SD MODEL OF URBAN WATER USING OF TIANJIN

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ABSTRACT

The paper presents a preliminary attempt for application of system dynamics in the study of urban water using and its management.

The SD model of urban water using describes the complicated system behavior. It will help us to understand and trace time interval behavior of urban water using system, to observe and handle dynamic trend of system behavior, to obtain the features of urban water using in different time. Therfrom we may have a quantified rational knowledge about water demand and have to find an effective may to strengthen scientific management of urban water using, to promote rationalization of urban water using, to save water resources and to resolve unbalance between supply and demand. Meanwhile, necessary informations and quantized references should be provided for administration and departments concerned to determine the speed of economic development, study layout and structure of industrial development, adjust key points and methods for urban water using.

1. Raising of The Problems

At present, like the situation in many other countries in the world, crisis of fresh water resources in China is growing seriously with each passing day, especially the shortage of urban water resources is a pressing problem. Water supply has become an important restrictive factor in the development of national economy. How to resolve the unbalance between supply and demand of urban water resources and how to bring the limited water resources into full play for maximum economic benefit? These are spectacular important problems, which need to be solved urgently. On the basis of a series of scientific researches, we try to reflect these problems from one side and lock for an effective way to resolve the unbalance between supply and demand of urban

water resources under the premise of limited water resources.
As a result of comprehensive review on water using in the whole city of Tianjin, we considered it is necessary to establish a related model for urban water using in Tianjin for further analyzing urban water using in every aspect and different time period, simulating urban water using in past and at present, tracing urban water using in future; in order to more deeply, systematically and accurately master the objective law of urban water using and thoroughly analyze the propect of urban water using in future. A rather clear picture of urban water using in Tianjin in the past, present and future thus can be drawn out. Corresponding measures will be taken according to this picture, every effort will be made to regulate, control and manage the mode of urban water using and to improve water using and management level to a possible extent under available condition of water resources. Development of national economy with high speed to the target——2000 A.D. can be guaranteed, as well as rational using of water, scientific management, saving of fresh water resources and making the most of economic benefit of water. For the above-mentioned we decided to establish a related model for urban water using in Tianjin.

II. Features of Urban Water Using System and Applicability of SD Method

The system of urban water using is a complicated social system, goal of which is pluralistic, variable and of remarkable non-solitary character. For example, index of each quantity of urban water using is not a single one, but a set of index system of combined measurement. Generally, parameters and structure in the system of urban water using vary with time, the change of parameters in different years van be observed directly, while the change of structure can be reflected only from the difference of interaction relationship in various stages. Moreover, this social system in non-linear, so it often shows the non-additivity of action and rusult. Even measures were adopted for water saving in double, but the result of water saving may not increase in double. This feature showed that we can hardly describe the system with mathematic mode. In short, features of urban water using system can be described as follows: 1. system is large in scale, it is not limited in some simple element, but a macroscopic phenomemon of various water quantity and conditions of water using in the whole urban water using; 2. complicated in structure, in which not only exists relation between water quatities, but also relation between action of man's administration and water, as well as more complicated relation between various water quantities and new growing informations; 3. multi-functions, so as mentioned above, the goal of system is pluralistic and non-solitary; 4. multi-factors, in the system there are not only various factors of water, but also man's factor (such as management factor), nature factor and etc.

As regards to such complicated system, decision study of urban water using needs to be quantified and dynamicized, it may not only rely on ordinary means and methods traditional inferential calculation and qualitative analysis, but on the development of static model turning toward to dynamic model. Besides, urban water using system is a system, deficient in data by its nature, moreover, there are many affecting factors, therefore, it is unsufficient, uncomplete and unactual to describe the system only according to data. Many features, going to be described in the system, can not be directly expressed numerically, they are of a definite fuzzy feature, for example, the delay phonomemon in the system.

