SYSTEM DYNAMICS IN STRATEGIC PLANNING

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March 1990

ABSTRACT

One approach to strategic planning is called "gap analysis". In gap analysis, the future of an organization under its present strategy is forecasted. Then, objectives, or the desired future for that organization, is identified and the gap between the objectives and the future conditions under current strategy is determined. Finally, new strategies which will help to close the gap will be designed. System Dynamics can be used in two important ways in the gap analysis. First, System Dynamics model can be used to forecast the future of an organization under current strategies and identify the gap between that future and the objectives. Second, System Dynamics model can be used to examine how much each strategy can be helpful to close the gap. The application of System Dynamics in gap analysis method is shown by an example of developing a strategy for water resource development in Iran.

1. INTRODUCTION

Gap analysis is an approach to strategic planning (Kami 1968), (Hussey 1982, Ch. 10), (Glueck and Jauch 1984,P.57). The essence of gap analysis is shown in Figure 1. In gap analysis approach, expected state of the enterprise under current strategy is forecasted in the future, (point A in Figure 1). Then, the desired state of the enterprise is identified (point B in Figure 1). Management should design and implement new strategies to close the gap between the desired states and those expected under current strategies. Each strategic program and action is to contribute to closing the gap. Thus, in application of gap analysis approach there are two important tasks to be done. First, forecasting the future state of the system under current strategies, and second, predicting the effect of each new strategic action in closing the gap.

None of the two tasks can be done properly in qualitative and intuitive way. As Foreman (1983) correctly argues, the complexity of the corporation (and socio-economic systems, in general) operating in an environment characterized by rapid changes precludes intuitive analysis of the policies and strategic actions. A sound and proper analysis of the consequences of current and new strategies requires some quantitative approach which can consider the complex relationships between different elements creating the behavior of a system. System Dynamics (Richardson and Pugh 1982) could be very helpful in performing both of the above mentioned tasks. System Dynamics model could be built to show the behavioral consequences of the current strategy in the past as well as in the future. Future behavior of the system shows the gap between the desired and expected states of the system. Then the model can be used to examine the behavioral effect of each strategic action to close the gap. The remaining of this paper describes a case study of applying System Dynamics in gap analysis for water resources development.

2. WATER RESOURCES DEVELOPMENT SYSTEM

The water resources development system consists of five sectors: water supply facilities to control surface and ground water resources , distribution channels which transfer water from supply facilities to agricultural lands, transfer pipelines which transfer water from supply facilities to city distribution network, city water refinery and distribution network, and water sewages.

In Iran, water resources facilities in all five sectors are developed by government investments which take place through development budget. Table 1 shows estimates of the values of facilities, annual depreciation, and average annual investment during 1983 to 1988. As the table shows, average annual investment in water supply facilities and in water distribution channels are less than their respective annual depreciation. As a result, water facilities in these two important sectors of the system experienced a net deterioration.

While water resource facilities are deteriorating, population and demand for water are rising. Growing demand for water necessitates increase in the capacity of the facilities. As the result of increasing demand for water and the lack of growth of water supply, price of water, e.g., in agricultural sector has increased considerably.

Figure 1 shows a sketch of past performance and expected behavior of the water resource facilities under current strategies. Figure 1 also shows the desired behavior of water facilities in the future to satisfy the growing demand. New strategies should now close the gap between desired and expected behavior.

A System Dynamic model is developed to generate the future behavior under current strategies, and to examine the effect of different other strategies in closing the gap.(for a detailed description of the model see Mashayekhi and Bakhoda, 1989).

3. THE MODEL

The overall structure of the System Dynamics model of concern is shown in Figure 2. The model consists of ten endogenous sectors. Population and ground water are exogenous to the model. Four sectors that represent water resource facilities are: Water supply facilities, water distribution and draining channels, water transfer facilities to cities, and city water distribution facilities. As shown in Figure 3, development of each sector consists of five stages: development planning, feasibility study, engineering design, project construction, and operation (Mashayekhi 1989).

