# Chapter 13

# Goal Programming for Decision Analysis in Government

In the same sense that a business corporation is an economic system that requires efficient planning, execution, and control by management aided by sound decision analysis, so may a government agency be regarded as such—indeed, should be. Basically, as an economic system a governmental agency has two primary functions:

1. Allocating the scarce resources in the most efficient manner to the production of goods and services that are to be consumed or invested.

2. Distributing the goods and services that it produces to the various groups that constitute the system in the most equitable manner.

As an economic system becomes more complex, the need for improved knowledge of the growing number of relationships and for an effective means of controlling these relationships becomes obvious. Government agencies have grown at a phenomenal rate during the past twenty years in their complexity and impact on the lives of the citizens. The widening scope and complexity of the government have been matched by the difficulties of coordination and decision analysis to provide needed services for the citizens. The basic decision





problem in government is selection of the optimum alternative among many competing programs because there is a scarcity of public resources in relation to overall demands and objectives.

There have been an abundance of studies and research on improving the efficiency of decision analysis in federal government agencies. However, only slight attention has been focused on decision analysis at municipal government level, especially for small to medium-sized municipalities.

Probably the most significant aspect of municipal government requiring effective decisions and controls is economic planning based on proper budgeting process. To date, relatively little has been done to apply an effective, fully integrated budget planning process to municipal economic planning with the aid of scientific decision techniques. This chapter presents a study that applies goal programming to economic planning in a small rural town. The model is specifically developed for the capital improvement requirements of a town for a three-year planning horizon. The author gratefully acknowledges Mayor John M. Barringer, Town Manager Mr. George Smith, and Treasurer Mrs. R. P. Brown of Blacksburg, Virginia, for their assistance in obtaining information and data for the study.

## AN AGGREGATIVE MODEL FOR MUNICIPAL ECONOMIC PLANNING[1]

Sang M. Lee and William R. Sevebeck

### INTRODUCTION

Municipal governments have never been so complex, numerous, and expensive to operate as they are today. Thus, economic planning of the municipal government has become one of the most difficult policy decision problems for local government officials. Policy analysis on the part of the administrator takes on a greater significance as the growing pains of the municipality multiply while available resources remain relatively steady. To accomplish the most efficient resource allocation, the administrator must establish sound long-range goals and priorities among these goals. This process is the most important part of policy analysis. Therefore, policy analysis is the foundation of economic planning that establishes means of coping with growing problems and scarce resources. This paper presents a goal programming model as an aggregative model for municipal economic planning.[2]

There are at least two reasons why a study of municipal economic planning is important. First, economic systems analysis of municipal governments, especially for small local municipalities, has been generally neglected by economists.[3] The second reason for undertaking a study in the problem area is that tools and facilities exist that are effective in designing and utilizing an aggregative economic planning model.

With the increasing size and complexity of the municipal government, a systematic analysis of relationships among the growing number of factors and an effective control of these relationships become imperative. Specifically, with the limited staffs and resources of many municipal governments, the burden of complex policy analysis falls more and more heavily upon a few administrators. Probably the most important and difficult aspect requiring effective decisions and control is budget planning.

To date, there have been only limited applications of effective, fully integrated budget planning processes aided by scientific decision techniques for municipal governments. One application has been suggested by Crecine, in which a computer simulation model comprising three basic stages of the municipal budgeting process was designed.[4] This suggested process is basically one of estimating revenues and expenditures, determining whether a change in controllable revenue sources is required, and deciding on the proper course of action to achieve the desired revenue. However, this simulation model does not consider the priority structure of the municipal government in planning economic activities based on the estimated revenues.

Another popular systems-oriented procedure for the budgeting process is the planning-programming-budgeting system, or PPBS.[5] This application has received general acceptance by agencies of the federal government, as well as many state and local governments. The PPB system is an output-oriented administrative process. The underlying goal is to achieve a broad, common objective with the minimum resources in a long-range planning horizon. The general objective must be broken down into subobjectives or subgoals, which are further reduced until a set of specific program elements emerges. The unit cost of these program elements forms the basis for cost-effectiveness analysis,[6] which compares the quantity and quality of output per dollar of expenditure for alternative programs. This approach to governmental decisions parallels the "heuristic programming" procedure for ill-structured or highly complex problems. The PPB system involves systematic thinking about objectives and alternative courses of action with regard to resource constraints.

