An Oil–Field Planning Support System
Based on System Dynamics

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ABSTRACT

In this paper, we connected the principles of System Dynamics with the intellectualized Decision Support System, proposed a theory and method system of "Simulation – Optimization – Planning – Decision". An applicable Oil–Field Planning Support System is being built.

Ⅰ. The basic problems of oil–field planning and the approaches to solve them.

1. The basic problems of oil–field planning.

To an oil–field, the basic problem of planning is how to develop the whole production – operation system on the basis of good circulation in economic operation.

Good circulation means keeping a good proportion between different production sectors, suitably organizing the links in the production chain, reasonably allocating production resource, and, making economic balance and enough money for further development.

Development means regulating the scale and structure of production according to the changes in environment, and realizing higher level good circulation under new circumstance.

So, to make reasonable and applicable strategic plans, we must: 1) research the mechanism of good circulation in oil–field;

2) forecast the changes in environment; and,

3) make decision according to the two above.

2. The approach of solution.

The problems of planning are, fundamentally speaking, the problems of decision making. We may solve the three critical problems above by means of an Oil–field Planning Support System (OPSS) which adopts the developing methodology of Decision Support

System (DSS).

We know that DSS is a system which can effectively assist decision making through a good humen–computer communication sub system. Generally, DSS includes: knowledge–base, method–base (model–base), problem–solver, and database. But how do we

establish an OPSS? Here, we give a fundamental approach which can be defined as: " Simulation – Optimization – Planning – Decision ".

SIMULATION: On the basis of System Dynamics (SD) and through the analysis about the basic cause–effect relation of the production– operation process of an oil–field, we can express the essential knowledge of oil–field planning in the form of DYNAMO equations. In this way, we get a knowledge–base which can not only reflect the basic mechanism of running but also forecast the future tendency of development through simulation. The knowledge–base, combined with a database, can either express relations or control data and information.

OPTIMIZATION: Since SD method has not the function of optimiza tion, we may bulid an optimization method–base which can optimize the result of simulation and provide a series choice of decision.

PLANNING: By means of common method of planning and artificial intelligence, we can bulid a planning problem–solver to assist strategic planning.

DECISION: Because SD model has the function of " policy labora tory", the whole system will have strong assistance to decision making through an effective human–computer communication sub– system.

An actual system based on the approach above will apply SD methods into micro–economic field, bridge the gap between SD and DSS, and provide a new way of strategic planning for large and complicated oil companies.

The whole system is shown in Figure 1.

II. SD model and database —— buliding the knowledge–base

The basic cause–effect relation of oil–field production– operation is shown in Figure 2.

According to the cause–effect relation in Figure 2, we can bulid our SD model.

When we bulid our model, we can use SD model as an approach for expressing special knowledge through carefully choosing variables and determining the relations between veriables, that is, SD model not only can be used for simulation but also has expressed the necessary professional knowledge of oil–field planning experts in the form of closed network.

Since SD model pays particular attention on the dynamic relations between variables, we add a database as supplement so that SD model may get necessary parameters to do simulation and the result of simulation will go back to the database.Therefore, the knowledge–base consisted of SD model and database has not only the knowledge about the cause–effect relations between the variables but also the knowledge about the future dynamic char acteristics of the whole system (through simulation).The second kind of knowledge is very important to a planning support system.

Ⅲ.The problems and models optimization——buliding method–base

An oil–field includes several sub–fileds. We can divide th ese sub–fields into different groups according to the degree of development (when the sub–fields are being developed) and the degree of exploration(when the sub–fields are being explorated). Under normal condition,the degree of development or exploration is increasing while investment increases so that the number of sub–fields in every group is gradually changing. From this ana lysis we get the following model:

$$Xi+1(k+1) = \alpha iXi(k) + (1-\alpha i)Xi+1$$

$$X0(k+1) = Ym(k)$$

$$Yj+1(k+1) = \beta jYj(k) + (1-\beta j)Yj+1(k)$$

$$i=0,1,2,...,n-1;\ j=0,1,2,...,j-1$$

In this model:

$Xi(k)$ —— The number of sub–fields in group i at time k;

$Xi+1(k+1)$ —— After one time period, the number of sub–fields in group i+1;

αi —— In group i, the proportion of subfields which degree of development has increased over the distance between groups;

$Yj(k)$ —— The number of sub–fields in group j at time k;

$Yj+1(k+1)$ —— After one time period, the number of sub–fields in group j+1

βj —— In group j, the proportion of subfields which degree of exploration has increased over the distance between groups.