Flow of projects through different stages in each sector can be conceptualized by a series of rate and level variables. Figure 4 shows the flow of projects during development process for water supply facilities - for a detailed description of rate variables and correspondence decision rules, see Mashayekhi (1989). The flow of projects in other sectors of water development system is similar to what is shown in Figure 4.

4. USAGE OF MODEL TO EXAMINE EXPECTED BEHAVIOR UNDER CURRENT STRATEGIES

A model is constructed to show the expected behavior of the system under current policies. Current policies are as follow. (1)_ Investment for the development of water facilities is financed only by the government through development budget. In the last decade government's revenues have not increased, but because of population growth, demand on government expenditures has increased and raised budget deficit. For this pressure on government's financial resources, water development budget has been either constant or decreasing. It is assumed that water development budget is financed only by the government's revenues and will remain constant in the future. (2)_ The allocation of budget to different sectors of water resources system at different stages is proportional to the amount of budget required for the work in process in different sectors and stages. (3)_ Starting rate of development projects at different stages are based on the volume of projects at the previous stage. (4)_ Inactivating rate of the projects in the construction stage is zero. (5)_ Price of water is assumed to be constant. (6)_ Starting rate of feasibility study is a function of the discrepancy between projected demand for water and sum of water supply capacity under operation, construction, design, and study. With the current policies the behavior of the model is shown in Figure 5.

Analysis of the model behavior showed that under current policies, net deterioration of the water supply facilities is due to two factors. The first is inadequate investment to circumvent depreciation, and the second which was not quite clear prior to the analysis is the fact that under current policies, the cost of completing water resource projects is more than normal.

The analysis of the model behavior showed that due to the pressure from demand, starting rate of feasibility study increases and raises the number of feasible projects. As the number of feasible projects increases, the feasible projects move automatically forward into design stage, and next, into construction stage, and thus the number of projects under construction increases. This in turn, raises the fixed cost to keep projects ready for progress in construction. When total budget is constant and fixed cost increases, the remaining budget for construction work decreases and hence make the completion rate of the projects under construction fall. The fall of completion rate of the projects under construction rises more rapidly and causes fixed cost to increase to a higher value. As fixed cost rises, unit cost of projects increases. With higher unit cost and a constant development budget, fewer projects can be completed. Lower completion rate increases the gap between completion rate and depreciation, and accelerate the decline of water resources facilities.

5. USAGE OF MODEL TO EVALUATE THE NEW STRATEGIES

Budget Availability Effect on Starting Rate of New Projects:

One strategy which was thought to be effective to improve the behavior of the model, is to make the starting rate of new projects at different stages and different branches a function of available budget. When allocated development budget is less than desired budget, the starting rate is decreased relative to what it would be in the base run. The new strategy was thought to be effective because when due to inadequate budget, starting rates of new projects at different stages decrease, the number of projects under study, design, or construction would not rise, and therefor completion cost and completion time of the projects would not increase as before, and thus the behavior of the system would improve.

However, model simulation showed that the new strategy is not effective as was thought. The behavior of water supply facilities under the new strategy is shown in Figure 5, along with the behavior of the same variable under other strategies. As the figure shows, under the new strategy, water supply facilities decline in the same manner that it does under the base run policies. The reason for such behavior is the existence of a compensating negative feedback loop: When due to lower starting rate of the new projects, growth of projects under study, or construction decreases, the gap between growing demand for water (which is the result of growing population) and capacity of water facilities under design, construction, and operation increases. As the gap increases, pressures to start new projects rise and compensate the effect of inadequate budget on the starting rates of the new projects. As a result, the number of projects under development increases and the model shows the same behavior as in the base run. Thus, the new strategy can not help to close the gap between the desired and expected states of the system.