The PPBS seems to be particularly well suited to municipal economic planning programs.[7] The planning of municipal expenditures involves such problems as multiple subobjectives relating to overall goals, numerous alternatives to achieve these goals, interrelationships among subgoals, and a system of constraints, such as limited financial and temporal resources. The PPB system is a management process, yet it does not automatically provide an optimization model for economic planning. There is a need for an effective tool to design an aggregative economic model if PPBS implementation is to be truly effective.

The problem of multiple goals with varying degrees of priority levels in municipal governments quickly compounds the policy analysis process, and it prohibits the solution by a simple linear programming approach. With the application of goal programming, it is possible to render optimal solutions to complex economic planning problems for the municipal government.



## AN EMPIRICAL STUDY

### A. The Data

In order to illustrate the design of the model, empirical data acquired from the municipal government of Blacksburg, Virginia, will be used. Blacksburg has a town manager form of municipal government. It is responsible for building and maintaining public rights-of-way, municipal planning and zoning, enforcement of traffic regulations, control of public utilities, and related operations. Municipal tax and public utility rates are also set by the town. The Town Council provides funds for town beautification, recreational areas, and equipment, as well as public land and institutions.

Blacksburg is a rapidly growing university town.[8] The natural population increase, the growth of the university, and the expansion of existing industries clearly indicate the need for new business areas and additional services to be provided by the local government in the not too distant future. But, in many cases, the immediate satisfaction of these needs will not be possible by the time that they make themselves obvious. This type of municipal responsibility also entails long-range planning and the efficient allocation of financial resources to ensure that future needs are satisfactorily met on time.

A capital improvement budget for the town is prepared on an annual basis. There is no formal long-term program which includes those projects that cannot be financed during the fiscal year but can be undertaken sometime within the next five years. For the illustrative purposes of the model, a three-year planning period will be used. The town's budgeting process takes place through essentially two funds, the general fund and the water and sewer fund. In the event that bond financing is used for some series of projects, a bond fund is also maintained. However, in the model the activity pertaining to bond financing will take place in the general fund. This has been done since all capital improvements

Table 13.1

Revenue and Expenditure Variables

**A. Revenue**

| *Fund* | *Current* | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|
| General fund | | | | |
| Amount of 1-year bank loan ($1,000) | 0 | $x_1$ | $x_{12}$ | $x_{21}$ |
| Assumed credit limits ($1,000) | | 100.00 | 100.00 | 100.00 |
| Amount of new bond issue ($1,000) | 0 | $x_2$ | $x_{13}$ | $x_{22}$ |
| Assumed upper limits of issue ($1,000) | | 0 | 200.00 | 250.00 |
| Property tax rate/$1,000 of assessed value | $20.00 | $b_1$ | $b_5$ | $b_9$ |
| Assumed upper limits | | 20.00 | 25.00 | 25.00 |
| Effective business license tax rate/$1,000 of receipts | $2.10 | $b_2$ | $b_6$ | $b_{10}$ |
| Assumed upper limits | | 2.30 | 2.50 | 2.50 |
| Average garbage collection charge/collection | $2.50 | $b_3$ | $b_7$ | $b_{11}$ |
| Assumed upper limits | | 2.50 | 2.75 | 3.00 |
| Real property valuation base ($1,000) | $8,503.05 | $a_1$ | $a_1$ | $a_1$ |
| Gross business receipts ($1,000) | $20,134.00 | $a_2$ | $a_2$ | $a_2$ |
| Number of garbage collections | $29,800.00 | $a_3$ | $a_3$ | $a_3$ |
| Water and sewer fund | | | | |
| Transfer from general fund | 0 | $x_5$ | $x_{16}$ | $x_{25}$ |
| Assumed lower limits | | 0 | 0 | 0 |
| Water and sewer service rate/10,000 gal. | $7.00 | $b_4$ | $b_8$ | $b_{12}$ |
| Assumed upper limits | | 7.00 | 7.50 | 8.00 |
| Water and sewer service charge base | $47,616.00 | $a_6$ | $a_6$ | $a_6$ |
| Fixed Revenues | | | | |
| General fund | ——— | $a_{12}$ | $a_{14}$ | $a_{16}$ |
| Value used | | 240,493.00 | 240,493.00 | 240,493.00 |
| Water and sewer fund | ——— | $a_{19}$ | $a_{20}$ | $a_{21}$ |
| Value Used | | 16,459.00 | 16,459.00 | 16,459.00 |

