios can be input in socio-economic development SD model with which a series of policy simulation can be run through interactive way in order to investigate some key issues that the municipal authorities much concern, such as economy growth rate, industrial structure and investment rate as well as investment allocation. During the simulation running, three policy factors, which affect actively the economy development of Harbin, i.e. investment rate, output rate and STM level* for respective sector, were taken into account in order to examine the system behaviour. Thus the detailed pattern of the scenario, for instance, the composition of the industrial product by branch, can be generated in this way.

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*Note: STM level means Scientific, Technical and Managemental level, that is a relative index to measure the quality of an economic sector and to coordinate the system development.

4. Policy Simulation

. Economic growth rate

The SD simulation for those three scenarios A, B, C, resulted in three different economic growth curves respectively that are shown in Fig. 3.

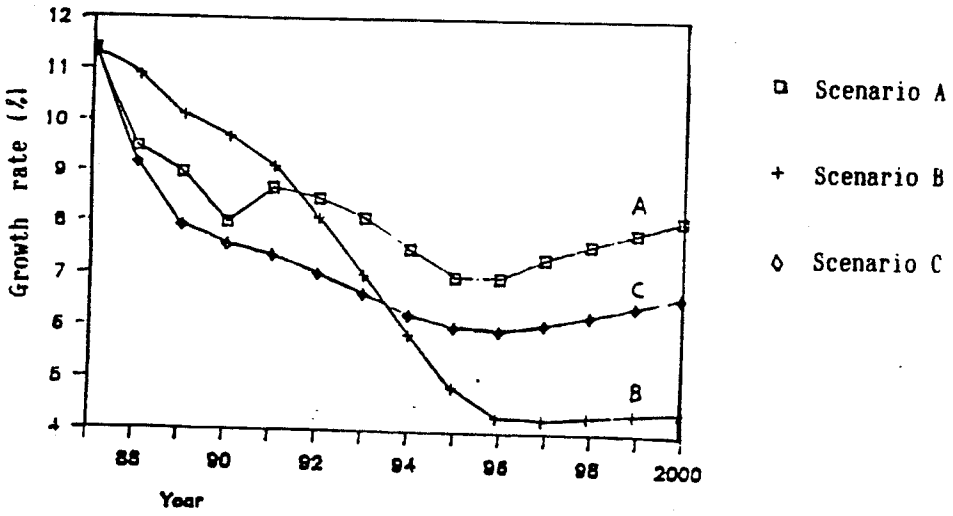
According to the current real economy situation in Harbin, the economy development is undergoing a transition stage from growth speed oriented to economic benefit oriented.

Neverthless keeping a certain steady growth rate is still one of key focus for the economy development. With this point of view, it can be found that sceranio B that tries to pursue a higher growth rate in 1990-1992 period through, will remain a "over heat" status during the period that has proven to go against the laws of healthy development of economy and is being overcome by the current economic adjustment policy, and then will fall down to a much slower status which does not make sense and cause unfavourable consequence for future development.

On the other hand however, scenario C appears a steep slope of reduction in economy growth rate after 1987 that seems unrealistic in real case because of inertia of economy development. Nevertheles scenario C, after all, is a receptible option in the case that limited accumulation of

investment funds can not meet the demand for high speed growth of economy. Therefore scenario A which avoids both shortcomes is thought to be more reasonable.

Fig. 3. Growth Rate of Total Product of Society in Harbin
Scenario A, B, C



For scenario A, the SD simulation can output the corresponding messages on requirement for output rate of fixed assets (also for STM level) and investment rate as well as its allocation, as shown below in Table 6, Fig. 4.

	1985	2000	increase rate
output rate of fixed assets	1.75	2.19	1.5%/a

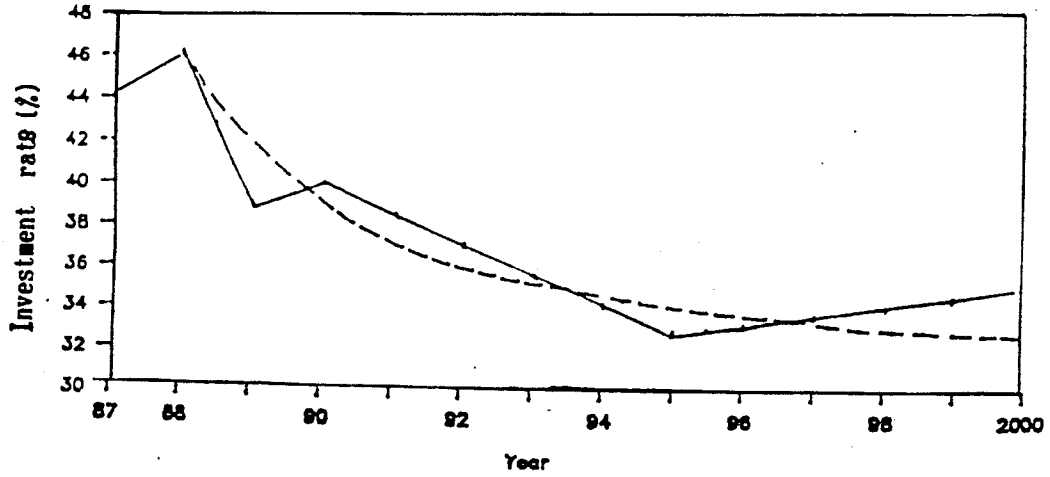
Table 6 Investment allocation for Scenario A