The model above is a multivariable differential system which describes the same dynamic relation as SD model but from different viewpoint.

1. The first kind of optimization —— optimization related to the subjects of production.

From the model above, we found that accompanying with production process the subjects of production are gradually changing. Therefore, the first problem we faced is how to optimizely distribute the limited investment to different subjects of production which are at different state so that the production process is continuous, the economic operation is the best, and the production tasks is completed.

To a sub–field in normal development state, keeping the process of production continuous may be described as keeping the value of ai within a suitable range, that is:

$ai < \alpha i < bi$

The value of ai and bi is determined by the technical parameters of sub–fields in different group. obviously, ai is the function of investment Ii : $\alpha i = fi(Ii)$

So, we get the model of the first kind of optimization:

OBJ: $\quad$ $Min\ I = \Sigma\ Ii$ —— minimum investment

Constraint: $\quad$ $ai < fi(Ii) < bi$ — constraint of continuity

$\Sigma pi\ Ii = P$ —— constraint of tasks

$Ii > 0$

In the model: $\quad$ P —— the task of production;

pi —— investment needed for per unit product in group i.

Obviously, we can also build the simular model to optimize the investment of exploration and other productions.

2. The second kind of optinmization —— optimization related to the tasks of production.

The total output of an oil–field has to distribute to every sub–filed, but the cost and capability of every sub–field are different because the difference of reservoir type and development methods. So, there is a problem of optimizely distributing the production tasks to raise the total economic benefit.

This kind of optimization may be described as:

OBJ: $Min\ TC = \Sigma ci\ xi$

Constraint: $\Sigma xi = A$ —— constraint of production tasks

$xi < Pi$ —— constraint of production capability

$xi > 0$

In the model:

TC —— total cost;

ci —— per unit cost of sub–field i;

xi —— the production task of sub–field i;

Pi —— the production capability of sub–field i.

This kind of optimization may be applied to several aspects of production–operation in an oil–field, such as: distributing of the tasks of exploration, distributing the construction tasks, and so on. *3. The third kind of optimization —— optimization related to the* production process.

The production of an oil–field is a coordinative process included many departments and with great scale. Generally, there are five subsystems: exploration, development, production, public construction, and multi–operation. In every subsystem, there are many complicated coordinative relations. It is required that the planning department must carefully determine and design these relations and keep the whole system in coordinative condition. The third kind of optimization is very complicated, we have to use different optimization methods according to different cases. For example, we may describe the problem about how to determine the proportion of investment between two sectors as:

The development of sector A, B depends on the investment:

$$Da = \varphi(Ia); \qquad Db = \xi(Ib)$$

The contribution to total production capability :

$TP = \alpha Da + \beta Db$

α, β ---- coefficients of importance

So, $TP = \alpha\, \varphi(Ia) + \beta\xi(I-Ia)$

By extreme value method, we may calculate out the optimize investment Ia, Ib.

Based on the actual data of oil–field production–operation system, we can build several optimization models. These models compose our method–base. The establishment of method–base make the OPSS has the the common knowledge of planning (SD model), the information and data base, and the special knowledge of planning (method–base). Consequently, OPSS can effectively support strategic planning.

Ⅳ. Modle of planning ---- building problem–solver

On the basis of above work, the model of planning mainly solve the following problems:

1. Forecast.
2. Planning.
3. Solve the problems of planning.

In order to make OPSS can intellectually complete the tasks above, we have to set a suitable reasoning mechanism in accordance with different problem on the basis of knowledge–base, method–base, and database so that we may solve these problems. For instance, the reasoning process of regularing planning targets can be described by the diagram in Figure 3:

In view of different problems of planning we may establish different reasoning mechanisms like in Figure 3. These mechanisms make up our model of planning (problem–solver). Because the SD model can not directly support the process of reasoning, we consider that we can express some critical relations by means of production rules of artificial intelligence. Since SD model is a good tool to express the total dynamic relations of the whole system, the production rule– base will not be very large.