**B. Expenditure**

| *Fund* | *Value* | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|
| General fund | | | | |
| Percent of completion to Main St. (Clay to Roanoke) | ——— | $x_3$ | $x_{14}$ | $x_{23}$ |
| Percent of completion of Main St. (Faculty to north corporate limits) | ——— | $x_4$ | $x_{15}$ | $x_{24}$ |

(Continued)

Table 13.1 (Continued)

**B. Expenditure** (Continued)

| *Fund* | *Value* | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|
| Transfer to water and sewer fund | --- | $x_5$ | $x_{16}$ | $x_{25}$ |
| Repayment to prior year's loan ($1,000) | --- | | $x_1$ | $x_{12}$ |
| Amount of principle due on first-year bonds | --- | | $a_9x_2$ | $a_9x_2$ |
| Amount of principle due of second-year bonds | --- | | | $a_9x_{13}$ |
| Prevailing interest rate on new bond issue | 0.05 | $a_{18}$ | $a_{18}$ | $a_{18}$ |
| Prevailing interest rate on bank loan | 0.06 | $a_{11}$ | $a_{11}$ | $a_{11}$ |
| Main St. improvement cost (Clay to Roanoke) ($1,000) | $87.4 | $a_4$ | $a_4$ | $a_4$ |
| Main St. improvement cost (Faculty to north corporate limits) | $1,018.9 | $a_5$ | $a_5$ | $a_5$ |
| Percent of new bond issue to be returned each year ($1,000) | 10.0 | $a_9$ | $a_9$ | $a_9$ |
| Water and sewer fund | | | | |
| Percent of completion of water tank A | --- | $x_9$ | $x_{18}$ | $x_{27}$ |
| Percent of completion of water tank B | --- | $x_{10}$ | $x_{19}$ | $x_{28}$ |
| Cost of water tank A ($1,000) | 70.0 | $a_7$ | $a_7$ | $a_7$ |
| Cost of water tank B ($1,000) | 70.0 | $a_8$ | $a_8$ | $a_8$ |
| Fixed expenditures | | | | |
| General fund | --- | $a_{13}$ | $a_{15}$ | $a_{17}$ |
| Value used | | $637,516 | 655,816 | 653,586 |
| Water and sewer fund | --- | $a_{22}$ | $a_{23}$ | $a_{24}$ |
| Value used | | $374,161 | 374,161 | 374,161 |

**C. Beginning and Ending Balances**

| | | | | |
|---|---|---|---|---|
| Beginning balances | | | | |
| General fund | | $x_6$ | | |
| Water and sewer fund | | $x_8$ | | |
| Ending balances | | | | |
| General fund | | $x_7$ | $x_{17}$ | $x_{26}$ |
| Water and sewer fund | | $x_{11}$ | $x_{20}$ | $x_{29}$ |

will be made out of either the general fund or the water and sewer fund, and provisions for transfers to the water and sewer fund will be made.

If the town is to provide an environment attractive to new industry and business, and also capable of meeting the needs of a growing population, it must consider the type of capital improvements that will contribute to achieving this goal and the relative priorities of their completion. It must also take into consideration what costs and revenue requirements will be involved and whether or not additional financing will be required.

The general fund and the water and sewer fund were broken down into variable revenues and expenditures and fixed revenues and expenditures. Included in the variable expenditures were terms that represented the amount of money to be spent in a year for each capital improvement project. Each set of variables (general fund and water and sewer fund) was given a different designation for each year. There were six basic subgoals for the three-year planning period, these subgoals being to remain solvent in each fund at the end of each fiscal year. In addition to the subgoals, each variable was constrained according to what were believed to be the objectives of the town. The list of revenue variables, revenue variable coefficients, expenditure variables, expenditure variable coefficients, fixed revenues, fixed expenditures, beginning balances, and ending balances is given in Table 13.1.