Sector	1985-2000 Investment (100 mln Yuan)	percentage (%)
Industry	175.5	40.9
Other material sectors	63.2	14.7
non-material sectors (excld, residence)	87.8	20.5
Residential construction	102.4	23.9
Total	428.9	100

Fig. 4 shows that after 1989 the investment rate will be lower than that level in 1988 and keep relative lower level during "Eighth-Five-year plan" until "Nighth-Five-Year plan" with average value of the rate being 36%

during 1985-2000. This trend is consistent with the current economy policy which intend to slow down the growth rate by adjustment. Therefore the feasibility of those requirement may guarantee the realizability of Scenario A.

Fig. 4. The Investment Rate for Scenario A
(Ratio of Investment to National Income)



. The role of STM level improvement

There are two ways of expanded reproduction. One is called intensive (connotative) way by improving the STM level of enterprises, another is called extensive way by simply increasing investment in fixed assets.

In the past the first way was usually ignored. It was the case in Harbin, For instance, the investment in fixed assets in industry sector in Harbin from 1980 to 1985 reached 3.37 billion Yuan. However the industrial production value increased from 4.97 to 7.5 billion Yuan only within the same period, that led to decrease in output rate of fixed assets from 1.78 to 1.75 and even decrease more for some particular industry sector.

To identify the role of STM level which plays in economy development, two policy simulation runs have been carried out one of which simulated the industry development in Harbin for year 2000 by setting different STM level and remain the investment rate constant (36%). The results are shown in Table 7.

It can be seen from Table 7 that under the constant investment rate, the increase of STM level enhances the "intensive" capability of output for the fixed assets and hence increases the gross product value of industry obviously, especially in the case when STM level is lower.

Another policy simulation examined the substitution between investment input and STM level, when keeping the industry production value at the constant planned target (29400 mln Yuan).

The results are shown in Table 8.

Table 7 SD Simulation on STM Level
(constant investment rate 36%)

STM	Output rate of fixed assets			Gross product value of Industry		
Level	1985	2000	increase rate (%)	1985	2000	growth rate (%)
0.9	1.75	1.97	0.79	75	253	8.4
0.95	1.75	2.08	1.16	75	274	9.02
1.0	1.75	2.19	1.5	75	296	9.6
1.05	1.75	2.29	1.81	75	319	10.1
1.10	1.75	2.40	2.14	75	343.5	10.65
1.15	1.75	2.52	2.46	75	368	11.2

Table 8 SD Simulation on Substitution
Between Investment Rate and STM Level.

Investment rate (%)	STM Level	Output rate of fixed assets			Total investment in industry (100 mln Yuan)	Investment intensity(*1)
		1985	2000	%	1985-2000	
33	1.15	1.75	2.52	2.46	148	60
35	1.05	1.75	2.30	1.84	168	91
36	1.0	1.75	2.19	1.5	176	117
37	0.95	1.75	2.07	1.13	189	167
38	0.90	1.75	1.96	0.76	199	262

Note *1: Investment intensity per unit of increase rate of output rate of fixed assets

It is clear to see the role of substitution of STM Level for investment rate by comparing two cases, which are in the top and bottom row, respectively, in Table 3.5. When STM level is only 0.9, the output rate of fixed assets is also lower, 1.96. So the investment rate must be 38% high which requires near 20 billion yuan of total investment in industry in order to realize 29.4 billion Yuan of planned target of industrial product value for year 2000. In the case the total investment intensity per unit of increase rate of output rate of fixed assets would be 26.2 billion Yuan high.

While on the other hand, when STM level increase up to 1.15 the output rate of fixed assets hence increase to 2.52. So the investment rate would be decrease down to 33%, which requires near 15 billion yuan of total investment in industry sector in order to realize the same planned target. Therefore the total investment intensity would go down to 6 billion Yuan. It led to the conclusion that increase in STM level by 0.25 might substitute about 5 billion Yuan of total industrial investment.

