# ESTABLISHING PRIORITIES

# FOR

# CONSTRUCTION GRANTS

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## APPENDIX B

## ESTABLISHING PRIORITIES FOR CONSTRUCTION GRANTS

The purpose of establishing priorities for disbursement of construction grant funds is to make it possible to select among a large number of projects applying for limited amounts of available Federal and State funds. The object of the selection procedure is to find that subset of projects which will be most effective in correcting water quality and public health problems without exceeding the available budget. The extent to which a project alleviates public health and water quality problems is measured by its benefits, while the question of whether or not a set of projects can be undertaken with available funds is answered by comparing the sum of the costs for all of the projects in each year with the annual budget for that year. The rpose of the priority system can thus be rephrased... "Maximize benefits subject to annual budgetary constraints".

Establishing priorities for construction grants amounts to establishing a program for investment in water pollution control facilities. Investment decisions of this type are governed by a set of economic principles, applicable throughout the economic ystem. In the private sector, much effort has been expended in deriving methods which apply these principles to find optimal solutions to investment problems quite similar to the State's problem of establishing priorities. This paper will outline ways in which these methods can be applied to the State's problem, and will review important considerations in their application.

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Before beginning to describe methodologies, however, a brief explanation of a few important concepts is in order. These have to do with Benefits, Costs, and Budgets.

In the case of sewage treatment facilities, benefits occur only after a project is completed. Different projects also have different construction time requirements depending on type, size, and purpose of a project. Therefore, if the benefits of several projects as started in one year are to be compared, their benefits as accruing in different years in the future have to be compared. This can be accomplished by discounting their benefits from the years they start to accrue back to the beginning of the investment period and comparing the so derived present values of the projects. It is important to note that benefits need not be computed in dollars in order for discounting to be appropriate. Any consistent set of units can be used eg., swimming days or unpolluted stream miles, or a weighted combination such as swimming days + 2.5 x unpolluted stream miles.

Discounting allows the direct comparison of a project whose benefits start in year 3 with a project whose benefits start in year 6. Such comparisons are absolutely necessary since the time for completion of projects range from 3 to 7 years after the date of initial funding, depending on the project. Discounting also implies a penalty for delaying of the construction of a project. At 6 1/8%, delay of a project for 4 years would cause the loss of about 1/5 of the present value of the benefits which could be achieved if the project were to be constructed immediately, all others things being equal. This factor is very important where budgets are limited, since the commitment of funds to one project necessarily dictates the delay of another project.

The concepts of budgets are very straightforward. Each year, the State receives an allocation of construction grant money from the EPA. The State supplements these funds with its own monies, primarily from previously authorized bond sales. The annual budget for construction is simply the sum of the Federal allocation and the State supplement. Likewise, for the purpose of setting priorities, the cost of the project is the requirements it puts on the annual budget, that is, the sum of the Federal and State shares of construction costs. The local costs of projects do not enter into the priority calculation, insofar as the State is concerned (unless, of course, the localities cannot fund projects, or local costs are considered as reducing benefits). This is because local costs do not affect the State's ability to fund other projects in the State.

The nature of the relationships between costs and budgets (the budget constraints) which affect the State's priorities are not as simple as it might seem at first glance. This is primarily due to the Federally mandated funding of projects in "steps". If implementation of plans is to proceed in an orderly fashion, then assurances must be given to local governments that monies will be available to complete steps 2 and 3 of the process when a step 1 grant is made. If no additional money is forthcoming, than the money spent on step 1 will be wasted. This could well occur if the State, without proper planning, allocates large numbers of step 1 grants in any year. Several years hence, when these projects mature to step 3 projects costing 20 to 30 times as much as the step 1 phases, funds will be insufficient. Therefore, when a commitment is made to fund a step 1 project, plans must account for future expenditures necessary to complete that project. This means that the priority system must take into account not only the present year's budget, but also budgets for future years.

The problem of setting priorities will now be restated in terms of the concepts just discussed. The problem is to maximize the sum of the present values of the benefits accruing to all projects. The present values are dependent on the date of commencement of funding of the project and the time from commencement of funding to completion of the project as well as the physical benefits derived. Finding a solution to the problem involves choosing the dates for commencement of the funding of the projects (i.e., setting priorities). These dates must be chosen so as not to violate the budget constraints, that is, so that the sum of the yearly funding requirements for all projects underway in a given year never exceeds the budget allocation for that year.