## B. Subgoals, Constraints, and Objective Functions

To summarize the long-range goals of the town, there is a serious need to increase the number of businesses and industries in the town in order to create a broader economic base, so that the town may become economically less dependent on population as such. At the same time, however, the physical needs of a rapidly expanding population must be adequately met. The financial resources of the town are limited and must be efficiently allocated to meet the present needs, and in addition provisions must be made for future needs. According to the Blacksburg Planning Commission, the most viable area for new business development is along Main St. from Faculty St. north. In addition, Main Street must be widened and improved from Clay Street to Roanoke Street. It is desirable that both of these stretches should be completed within the next three years.[9] Also, it is essential to improve water storage capacity within this period, which will require two new water tanks. These may be constructed concurrently.[10]



The goal programming model thus developed contained 29 real variables, 70 deviational and/or slack variables, and 35 constraints. The general subgoal equations, in both descriptive and algebraic forms, are presented below. It should be noted that since there are no deviational variables in the subgoal equation, slack variables ($S_i$) will have to be inserted.

### *GENERAL FUND, YEAR 1:*

(short-term bank loan + amount of new bond issue + property tax revenue + business license taxes + garbage collection charges) + (fixed revenue) − [(amount spent on Main St., Clay to Roanoke) + (amount spent on Main Street, Faculty to north corporate limits) + (interest due on new bonds)] − (fixed expenditures) − (transfer to water and sewer fund) + (beginning balance) − (ending balance) = 0

$$\begin{aligned}(13.1)\quad & 1000x_1 + 1000x_2 + a_1b_1 + a_2b_2 + a_3b_3 + a_{12} - a_4x_3 - a_5x_4 \\ & - a_{18}x_2 - x_5 + x_6 - x_7 + S_1 = 0\end{aligned}$$

### *WATER AND SEWER FUND, YEAR 1:*

(water and sewer service charges) − (amount spent on water tank A) − (amount spent on water tank B) + (transfer from general fund) − (ending balance) = 0

$$(13.2)\quad a_6b_4 + a_{19} - a_7x_9 - a_8x_{10} - a_{22} + x_5 + x_8 - x_{11} + S_2 = 0$$

### *GENERAL FUND, YEAR 2:*

(short-term bank loan + amount of new bond issue + property taxes + business license taxes + garbage collection charges) + (fixed revenue) − [(amount spent on Main Street, Clay to Roanoke, year 2) + (amount spent on Main Street, North, year 2) + (interest due on year 1 bonds) + (principle due on year 1 bonds) + (interest due on year 2 bonds) + (repayment of Year 1 bank loan) + (interest due on year 1 bank loan)] − (fixed expenditures) − (transfer to water and sewer fund) + (beginning balance) − (ending balance) = 0

$$(13.3)\quad 1000x_{12} + 1000x_{13} + a_1b_5 + a_2b_6 + a_3b_7 + a_{14} - a_4(x_{14} - x_3) - a_5(x_{15} - x_4) - a_{18}(x_2 - a_9x_2/1000) - a_9x_2 - a_{18}x_{13} - 1000x_1 - a_{11}x_1 - a_{15}x_{16} + x_7 - x_{17} + S_3 = 0$$

*WATER AND SEWER FUND, YEAR 2:*

(water and sewer service charges) – (amount spent on water tank A, year 2) – (amount spent on water tank B, year 2) + (transfer from general fund) + (beginning balance) – (ending balance) = 0

$$(13.4)\quad a_6b_8 + a_{20} - a_7(x_{18} - x_9) - a_8(x_{19} - x_{10}) - a_{23} + x_{16} + x_{11} - x_{20} + S_4 = 0$$

*GENERAL FUND, YEAR 3:*

(short-term bank loan + amount of new bond issue + property taxes + business license taxes + garbage collection charges) + (fixed revenue) – [(amount spent on Main Street, North, year 3) + (amount spent on Main Street, Clay to Roanoke, year 3) + (interest due on year 1 bonds) + (principle due on year 1 bonds) + (interest due on year 2 bonds) + (principle due on year 2 bonds) + (interest due on year 3 bonds) + (principle due on year 3 bonds) + (repayment of year 2 bank loan) + (interest due on year 2 bank loan)] – (fixed expenditures) – (transfer to water and sewer fund) + (beginning balance) – (ending balance) = 0

$$(13.5)\quad 1000x_{21} + 1000x_{22} + a_1b_9 + a_2b_{10} + a_3b_{11} + a_{16} - a_4(x_{23} - x_{14}) + a_5(x_{24} - x_{15}) - a_{18}(x_2 - 2a_9x_2/1000) - a_9x_2 - a_{18}(x_{13} - a_9x_{13}/1000) - a_9x_{13} - a_{18}x_{22} - 1000x_{12} - a_{11}x_{12} - a_{17} - x_{25} + x_{17} - x_{26} + S_5 = 0$$

