Cost Effectiveness as a Measure for Setting Maintenance Levels and Priorities

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Tremendous progress toward effective management already has been made by at least some highway agencies. Such approaches as setting realistic standards, and developing computer-based methods for planning, scheduling, and controlling the maintenance function are in full accord with the best present-day thinking.

The construction industry prides itself on being progressive and claims to be far ahead of governmental agencies in its initiative and in developing new methods. But it can be stated without fear of argument that many of the maintenance techniques and procedures are far more effective than those employed by all but a handful of contractors. Particularly noteworthy is the use of the industrial engineering approach to develop improved methods, standard times to measure job performance, and the attention being given to the "people" side of management.

There is no question that many decisions regarding maintenance policy and procedures require choices on how to use that very scarce commodity, money. But are these decisions money based? Figure 1 is a plot of the responses of the state highway departments to a 1963 questionnaire (1). It shows that formal economic analysis was almost never employed in making maintenance decisions.

It can be argued then: (a) that since many decisions about maintenance expenditures can be money-based, (b) that current decision-making procedures are not money-based, and (c) that there are strong pressures on public agencies to explain and justify how the money entrusted to them is being spent, it is time to get busy developing techniques and procedures for looking at the "cost effectiveness" of maintenance.

WHAT IS COST EFFECTIVENESS?

The term cost effectiveness immediately suggests a comparison between an expenditure and the gains that that expenditure brings. However, the term does not say how that comparison should be made, and at the present, no universal basis for such comparisons is available in the private sector of the economy, let alone in the public sector. In the highway field, Figure 1 suggests how little has been accomplished in any of the divisions of highway practice.

Cost effectiveness is relatively easy to define in the private sector. Here, the aim is to make money or, stated more elegantly, to "maximize profits." This must, of course, be done under certain rules of the game which require observance of the law, payment of taxes, and some degree of recognition of social responsibility. It is admitted that projecting costs and gains into the future is neither an easy nor exact science, but at least, the objective of private enterprise is clear: to deploy the available money and other resources to maximize one thing—profit after taxes.

In the public sector, merely to define cost effectiveness is difficult indeed. Here, the aim is to "maximize the public good," whatever that may be. However, one thing is clear: it is that the aim is not to maximize the "good" of the highway agency or of the maintenance division of that agency. It is an agency developed to spend public money to perform a public service, and it and its employees are stewards (house wardens) charged with a responsibility to make the best possible use of the funds placed in their hands.

In the public works field, as in private enterprise, accounting for costs is primarily a matter of devising and operating a suitable estimating and measuring system. On the other hand, it is extremely difficult to set up measures of the public good that are

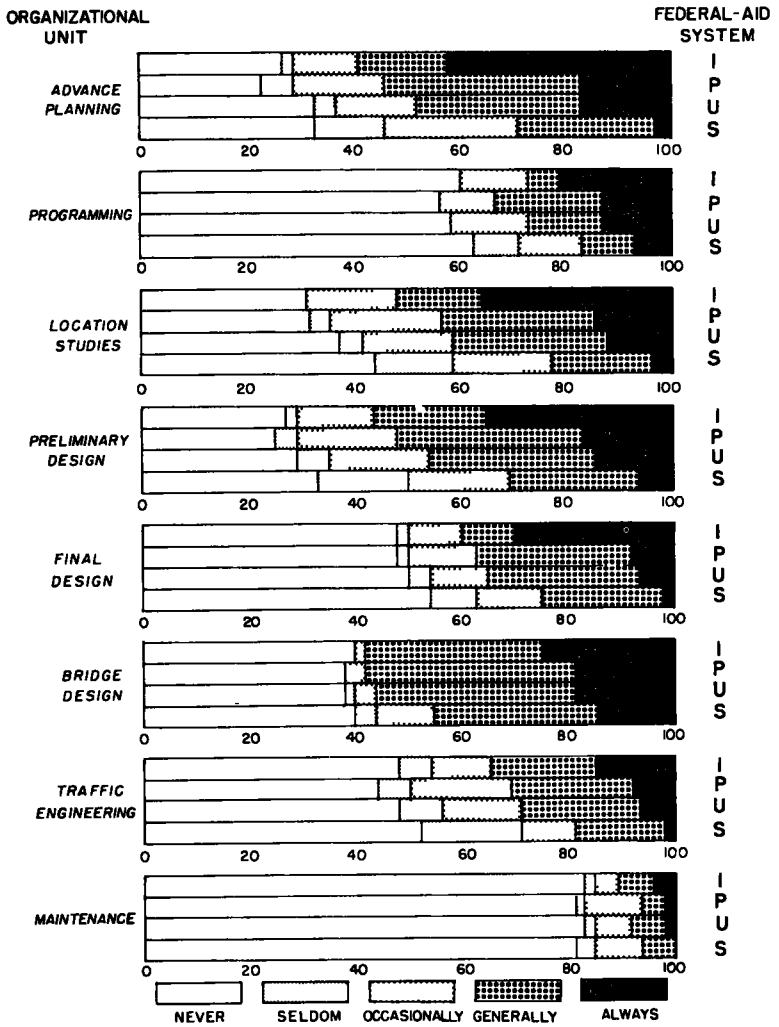

Figure 1. Percentage use of economy analysis by Federal-aid system, organizational unit and frequency category (1).

to be mazimized by public works decision-makers. Possibly the most important of these goods is, however, reflected in the term cost effectiveness. It covers the efficient use of resources, be they money, land, plant and equipment, air, water, or human productive capacity.