In accordance to these features corresponding requirements were proposed for the method with model, i. e. the model building might be installed deeply into the interior of the system in order to analyze the structure of system, reveal interdependent relation between various elements and interact on each other in the system, the content expressed by model should be kept in a same structure relation with the real system to a certain degree, close to or coincident with the actual circumstance in past and at pressent, possibility of development in future. The whole dynamic process flowing in past, at present and in future should be understood from the view of macroscopic tendency, and the feature of urban water using in each time will be shown and studied, i. e. it is possible to describe time interval behaviour of the system in a state space. Because the history is continuous, one can follow the law of its development in past, present and future; on the basis of the past and present, meanwhile with utilization of a logic structure, we can link them up with the future, analyze those uncertain factors by means of systematic, moving, coneective and changeable philosophic view to describe and reveal the actual system being studied. In the meantime, because human ability falls behind his will in dynamic tracing of complicated social system during long time period, so it is necessaty to build an indispensable man-machine system, whihh may accomplish the tracing to the social system. According to the above-mentioned, a mâcroscopic, fuzzy and long-term trend study of non-linear, complicated system with time delay can not be solved only by mathematical analysis. An alternative is the experimental method for system analysis, i. e. a system simulation method. System Dynamics is just a new scientific subject in this field.

Our extra attention was directed to the specific predominance of SD method, it permits mode builder to form various modes of system performance through the modification of parameters and repetitive simulation after different policy choice,providing the convenience for the study of policy effect. Through mathematical simulation for the system, tracing the conceived policy scheme and observing the changing trend of the system, it may not only make the actual policy decision more coincident with the objective law of the system development, but also affect the thinking activity of policy decider in return.

The more features of the System Dynamics method will be revealed and analyzed in detail and profound, the more distinctively will be shown the method availability for urban water using system. Thus, it impeled us to build a SD model for urban water using in Tianjin, a attempt in application of System Dynamics is expected.

III. SD Mosel of Urban Water Using in Tianjin

Process of model building is a process by use of a special language to describe the models of system behavior and by use of computer to solve this dynamic mode progressively, that is to say, a real system through a specially designated abstraction can be transferred on computer to a artificial system, which can be controlled and regulated. The steps are as follows:

1. Determine goal of the system and aim of model building

The SD model of urban water using can describe the complicated system behavior in a long time interval of 40 years from 1960 to 2000. With the aid of computer model simulated qualitative and quantitative conditions of urban water using system within these 40 years, so as to complete abstractive process of the real system. A series of simulation results and different data of variables obtained after computer operation will help us to understand and trace time interval behavior of urban water using system reflected by model (including the course of history, which has passed or will pass in future), to observe and handle dynamic trend and objective law of the system behavior of urban water using, to obtain the features of urban water using in different time, especially in 2000 A.D. Therefrom we may have a quantized rational knowledge about water demand produced due to the development of national economy and improvement of people's living standard. In the meantime, we shall have a vivid understanding and more imaginal, quantitative concept about hardship and sense of crisis due to the fact that the limited water resources are attempting to meet such demand. We have to find an effective way to strengthen scientific management of urban water using, to promote rationalization of urban water using, to save water resources and to resolve unbalance between supply and demand. Meanwhile, necessary informations and quantized refernces should be provided for administration and other departments concerned to determine the speed of economic development, study layout and structure of industrial development, adjust key points and methods for urban water using, strengthen scientific management of industry water, reform technology of water using, make an investment in fixed assets for water saving and etc.

2. Determine the boundary and range of the system

Because the built model is used to describe urban water using system, so all quantities of water (such as gross water, water taking, saved water, recycling utilization water and etc.), fixed assets (such as for water saving, technology reform and etc.), management level, pressure of water saving, recycling rate and etc. are regarded as internal variables entering into system boundary, while values of industry output, quantity of water resources and etc.——exogenous variables.