*WATER AND SEWER FUND, YEAR 3:*

(water and sewer service charges) – (amount spent on water tank A, year 3) – (amount spent on water tank B, year 3) + (transfer from general fund) + (beginning balance) – (ending balance) = 0



$$(13.6)\quad a_6b_{12} + a_{21} - a_7(x_{17} - x_{18}) - a_8(x_{28} - x_{19}) - a_{24} + x_{25} + x_{20} - x_{29} + S_6 = 0$$

The category "variable revenue" (bank loans, bonds, property taxes, business license taxes, and garbage collection charges) provides for two common forms of external financing, as well as three of the most significant sources of revenue in the town budget. In addition to the above revenue sources the water and sewer fund utilizes the combined water and sewer service charges. The bank loans and bonds were left as unknown in the model, since it was desired to solve for only the amount of financing needed and no more. However, these external sources of funds were constrained by establishing upper limits of borrowing for each year. Thus, if external funds were required, they could only be appropriated up to the amounts set by the credit limits. As for the internal sources of revenue, these were precalculated before insertion into the model; therefore, they were treated as constraints in the development of the final model. The values used for each of these rates were assumed to be the permissible upper limits for each year as determined by the existing financial policies of the town. These rates multiplied by their respective computation bases yielded the maximum amounts of revenue expected in each year from these sources. This is a type of procedure that would normally be used in budget planning regardless of goal programming. The "fixed revenue" terms in the subgoals consisted of budget items that, although variable to some extent, were not considered to contribute significantly to revenue individually, nor were they related to the planned capital expenditures.

As it may be noted from the subgoal relationships, the primary financial activity takes place through the general fund, which is common to many municipalities. With respect to major capital expenditure, the general fund has been utilized for all new road construction or street improvements. The water and sewer fund has been used for construction of new water tanks. Although it is possible for needed extra funds to come into the water and sewer fund from the general fund if they are available, it was felt that any revenues accruing from water or sewer sources should be applied only to water and sewer expenditures. Also, the general fund has access to external financing, but the water and sewer fund does not. Whereas the subgoal equations allow for transfers into the water and sewer fund, there were no transfers permitted out of it into the general fund. It was also necessary to assume for purposes of the model that all capital expenditures would be on a "pay-as-you-go" basis since construction can conceivably take place in all years of the planning period. Furthermore, many of the variables that were developed had to be simplified in order to include them successfully in the model. For instance, the business license tax actually consists of a schedule rather than one flat rate. However, this does not detract from the usefulness of the model for budget programming. The model will pinpoint the expected degree of completion of projects based on the expected values of various revenues, not rates in particular.

Although the general model can be adapted to changing environmental conditions by forecasting the expected values of the revenue and expenditure coefficients for each year in the planning period, for the purpose of clarity, this was not done in this paper. Instead, it was assumed that for the three-year period under consideration, factors such as gross business receipts, water consumption, etc., remained constant.

By substituting the various coefficients, constants, and deviational variables into the subgoals and rearranging, the appropriate constraints may be written as shown in Table 13.2.

Table 13.2

Model Constraints

General fund, year 1:

$$1000x_1+950x_2-87.4x_3-1018.9x_4-x_5+x_6-x_7+S_1=47{,}305 \tag{13.7}$$

Water and sewer fund, year 1:

$$-x_5-x_8+70x_9+70x_{10}+x_{11}+S_2=3{,}129 \tag{13.8}$$

General fund, year 2:

$$-1060x_1-145x_2+87.4x_3+1018.9x_4+x_7+1000x_{12}+950x_{13}-87.4x_{14} -1018.9x_{15}-x_{16}-x_{17}+S_3=1{,}614 \tag{13.9}$$

Water and sewer fund, year 2:

$$70x_9+70x_{10}+x_{11}+x_{16}-70x_{18}-70x_{19}-x_{20}+S_4=582 \tag{13.10}$$

General fund, year 3:

$$-140x_2-1060x_{12}-145x_{13}+87.4x_{14}+1018.9x_{15}+x_{17}+1000x_{21} +940x_{22}-87.4x_{23}-1018.9x_{24}-x_{25}-x_{26}+S_5 = 1{,}934 \tag{13.11}$$