Also, to solve the complicated planning problems we need a strong human–computer communication subsystem. The basic structure of the model of planning is shown in Figure 4.

Ⅴ.The application of OPSS and decision making

The method of SD has the function as "policy laboratory"; the method–base introduced a lot of scientific decision making methods into oil–field planning; the model of planning established a intellectualized problem solve mechanism; and the database relized the data control and communication among the three parts above.

Therefore, the whole OPSS can strongly assist the planning and decision making in oil–fields.

The structure of the whole OPSS is that several models piled up based on the database. Every model may be independently used and be combined together to get higher benefit. Especially, the problem–solvers in the model of planning are orented to solve different problem, so we can add new problem–solvers according to the need of decision to extensively assist planning and decision making.

The OPSS in this paper has experimently adopted in a large gas–field in China and got the expected effect. Now, we are designing and applying the OPSS in a large oil–field in China cooperated with the experts of planning in the oil–field.

The OPSS is just a frame. By adding different special knowledge the OPSS may be applied to assist the planning and decision making of other large and complicated companies that are simular to oil–field companies.

The excellent applications of SD in marco–economic field have shown the strong effect and importance. But, to make SD itself get further development, we have to apply SD in more extensive fields. The large and complicated companies like oil companies are the best places to apply SD methods. In this paper, we suggest that: 1). SD model may be used as an approach to express the complicated knowledge; 2). SD model may be combained with the methods of optimization; 3). SD model may be used as the basis of an intellectualized OPSS. And, we have proposed a framework of OPSS design. We hope, our work may have some assistance to promote the development of SD.