3. Determine and select model variables and causal relations between variables

Selection of model variables must be carried out around the goal of system and the main features of the system might be shown through selected variables. Build of feedback relation link is the key of model building, it describes internal structure of the real system, it is a frame of system structure. The causal relations of this model is shown in Fig. 1. The main feedback loops in this model are shown in Fig. 2, 3 and 4.

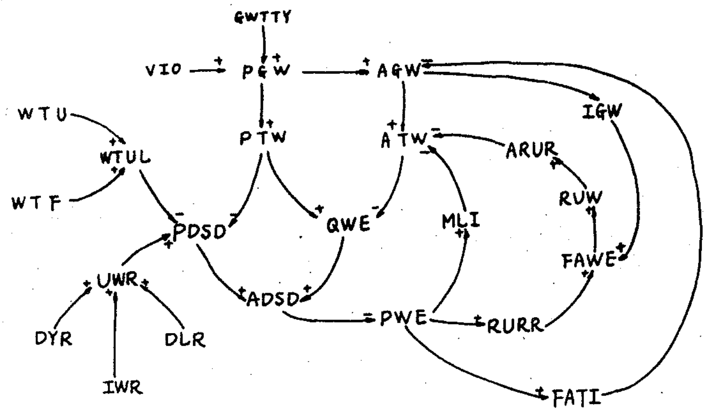

Fig. 1. Causal-loops diagram

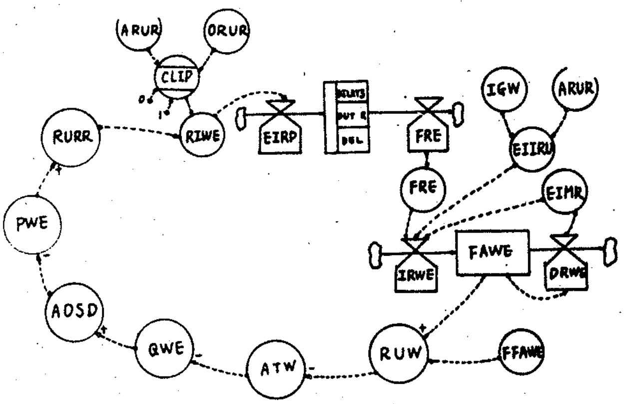

Fig. 2. Feedback loop of fixed assets for water saving

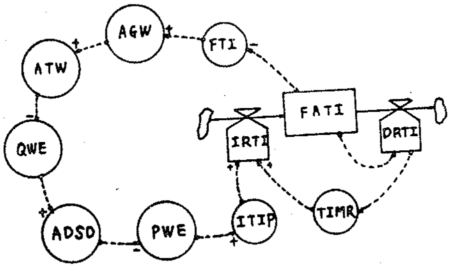

Fig.3. Feedback loop of fixed assets for technology reform

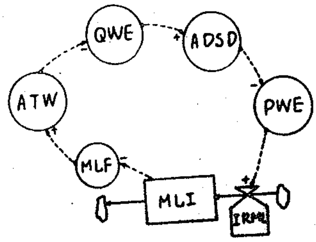

Fig.4. Feedback loop of management level

4. Flow diagram of SD model for urban water using in Tianjin

Substantiate and detail the frame (feedback relation link), express various elements and their relationship as various variable and their relationship; thus, the flow diagram of this model can be drawn out as shown in Fig. 5.

5. Selection and determination of parameters and TABLE functions

A series of TABLE functions, parameters and initial values in the model are defined at last respectively according to historical statistical data, tendency of objective development, planned numerical values, present situation analysis as well as necessary judgement and through repetitive debugging. Concrete numerical values, tables and configuration are omitted here.