Inactivating Excess Projects Under Construction:

In this section, in addition to the consideration of the new starting rate policies, some of the projects in construction phase are inactivated when the available budget is less than desired. Inactivated projects have a lower fixed cost relative to active projects. Inactivated projects are activated when insufficiency of budget disappears. No construction activity takes place in inactivated projects and therefor no money is spent as variable cost. The behavior of the water supply facilities in the model under the new strategy is shown in Figure 5.

Inactivating excess projects under construction decreases fixed cost of projects under construction. Lower fixed cost allows more money to be available for construction activities and increases completion rate of projects. As completion rate increases, water facilities would become more available than it would be under the base run. As a result the capacity of water supply facilities does not decline as much as it did in the base run. This can be seen in Figure 5.The model shows that the new strategy is helpful to narrow the gap between desired and expected state of the system. However, the model behavior in Figure 5 shows that, although the new strategy narrows the gap, but still the capacity of the water supply facilities still declines because of the inadequacy of the development investment to hinder depreciation rate.

Borrowing Strategy:

In this section, in addition to the consideration of the new starting rates and inactivating rate policies, borrowing strategy is also examined. In Iran, development of water facilities requires both domestic and foreign currencies. Under the new strategy, the management of water resources borrows domestic and foreign currencies to upgrade its financial power so as to adequately respond to the investment need in water facilities development. The resultant domestic debts are paid back by collecting adequate connection fees for connecting different users to the newly developed water facilities. And the foreign debts are assumed to be paid back by the foreign currency saved through substitution of imported agricultural products as production of agricultural sector increases due to new water facilities developed. The model can be used to examine the behavioral results as well as the feasibility of the new strategy.

Figure 5 shows the behavior of water supply facilities under the new strategies. As the figure shows, the new strategy is very effective in increasing water supply facilities and closing the gap between desired and expected state of the system. As financial resources become more available through borrowing, available budget increases to provide the required variable budget to make adequate progress in the projects under development and complete them during a normal completion time. As completion time of projects decrease, so does the total fixed cost and unit cost of projects. With a lower unit cost, more water facilities can be completed with a given amount of financial resources. Under the new strategy, as far as the limits of water resources of the country allow, water supply facilities grow to satisfy growing demand. As more water supply facilities are developed to control the country's water resources, less water resources remain to be controlled by new facilities. As a result of limited water resources in the country, eventually growth of water supply facilities slow down, as is shown in Figure 5.

The model also shows the financial feasibility of the new strategy. In the model, connection fees are set as a fraction of market price for the availability of water on urban and agricultural lands. With such a feasible connection fees, the water sector will be able to pay back the domestic debts and interest expenses which occurs as a result of borrowing. Also the model shows that substitution of the imported agricultural products by the agricultural output from newly developed water facilities generate more foreign exchange savings than necessary to pay back the foreign debts of the water development sector. Figure 6 shows the behavior of domestic and foreign debts of the water sector under the borrowing strategy. As is shown in Figure 6, foreign debts become negative indicating net foreign exchange saving as a result of new water facilities development because of borrowing strategy.

6. CONCLUSIONS

System Dynamics models can be used in gap analysis to develop new strategies in two effective ways. First, it can be developed to show the expected state of a system in the future under current strategies and policies. Second, the models can be used to examine the feasibility, effectiveness, and efficiency of a proposed strategy to close the gap between expected and desired state of a system in the future. This paper showed such usage of a System Dynamics model in developing water resources development strategies.