Figure 1

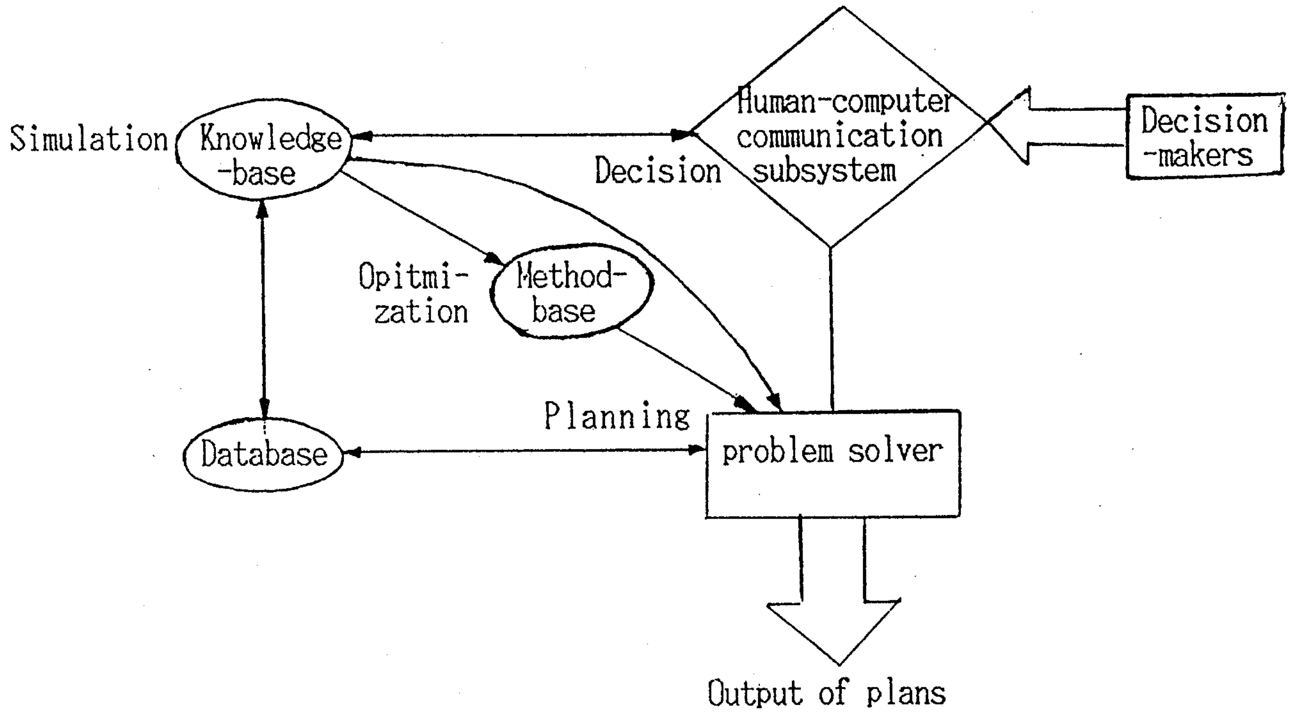

Simulation
Knowledge -base
Human-computer communication subsystem
Decision -makers
Decision
Opitmi- zation
Method- base
Planning
Database
problem solver
Output of plans