6. Analysis of experimental results

This Man-machine system was built and perfected through repetitive similation, operation and debugging of the model and through adjustment of various parameters and input of various TABLE functions, so that we can perform

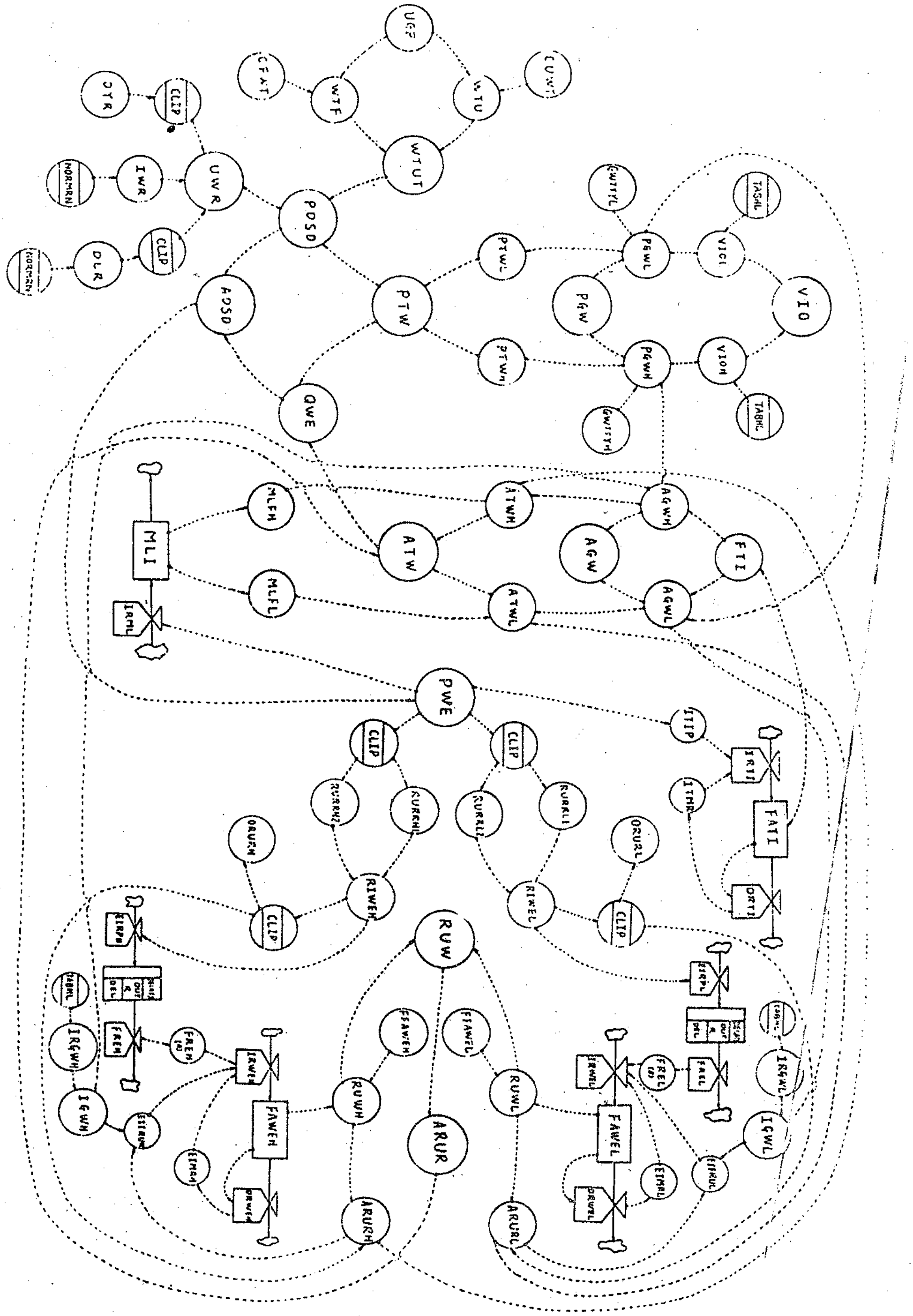

Fig. 5. Flow diagram of SD model of urban water using

simulation and tracing urban water using system in laboratory, otherwise it is impossible to be performed in reality. Computer with the aid of its specific simulation means shows us system dynamics in different time interval, prospect of urban water using of Tianjin in future and shows numerical values of various water quantities concerned for the years desired.