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Table 1 : Annual Depreciation and Investment in Water Facilities

	Water Supply Facilities	Water Distribution Facilities	Water Transfer Facilities	Urban Water Facilities	Total
Capacity (Unit)	24 (10e9 Cub. M)	852000 (Hectare)	2.1 (10e9) (Cub. M./Yr)	1.3 (10e9) (Cub. M./Yr)	
Unit Cost at 1988 Price (Rials)	31.7e9	1188500	73.2e9	36.8e9	
Values at 1988 Price (10e9 Rials)	761.52	974.63	153.72	47.84	1937.71
Useful Life (Years)	50	30	30	30	
Annual Depreciation (10e9 Rials/Yr)	15.32	32.48	5.124	1.59	54.48
Average Annual Budget at 1988 Price During 1983-88 (10e9 Rials/Yr)	13.24	15.72	13.56	4.54	47.06

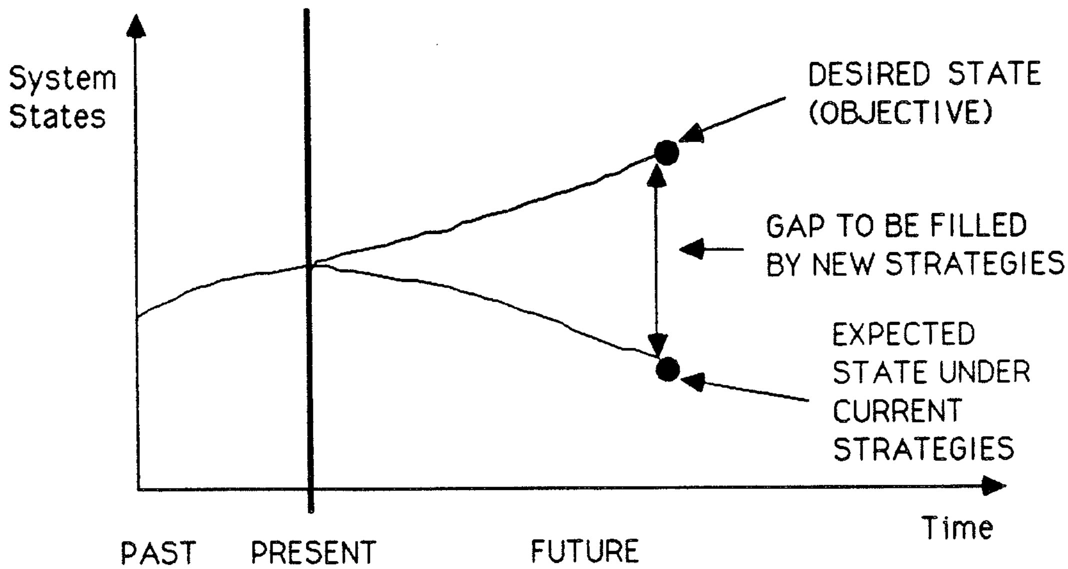

Figure 1: Gap Analysis in Strategic Planning

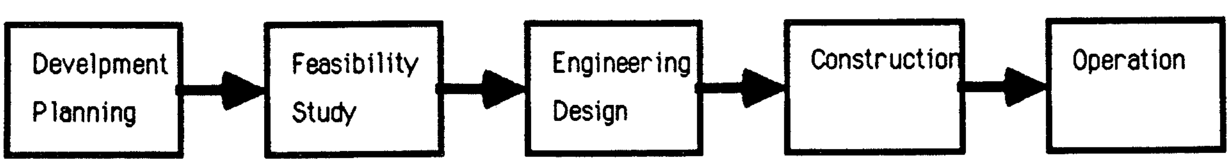

Figure 3: Stages of Water Development Projects in Each Sector.