Note that the setting of priorities has been defined as the choosing of dates for commencement of funding of projects. This is very important. Any priority system which assigns numbers to projects automatically implies dates for construction of the projects because of the budget constraints. To state this another way, given a priority system which ranks the projects from one to the last project, one can find out when each project on the list will be built. This can be done by comparing the projects, in order, to the available budget. Projects are funded in year one until no more money is available, additional projects are funded from year 2, then year 3, and so on. Once the funding dates for the projects are known, the completion dates of the projects can be estimated, and present values for the benefits calculated as described above. The date of commencement of funding of a project determines not only the present value of benefits, but also which years' budget it affects. IN EVALUATING THE EFFECT OF PRIORITIES ON BUDGETS AND BENEFITS, IT IS THE DATES OF FUNDING WHICH ARE MOST IMPORTANT.

Several methods for assigning priorities will now be compared. The first will be similar to the system currently in use in Maryland. For this system, the benefits which are expected from the completion of each project are calculated. Projects are then ranked in order of the magnitude of the benefits they produce. If one wished to evaluate the present value of the benefits which would accrue to such a ranking, the following procedure could be used. Take the first project on the ranking list. Assume it is funded in the first year and figure the capital requirements for that project for suceeding years, and subtract those requirements from the budgets for each of those years to determine the funds remaining. This process can then be repeated for each project on the list, in order of the ranking, until a project is reached which will violate a budget constraint if it is funded. This project is then delayed until the first year in which it is fundable (that is, the first year such that if funding starts that year, future funding is still available). This process is repeated until the starting dates for each project on the list are found. Once the starting dates are found, completion dates are known. Benefits for each project can thus be appropriately discounted. The present value of all benefits is then the sum of the discounted benefits for all projects.

It is not likely that the ranking described above will maximize the present value of benefits. The prime reasons for this are 1) relative costs were not taken into account in arriving at the rankings, and so large projects are favored regardless of cost and 2) the time lag between commencement of funding and completion of the project was also ignored when determining rankings, i.e., discounting was not built into the ranking procedure. Finally, no attention is paid to finding groups of projects which make use of all available funds.

One might attempt to correct some of the flaws in the previous ranking method by taking the ratio of costs to benefits for all projects and ranking in order of the decreasing ratio. The present value of all benefits could then be evaluated as above. Once again, this ranking is not likely to be optimal, since although costs are explicitly considered, they are not considered in relation to the annual budgets, and discounting, again, is not built into the ranking procedure.

An optimal solution to the problem can be found by evaluating the present value of benefits for every possible combination of construction dates for the projects. This would be a horrendously large and fortunately unnecessary task. Modern techniques of operations research, particularly the linear programming formulation of the capital budgeting problem (a similar problem frequently encountered in the private sector) finds optimal solutions by implicitly comparing all possible combinations of dates, and reduces computational requirements to easily manageable proportions. The linear programming formulation of the problem of setting funding priorities follows this discussion. The input required for the use of the linear programming technique is no different than that required to evaluate the present value of benefits from any other priority scheme.

If the specified inputs can be supplied, the linear program will perform well. The many "canned" linear programming packages available require little time to use and are quite straightforward. The output of the program will indicate which projects should be funded in each year. No preferences among projects to be started in any one year will be given, however.

There are two major limitations to the use of a linear programming approach. First, the output of the program is no better than the information used as input. Cost estimates and budget predictions are all subject to a good deal of uncertainty. The benefits of projects must be defined and then estimated. (With regard to benefits, the scores in the State's current ranking system might well be used as estimates). To the approach's credit, sensitivity to costs, budgets, and benefits can be easily explored, but the limitation of data must be recognized.

Second, the approach is not sensitive to important political considerations. These might include equitable disbursement of funds and other factors. The costs of these political considerations can be explored, however, through the judicious use of sensitivity analysis. Some political factors may even be included explicitly in revised formulations of the problem.

As a minor issue, some technical difficulties may preclude the program from finding the absolute optimal solution. In such cases, nearly optimal solutions can be found. In all cases, the technique can generate several nearly optimal alternatives.