Water and sewer fund, year 3:

$$-70x_{18}-70x_{19}-x_{20}-x_{25}+70x_{27}+70x_{28}+x_{29}+S_6 = 23{,}226 \tag{13.12}$$

Other constraints:



(13.13)

| | |
|---|---|
| $x_1+d_1^-=100.0$ | $x_{16}-d_{13}^++S_{13}=0$ |
| $x_2+S_7=0$ | $x_{17}-d_{14}^++S_{14}=0$ |
| $x_3+d_2^-=1000.00$ | $x_{18}+d_{15}^-=1000.00$ |
| $x_4+d_3^-=1000.00$ | $x_{19}+d_{16}^-=1000.00$ |
| $x_5-d_4^++S_8=0$ | $x_{20}-d_{17}^++S_{15}=0$ |
| $x_6+S_9=0$ | $x_{21}+d_{18}^-=100.00$ |
| $x_7-d_5^++S_{10}=0$ | $x_{22}+d_{19}^-=250.00$ |
| $x_8+S_{11}=0$ | $x_{23}+d_{20}^-=1000.00$ |
| $x_9+d_6^-=1000.00$ | $x_{24}+d_{21}^-=1000.00$ |
| $x_{10}+d_7^-=1000.00$ | $x_{25}-d_{22}^++S_{16}=0$ |
| $x_{11}-d_8^++S_{12}=0$ | $x_{26}-d_{23}^++S_{17}=0$ |
| $x_{12}+d_9^-=100$ | $x_{27}+d_{24}^-=1000.00$ |
| $x_{13}+d_{10}^-=200.00$ | $x_{28}+d_{25}^-=1000.00$ |
| $x_{14}+d_{11}^-=1000.00$ | $x_{29}-d_{26}^++S_{18}=0$ |
| $x_{15}+d_{12}^-=1000.00$ | |

## C. Solutions

The goal programming solution is primarily based upon the priority structure of the established goals. In other words, the model dictates the solution according to the policy of the administration. In this study three separate solutions are presented according to the priority structure of goals.

Because of the nature of the simplex algorithm for solving goal programming problems, if there is no evident first solution by inspection, which is the case in this model, an artificial slack variable must be provided whenever no such real variables $d_i$ exist. Because it is necessary to eliminate these slack variables from the program first, they must be assigned the uppermost priority, $P_1$, to be minimized to zero. These slack variables include the variable that represents no new bonds in year 1. This is necessary because the town issued $850,000 bonds in 1968. In all three solutions, the first goal remained the same.

## Solution 1

The administration has no definite priority structure of goals. However, the road improvement projects are thought to be the most immediate problems of the town.

### 1. *PRIORITIES OF GOALS*[11]

$P_2$: Since it is desirable to obtain external financing before attempting to start any projects, the second priority factor, $P_2$, is assigned to minimizing underachievement of the credit limits for bank loans and bonds.

$P_3$: The third goal is to complete the improvement of two Main Street sections. The completion of a short section between Clay Street and Roanoke Street is assumed to be twice as urgent as one between Faculty Street and the corporate limits.

$P_4$: The fourth goal is to complete the construction of two water tanks. It is desired, however, to complete tank A before tank B is considered. Therefore, twice the weight is assigned to the completion of tank A.

$P_5$: It is desirable to be able to utilize any surpluses resulting in the general fund for the water and sewer fund. Therefore, the fifth goal is the minimization of any overachievement of the transfer constraint from zero.

$P_6$: The last goal is the minimization of ending balances in the general fund and water and sewer fund.

### 2. *OBJECTIVE FUNCTION*

$$
\begin{aligned}
\text{(13.14)}\quad \text{Min } Z = {} & P_1 \sum_{i=1}^{18} S_i + P_2 d_1^- + P_2 d_9^- + P_2 d_{10}^- + P_2 d_{18}^- + P_2 d_{19}^- + 2P_3 d_2^- \\
& + 2P_3 d_{11}^- + 2P_3 d_{20}^- + P_3 d_3^- + P_3 d_{12}^- + P_3 d_{21}^- + 2P_4 d_6^- + 2P_4 d_{15}^- \\
& + 2P_4 d_{25}^- + P_4 d_7^- + P_4 d_{16}^- + P_4 d_{15}^- + P_5 d_4^+ + P_5 d_{13}^- + P_5 d_{22}^- \\
& + P_6 d_5^+ + P_6 d_8^+ + P_6 d_{14}^- + P_6 d_{17}^- + P_6 d_{23}^- + P_6 d_{26}^-
\end{aligned}
$$

subject to the constraints set forth above.