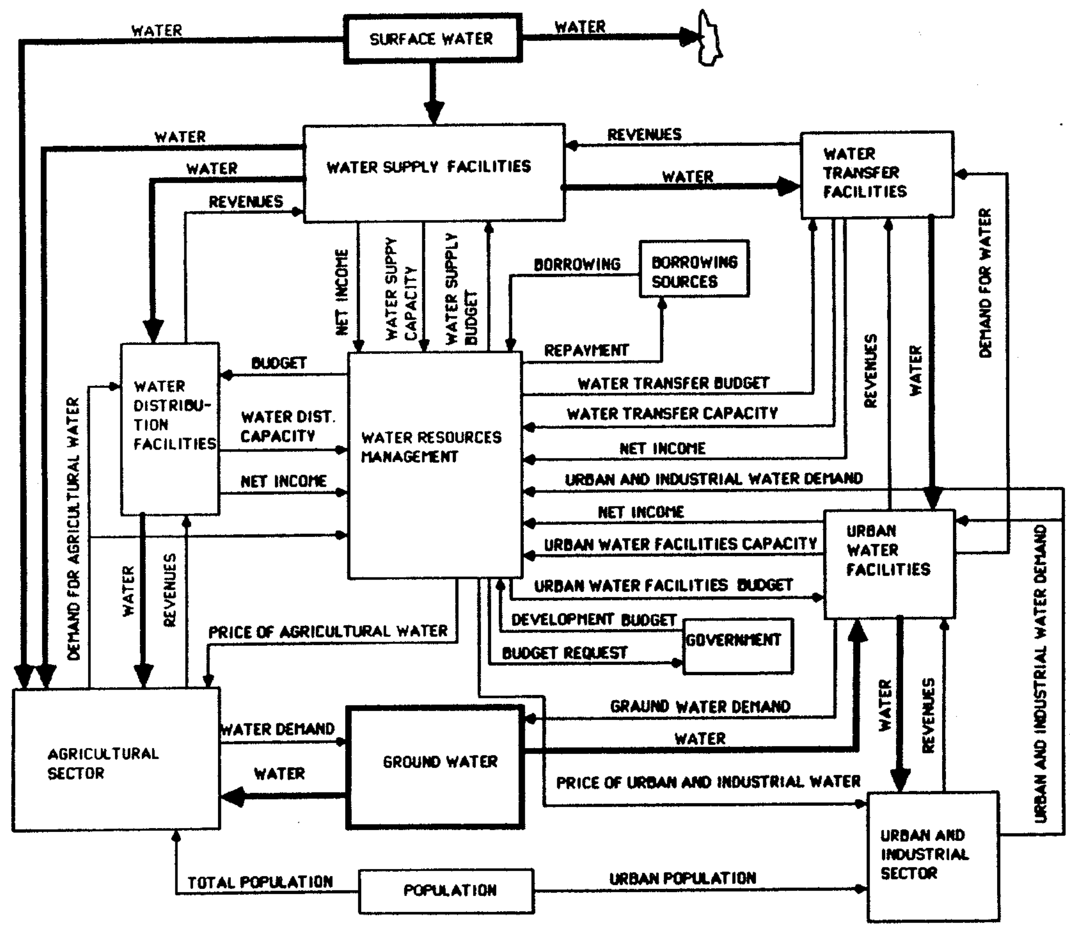

Figure 2: Overal Structure of The Model