In summary, a technique has been presented which can be used to determine a priority system which maximizes the benefits the State receives from the expenditure of construction grant funds. The technique considers the important issues of the timing of the receipt of benefits (caused by time required for construction and deferment of funding caused by low priority), and the future funding requirement of currently initiated projects. The technique can be used to analyze sensitivity to differences in cost, budget, and benefit estimates, and it can provide detailed information as to the funding requirements for all steps of funded projects.

# LINEAR PROGRAMMING FORMULATION AND REQUIRED INPUT

## Linear Programming Formulation

The Linear Programming Formulation is shown in Table 1.

Explanation of Equations:

Objective function: The sum of the benefits to be derived from all projects (i) as initiated in some year (j) is to be maximized. The middle term assures that benefits will be discounted from the year they accrue back to year 1. Since the x variables are equal to 1 only if project i is started in year j, and 0 otherwise, the sum contains only the relavent benefits for each project.

First series of constraints: Assures that each project will be initiated only once, i.e., no multiple benefits can be derived from one project by building it over and over.

Second series of constraints: Assures that investments to be made in year k will not exceed the FY k budget. Since as explained above for any project the year it is started and the years additional funds will be required are only identical for Step 1, double subscripts are used to express the time lag between initiation and required successive investments.

## Required Input

(1) Interest rate

(2) Budget estimates from FY76 through FY81 (6 Years). If firm budget estimates beyond the first few years cannot be established, estimates can be substituted. The sensitivity of solutions to future budget constraints can easily be investigated.

(3) For each project, the following information:

a. Project ID number

b. Estimates of Step 1, 2 and 3 cost; it should be possible to estimate these costs using the following methodologies:

for Step 1: Standard estimates based on the complexity of the planning area (including the complexity of the existing sewerage system, which determines I/I analysis cost) can be used.

for Step 2: Can be computed as percentage of estimated Step 3 cost.

for Step 3: Available cost curves in conjunction with knowledge of required treatment and flow projections should supply reasonable estimates. If interceptor construction will be part of Step 3 work, an estimate based on length, diameter, terrain, etc. can be worked up. (MES has developed some generalized cost curves for this).

c. Estimates of time lags between initiation of step 1, Step 2, Step 3, and commencement of operation.

d. Estimate of benefits to be derived from completed project; a methodology very similar to the one now in use to establish the priority list can be used for this.

All inputs required under (3) can be summarized in tabular form as shown in Table 2.

Table 1

LINEAR PROGRAMMING FORMULATION

Maximize:

$$\Sigma_i \; x_{ij} \; e^{-r(t_i t_j)} \; B_i$$

Subject to the constraints:

$$\Sigma_j \; x_{ij} \leq 1 \qquad \text{for all: } i$$

$$\Sigma_{ij} \; x_{ij} \; C_{ijk} \leq K_k \qquad \text{for all: } k$$

<u>Notation Used:</u>

Subscript i = project number
" j = year in which a project i is started
" k = year in which an investment into project i needs to be made (for Step 1 projects k = j)

$x_{ij}$ = 1, if project i is started in year j, otherwise = 0

$t_i$ = time lag between initiation of project i and production of benefits by it.

r = interest rate

$B_i$ = PV benefits of project i discounted over its entire life to the year it comes on line.

$C_{ijk}$ = cost of project i in year k (for Step 1 projects the year a project is started and the year an investment needs to be made are the same, i.e. j=k; for Step 2 and 3 projects the time lag between j and k can be fixed in the data input (see below).

$K_k$ = budget in year k

TABLE 2

TABULAR FORMAT FOR
SUMMARIZING PROGRAM INPUT

| Project Description | ID # | Steps | Implementation Sequence (years) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Hagerstown System | 43 | 1,2 +3 | C | | C | | | C | | | |
| North East (Seneca Point) STP | 62 | 2 + 3 | C | C | | B | | | | | |

Explanation of examples:

Hagerstown System: Time lags between initiation of Step 1 and Step 2, and Step 2 and Step 3 are 2 and 3 years respectively. Construction will take two years.

North East STP: Step 1 has been completed already and Step 2 could be started immediately. This is expressed by entering Step 2 cost (C ) in column one.

It is expected that Step 2 work takes one year and that Step 3 can be started the following year. Therefore, the Step 3 cost is entered in column 2 (immediately following C ).

Construction of the facility is expected to take 2 years, therefore benefits (B) are expected to start accruing in year 4.