. Readjustment of industrial structure

If the investment allocation be readjusted, when keeping the investment rate at the constant (36%), what's to happened? The 5% investment (called readjustment funds) has been taken to some industrial sectors which are efficient, the results are shown in Table 9. I designed a C program to connect the DYNAMO program which compared the efficiency of each industrial sector with the conditions of market, supply of materials, etc.

Table 9 SD Simulation on Readjustment of Investment Structure (for year 2000)

Item	Scheme 1*	Scheme 2*
Total product of society (in 100 million Yuan)	380.0	403.9
National income (in 100 million Yuan)	129.1	137.1
Gross output value of industry (in 100 million Yuan)	296.0	318.4
Living floor space per capita (sq.m/man)	7.44	7.84
Output rate of fixed assets	2.19	2.30

Scheme 1: no readjustment of industrial structure
Scheme 2: readjustment of industrial structure

It can be seen from Table 9 that under the constant investment rate, if we only readjust the structure of investment, the gross output value of industry, national income and total product of society would have increased. The conditions of living floor improve because of the municipal finance increasing. At same time, the investment on energy production, education, science and technology would also increase. I have done a series of simulation under different market condetions.

Summary:

I. It is feasible to select scenario A that pursue 38 billion Yuan of total product of society for year 2000, as target. This argument is supported by the following point of view that the investment rate will be all lower than 44% of 1988 in after years.

It seems that scenario A may enable the economy in Harbin to develop at a relative higher growth rate provided that investment demand can be ensured, and meanwhile may prevent from "over heat" status.

II. The output rate of fixed assets is a key issue concerning the economic strength of Harbin. The marginal utility of output rate of fixed assets will diminish year by year with improving of STM level. Therefore at the present stage, in which the STM Level is rather low the emphasis should be put on raising the output rate of fixed assets by improving the STM level, such as fully making the most of capability of existing industrial equipment, speeding up the update of backward equipment, improving productive processing technique, skill and management training, and so on.

On the other hand for long term the strategical measures to be taken should be adjustment of product composition, increase of the value added of products, reduce the processing losses and so on.

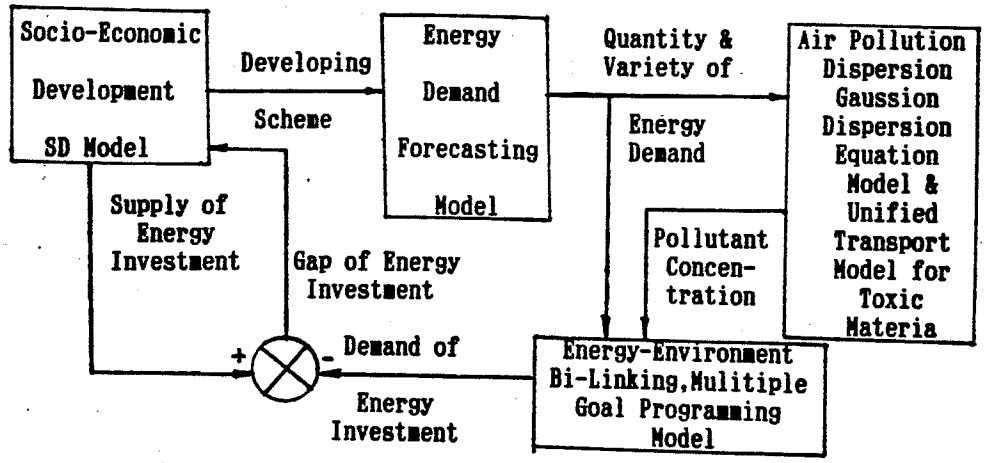
III. There are substitution role between improving of STM level and increasing of investment in fixed assets in order to realize future target of product value. So it is suggested that part of investment budget for fixed assets should be shifted to the budget for scientific technology and management. The significance of the suggested shifting will not only appear by the end of 2000, but also has historical influence on the development in 21 century.

5. Model System

To achieve those socio-economy, living standard and environment targets, there are several planning alternatives, each of which may put emphasis on certain strategical factors mentioned above. Therefore the problem to be solved is a multiple objectives, multiple criteria decision problem for a large scale socio-economy system of Harbin, that should be solved by using model system approaches.

Although the SD method has a lot of advantages, it's most inefficient on some technical studies. To give the comprehensive assessment and policy analysis for these alternatives, the systematic analysis by using model approaches is necessary also. For the purpose a completed model system has been developed (See Fig 5). These technical models can reserach carefully on energy demand, eaergy supply, pollution, etc, and counteract SD method's weaknesses. I think that SD co-operated with other methods is the direction of the system dynamics method development.

Fig. 5. Model System



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