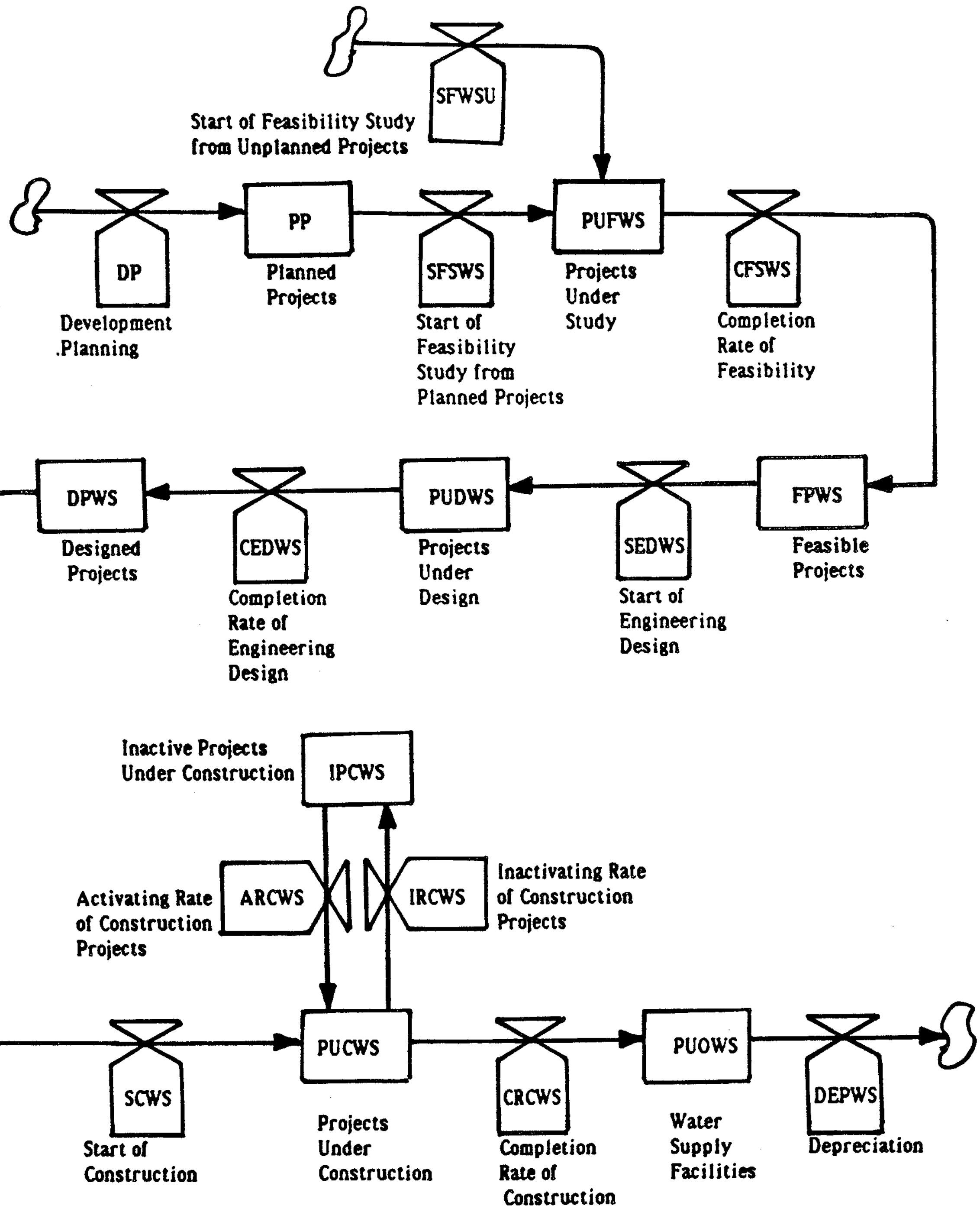

Figure 4: Flow of Projects in Water Development System.