### 3. *THE RESULTS*

The results of the computer solution are presented in Table 13.3. With the output variables shown in the table, the following achievement of goals resulted.



$P_1$: Achieved—no bonds were issued in year 1

$P_2$: Achieved—the full borrowing limits were utilized for bank loans and bonds.

$P_3$: Not achieved—the Clay Street to Roanoke Street section is completed in year 2, but the Faculty Street to north corporate limits section is completed only 24.36% in year 3.

$P_4$: Not achieved—water tank A is completed only 36,82% at the end of year 3, and tank B is not even considered.

$P_5$: Achieved—road improvements exhausted funds in the general fund and there was none to be transferred to the water and sewer fund.

$P_6$: Achieved—all funds were exhausted and there were no ending balances.

Table 13.3

Solution 1: Model Results

| | Computer Value | | |
|---|---|---|---|
| ***A. Revenue Variables*** | | | |
| *Fund* | *Year 1* | *Year 2* | *Year 3* |
| General Fund | | | |
| Amount of 1-year bank loan ($1,000's) | 100.00 | 100.00 | 100.00 |
| Amount of new bond issue ($1,000's) | 0 | 200.00 | 250.00 |
| Water and sewer fund | | | |
| Transfers from general fund | 0 | 0 | 0 |
| ***B. Expenditure Variables*** | | | |
| General fund | | | |
| Percent of completion of Main St. (Clay St. to Roanoke St.) | 60.29 | 100.00 | 100.00 |
| Percent of completion of Main St. (Faculty St. to north corporate limits) | — | 14.49 | 24.36 |
| Ending balances | 0 | 0 | 0 |
| Water and sewer fund | | | |
| Percent of completion of water tank A | 4.47 | 8.11 | 36.82 |
| Percent of completion of water tank B | — | — | — |
| Ending balances | 0 | 0 | 0 |

## Solution 2

When the outcome of the first solution was presented, the town administration realized the fallacies in its priority structure of goals. The most urgent immediate need is an additional water tank. It must be completed by the end of year 2. It is also desirable to start the second water tank as soon as possible. The second solution is based upon this modification of priorities.

### 1. *PRIORITIES OF GOALS*

$P_2$: Same as solution 1.
$P_3$: The third goal is to complete the needed water tanks. Since it is desirable to complete tank A in year 2 before tank B is considered, twice the weight is assigned to the completion of tank A in comparison to tank B.
$P_4$: The fourth goal is to complete the improvement of the road sections. The shorter of the two sections, Clay Street to Roanoke Street, is assumed to be twice as urgent as Faculty Street to north corporate limits.
$P_5$: Same as solution 1.
$P_6$: Same as solution 1.

### 2. *THE RESULTS*

The objective function will not be repeated here, since the only change in the function will be the transposition of $P_3$ and $P_4$. The results of the computer solution are presented in Table 13.4. With the output variables shown in the table, the following goal attainments are possible.

$P_1$: Achieved.
$P_2$: Achieved.
$P_3$: Achieved—water tank A is completed 79.75% at year 1 and 100% in year 2; water tank B is also 100% completed in year 2.
$P_4$: Not achieved—the improvement of Clay Street to Roanoke Street is completed in year 2; however, the Faculty Street to north corporate limits section is completed only 1% in year 2 and 20.54% in year 3.
$P_5$: Achieved—appropriate transfers are made.
$P_6$: Achieved.



Table 13-4

Solution 2: Model Results

| *Fund* | *Computer Value* Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| **A. Revenue Variables** | | | |
| General fund | | | |
| Amount of 1-year bank loan ($1,000's) | 100.00 | 100.00 | 100.00 |
| Amount of new bond issue ($1,000's) | 0 | 200.00 | 250.00 |
| Water and sewer fund | | | |
| Transfers from general fund | $52,695.00 | $84,757.75 | 0 |
| **B. Expenditure Variables** | | | |
| General fund | | | |
| Percent of completion of Main St. (Clay St. to Roanoke St.) | — | 100.00 | 100.00 |
| Percent of completion of Main St. (Faculty St. to north corporate limits) | — | 1.00 | 20.54 |
| Ending balances | 0 | 0 | 0 |
| Water and sewer fund | | | |
| Percent of completion of water tank A | 79.75 | 100.00 | 100.00 |
| Percent of completion of water tank B | — | 100.00 | 100.00 |
| Ending balances | 0 | 0 | 0 |

## Solution 3

The town administration was not completely happy with the outcome of the model. The completion of water tank A in year 2 is necessary, but the completion of tank B in the same year is not the most urgent project. The administration desires to start tank B with the water and sewer fund alone and use all other available funds for the completion of road improvements. The third solution is based upon this modification of goals.