Figure 2

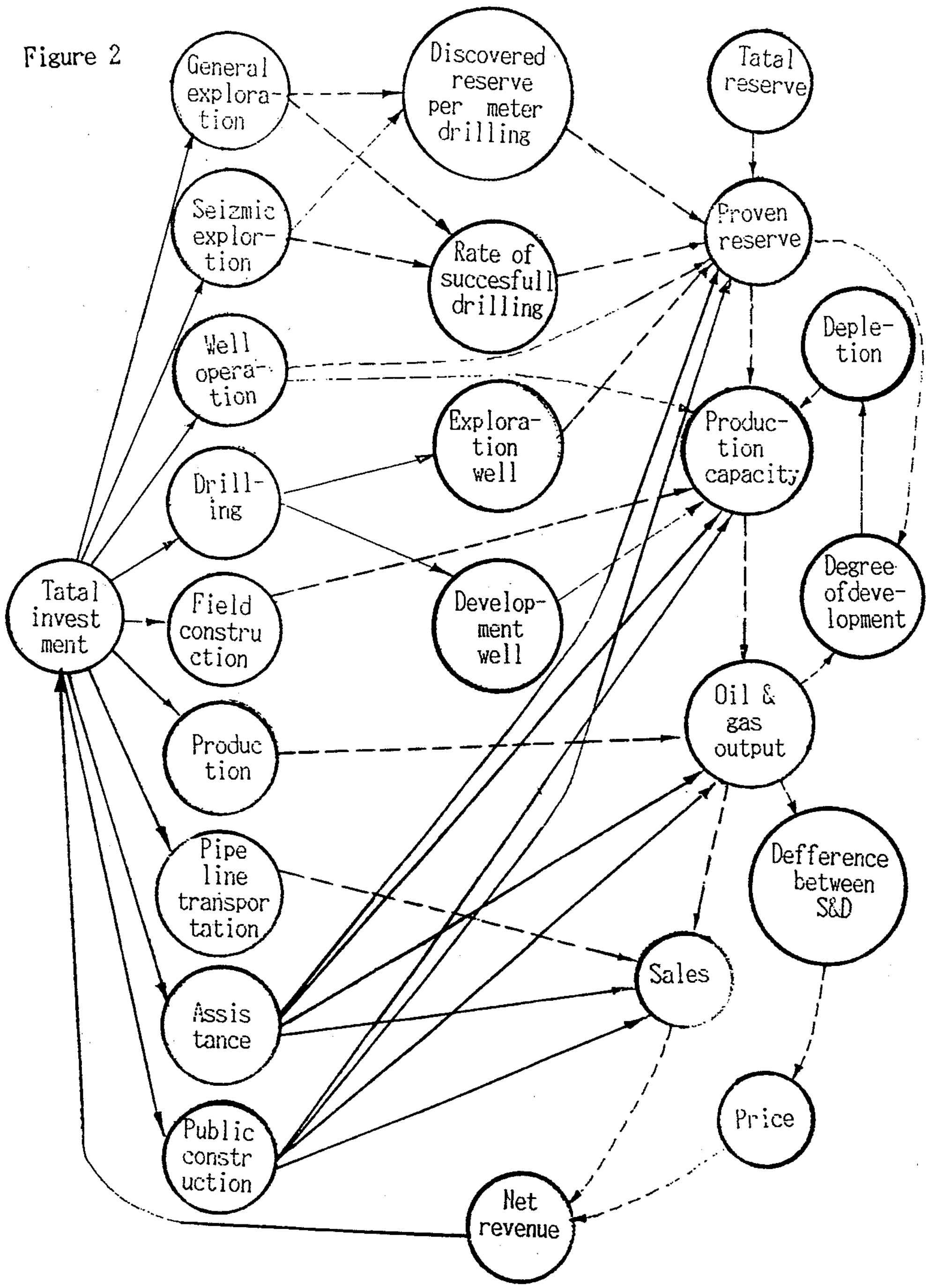
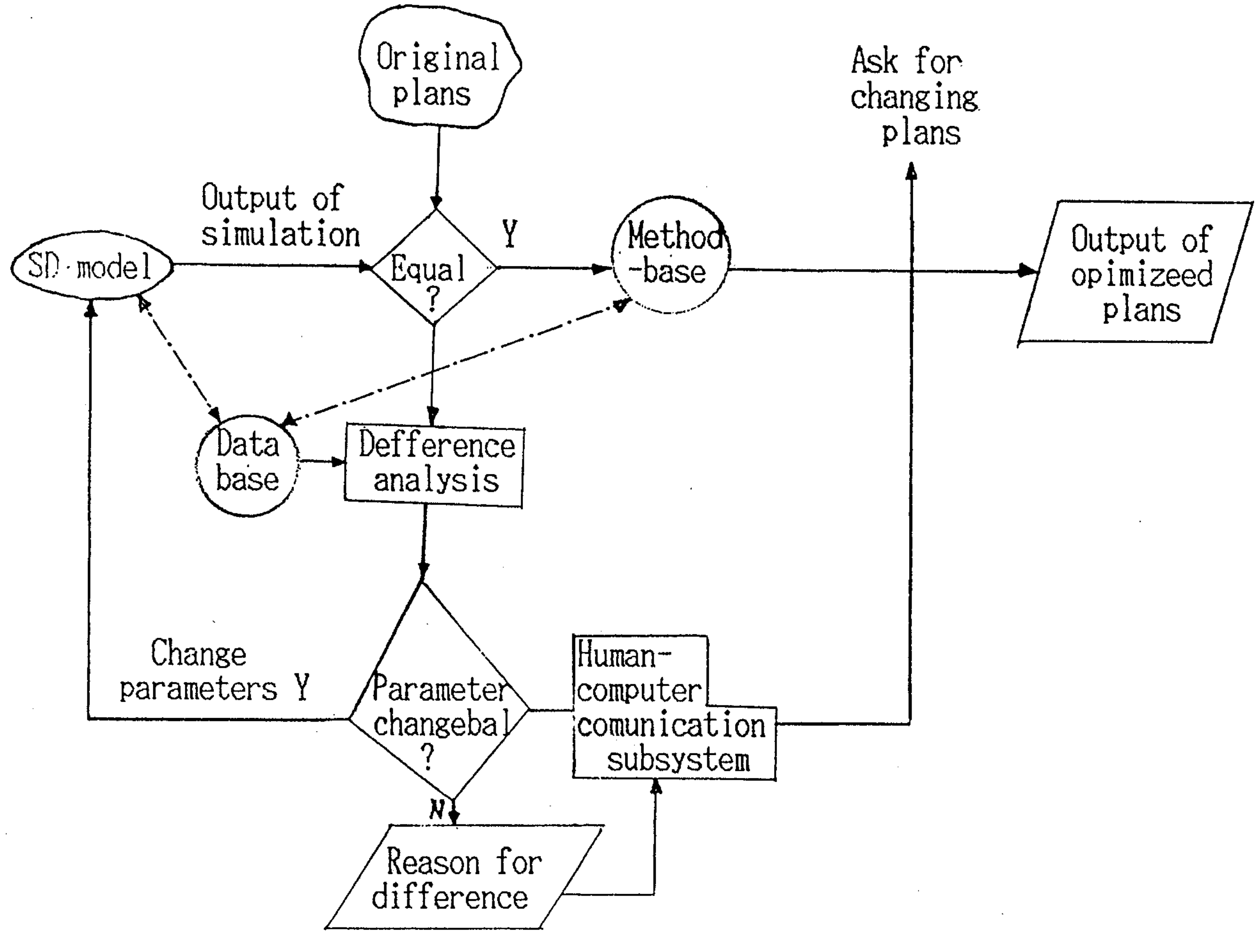
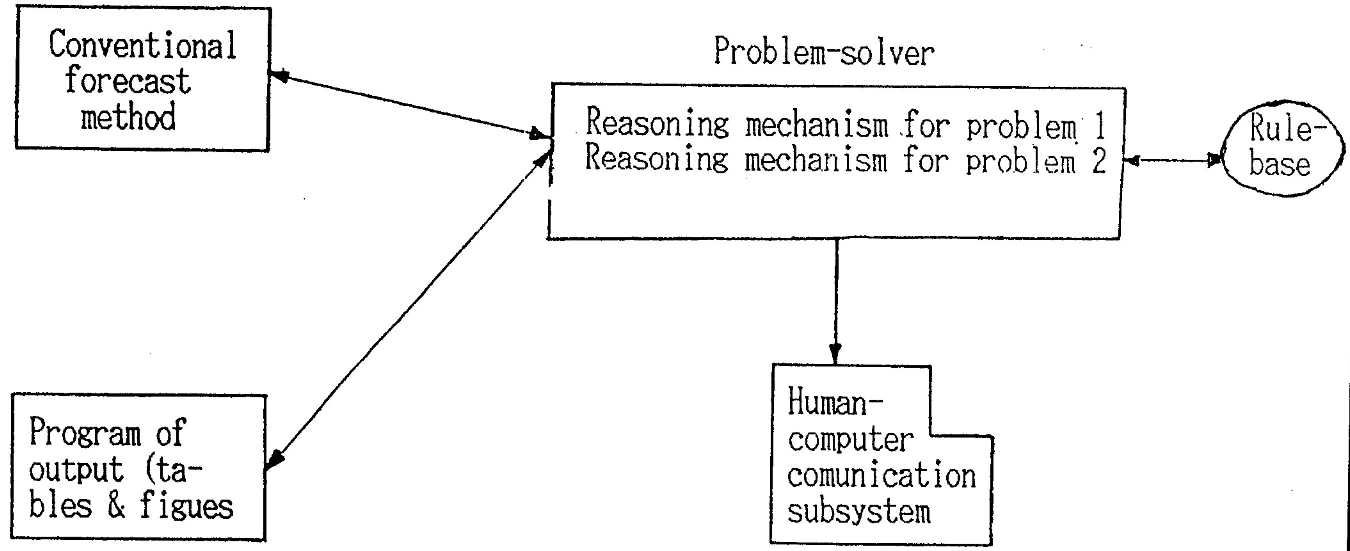

General exploration
Discovered reserve per meter drilling
Tatal reserve
Seizmic explortion
Rate of succesfull drilling
Proven reserve
Well operation
Depletion
Exploration well
Production capacity
Drilling
Tatal investment
Field construction
Development well
Degree of development
Oil & gas output
Production
Pipe line transportation
Defference between S&D
Sales
Assistance
Price
Public construction
Net revenue

Figure 3



Original plans
Ask for changing plans
Output of simulation
SD·model
Equal ?
Y
Method -base
Output of opimizeed plans
Data base
Defference analysis
Change parameters Y
Parameter changebal ?
Human-computer comunication subsystem
N
Reason for difference

Figure 4


Conventional forecast method
Problem-solver
Reasoning mechanism for problem 1
Reasoning mechanism for problem 2
Rule-base
Program of output (tables & figues
Human-computer comunication subsystem