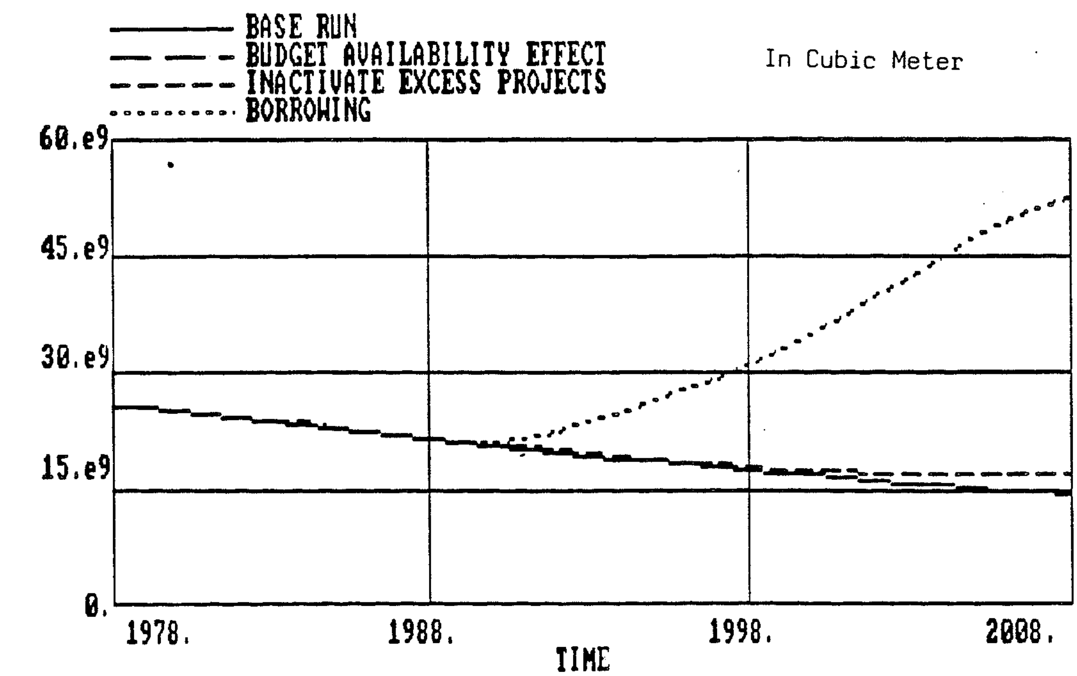

Figure 5: The Behavior of Water Supply Facilities Under Different Strategies.

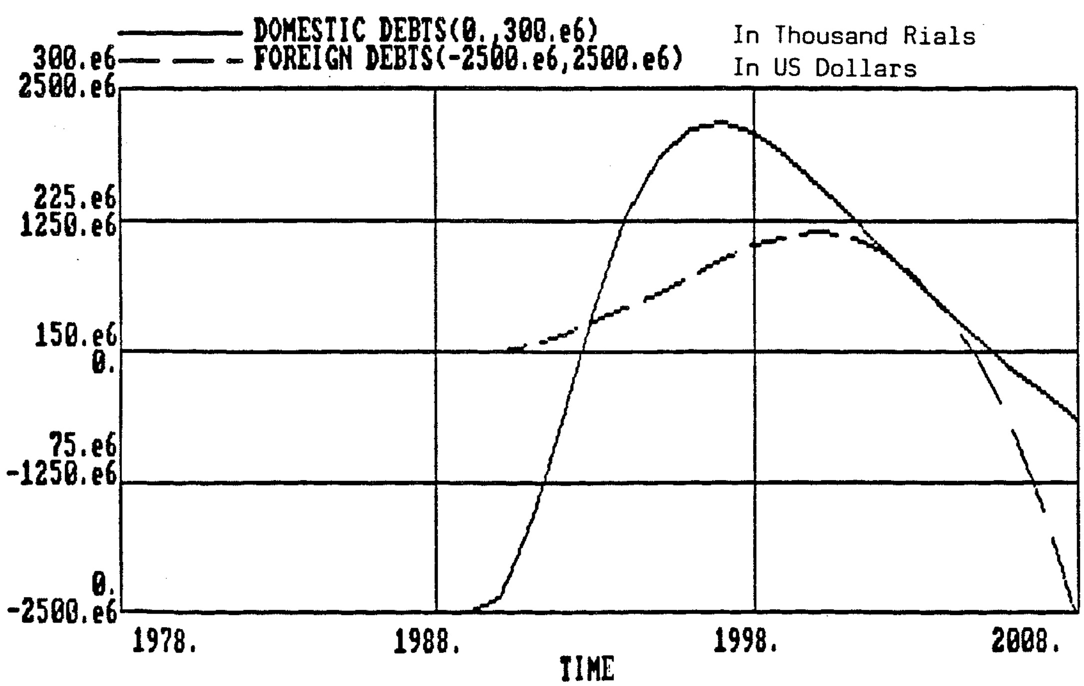

Figure 6: Domestic and Foreign Debts.