### *1. PRIORITIES OF GOALS*

$P_2$: Same as solution 1.
$P_3$: The third goal is the completion of water tank A and the road improvement between Clay Street and Roanoke Street. However, completion of tank A is given twice the weight.
$P_4$: The fourth goal is the completion of the road improvement between Faculty Street and north corporate limits and water tank B. The road improvement is assumed to be twice as urgent as the completion of water tank B.
$P_5$: Same as solution 1.
$P_6$: Same as solution 1.

### *2. THE RESULTS*

The results of the computer solution of the third run are presented in Table 13.5. The degrees of goal attainments are:

$P_1$: Achieved.
$P_2$: Achieved.
$P_3$: Achieved—water tank A is 79.74% completed in year 1 and 100% completed in year 2. The improvement of the Clay Street to Roanoke Street section is completed in year 2.
$P_4$: Not achieved—the Faculty Street to north corporate limits sections is 7.87% completed in year 2 and 17.74% complete in year 3; water tank B is completed only 33.18% in year 3.
$P_5$: Achieved—appropriate transfers are made.
$P_6$: Achieved.



Table 13.5

Solution 3: Model Results

| *Fund* | Computer Value *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|
| **A. Revenue Variables** | | | |
| General fund | | | |
| Amount of 1-year bank loan ($1,000) | 100.00 | 100.00 | 100.00 |
| Amount of new bond issue ($1,000) | 0 | 200.00 | 250.00 |
| Water and sewer fund | | | |
| Transfers from general fund | $52,695.00 | $14,757.98 | 0 |
| **B. Expenditure Variables** | | | |
| General fund | | | |
| Percent of completion of Main St. (Clay to Roanoke St.) | 0 | 100.00 | 100.00 |
| Percent of completion of Main St. (Faculty St. to north corporate limits) | 0 | 7.87 | 17.74 |
| Ending balances | 0 | 0 | 0 |
| Water and sewer fund | | | |
| Percent of completion of water tank A | 79.74 | 100.00 | 100.00 |
| Percent of completion of water tank B | | 0 | 33.18 |
| Ending balances | 0 | 0 | 0 |

The solution outcome provided by solution 3 indicates that the administration could achieve the most urgent goals and get a start toward other important goals. This solution provides the best outcome to be expected under the given decision environment. The model has shown that, with the existing limitations of financing, tax schedules, and service charges, and the priority structure, it was not possible to achieve full completion of all the projects. However, the most important goals were met to the greatest extent, consistent with the assigned priorities. This type of situation is quite common in municipal planning.

## CONCLUSION

A goal programming model has been developed specifically for the town of Blacksburg for illustrative purposes in this study. This approach can be applied, with some variations according to the characteristics of the municipal government, to many municipal planning problems. The model can be expanded to comprise a much larger scope of consideration, a finer treatment of goals, and a longer planning horizon.

The goal programming approach requires administration to identify and establish critical interrelationships, and define the relative importance of various objectives. The structure thus derived represents a given policy or set of policies. Goal programming modeling helps to determine where some incompatibility exists among goals under a given policy and where the policy must be reviewed and modified in view of the most desirable objectives.

The simulation capability of the goal programming model provides the following four important advantages:

1. It can save considerable time in planning economic activities of the municipal government.

2. The results of the model may be used for further planning, realignment of goals, and reevaluation of constraints. In this case, the upper limits of property tax, business license tax, water service, or garbage collection rates may have to be reconsidered.

3. Further, if the absolute upper limit of credit has not been used, the information derived from the model can be useful in planning for additional external financing.

4. This approach to economic planning stresses the organized and integrated understanding of objectives, the interrelationships among variables in the system, and a careful consideration of alternatives and constraints. It is believed that this type of systematic thinking by management will lead to long-range effectiveness in planning, operations, and control.



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