As regards to the result of operation, we carried out goodness of fit analysis at first. The course of history, passed has been simulated by model, can be used to verify whether the simulation results of the model will be in coincidence with practical state of the real system or not, i. e. to verify the goodness of fit of the method. According to the above-said, we may check and determine the capacity and reliability of the model to simulate system in future in a sense, or fidelity of the model. Relationships of goodness of fit of actual quantity of water taking and of quantity of water taking per ten thousands yuan value of output are shown in Fig. 6 and 7.

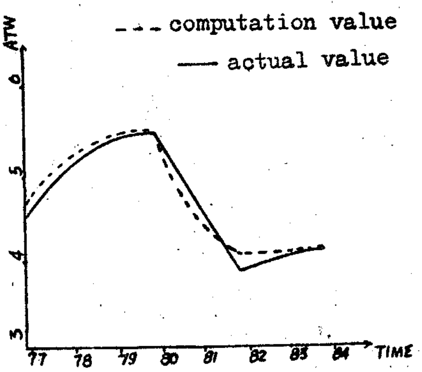

Fig. 6. Fit goodness relationship of actual water taking quantity

In addition, considering that the different proportion of development of light and heavy industry, the different level of industry output value in developing plan of national economy, the effect of diversion quantity of the Yellow River, the proportion of water taking quantity for urban life and for industry, pressure of water saving, measures to be adopted for reducing pressure of water saving and etc., the model will carry out operation and analysis to all these different policy choice and obtain corresponding analysis result and policy proposition. For instance, in order to reduce water saving pressure and release unbalance between supply and demand of water under the conditions of present water resources, three effective ways can be adopted in a definite period: a. to make an investment in water saving,

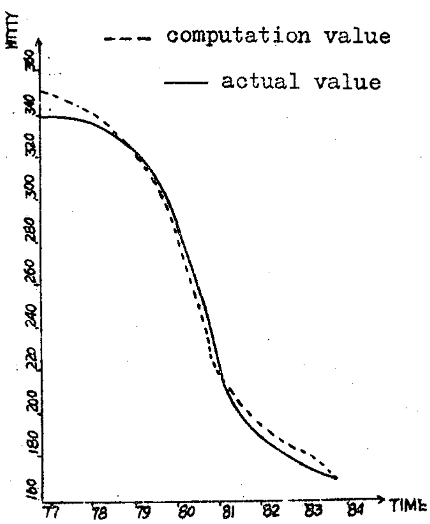

Fig. 7 Fit goodness relationship of water taking quantity per ten thousands yuan value of output

increase water quantity of repetitive utiliztion, improve the rate of repetitive utilization of water for decreasing the quatity of insustry water taking; b. to make an investment in processing improvement, to reform backward process, which uses more water in production, into an advanced one, which uses less water or needs no water, thus, increasing the level of industrial usage of water, as a result, decreasing the quantity of gross water used and water intaked; c. to improve the level of scientific management of industry water using, stop up water wasting loophole, tap the potentialities of water saving to reach a reasonable water using,scientific management of water can directly decrease the quantity of industry water taking to a certain extent, relieve the pressure of water saving.

In short, model can privide an effective experimental method and a field for urban water using, especially for the policy and management of industry water using. On these grounds administration concerned can, according to the changing of various policies, find out an effective way for solving unbalance between supply and demand under the conditions of present water resources, so that the limited water resources can make maximum economic benefit.

System Dynamics is a new technology of scientific management, it was introduced to China recently. Management work for urban water using just steps forward, a complete management system and theory are not formed yet, so there are no ready mode and rippened method for applying System Dynamics in the field of urban water using, it is only an initial attempt and process of practice. Owing to the limited knowledge of the author, there must be deficiency and errors, Kindly give us your advice.

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