In the developing nations where food and shelter are so scarce that human survival is a problem, these economic considerations may well be overriding, and even in the developed nations where resources are abundant, economic comparisons are important. There are many instances where choices among the possible use of resources can be made solely on economic grounds. In other cases, economic comparisons provide a means for weighing the relative desirability of consequences for which money values are either unknown or for which they seem inappropriate.

It must be recognized that in today's world, it is not possible to completely overlook the "other than economic factors" that are affected by public works decisions. Examples in the highway field include the comfort and convenience of motorists, the

presence or absence of noise, dust, and fumes, and the suffering and deprivation resulting from highway accidents. Furthermore, the implications of highways to neighborhoods and the community must be weighed.

It follows that, not only must the techniques for measuring cost effectiveness be broad and all-encompassing enough to reflect economic and social costs, but also that, in some situations, other measures that cannot be stated in money terms must be considered in the decision-making process.

THE SYSTEMS APPROACH

One of the most popular words in today's technical jargon is "systems." It means many things to many people, but for the purposes of this paper, it offers a useful concept, and that is "to reach a proper solution to a problem, it is necessary to make the circle encompassing a study large enough to include all relevant factors." Unfortunately, this systems concept has often created confusion rather than clarity because it has been used capriciously and without thought.

In applying the systems approach, it must be recognized that for decisions made at the top, the system must be comprehensive; in other words, the circle encompassed by the study is large. As the decision-making power moves lower and lower in the management hierarchy, the system becomes more and more restricted in scope and the circle gets smaller and smaller. On the other hand, as the system becomes more and more complex, fewer and fewer particulars can be encompassed in it. Applying these concepts to cost effectiveness, it should be clear that no single approach to or set of answers for cost effectiveness will be appropriate for all levels of management.

For example, in the case of snow removal, top administrators will be concerned with broad questions such as the economic and political implications of a bare pavement policy and, within that, deciding which roads to keep open. The equipment manager will be concerned primarily with the relative economy of various types and sizes of snow-removal machinery, and the maintenance supervisor will be looking for economies in, among other things, setting routes for equipment to follow and determining the circumstances under which he begins and carries out snow removal activities. Of course, accurate cost information is needed to make correct decisions at all these levels. However, it is only at the higher levels that the broad policy questions regarding "gains" enter directly into studies of cost effectiveness.

Research now being carried on may have far-reaching effects on how decision-making on more complex problems is carried out. The behavioral scientists have developed strong evidence to show that the human mind can deal effectively only with about six or seven major elements of a problem at one time (2). Yet, many problems have far more than this number of facets. The effort is, then, to find workable means for alternately breaking a problem down to show the detail and then reassembling it into a relatively small number of variables. One very promising approach is to couple a visual display cathode ray tube to an on-line computer. It is then possible to assemble the major variables graphically or in words or to instantly recall and display the details underlying these variables.

APPROACHES TO COST EFFECTIVENESS

In the broadest interpretation, cost effectiveness programs will have the aim of permitting comparisons of the costs and benefits of all expenditures of the governmental agency in question. They will include evaluations in money of long-term investments in capital improvements in such areas as highways and other transportation media, water projects, and air and water pollution. Also, the expenditures for day-to-day governmental services such as a law-enforcement and protection of the public through the licensing of engineers, doctors, lawyers, contractors, and barbers will be rated.

As indicated earlier, it should be possible to determine the costs of providing such governmental services within reasonable limits. Admittedly, there is much uncertainty and argument on investment criteria such as interest rates and useful lives of capital investments, but at least all costs can finally be stated in terms of money.

On the gain side, however, only the beginnings have been made in reaching overall evaluations. For example, in the highway field, reasonable estimates can be made of gains from reductions in vehicle operating and time costs that accompany an expenditure to improve traffic flow, assuming traffic volume projections are fairly accurate. However, money measures of the socioeconomic and certain nonquantifiable effects of highway improvements have yet to be developed, and in a field such as the licensing of professions, what possible measure is there of the gains to society that result because, for example, barbers have passed an examination?

The above arguments are not intended to say that the cost effectiveness approach cannot be implemented. It is, rather, to say that a long road lies ahead. In the meantime, it will often be necessary to "suboptimize," that is to look at only that part of the problem that can be handled. Again, in many instances, it will be necessary to minimize the costs necessary to achieve some arbitrary measure of gain, but the aim will always be to give the public the most for its money, even though the measures are imperfect. It goes without saying that decisions made with as much factual knowledge of costs and benefits as can be assembled will be better than those based solely on opinion or reaction to pressure.

IS COST EFFECTIVENESS BEING APPLIED IN HIGHWAY MAINTENANCE?

It can probably be said truthfully that only a few of the many highway agencies in the United States have meaningful data on either the cost or gain sides of highway maintenance. A recent study sponsored at Stanford University under the National Cooperative Highway Research Program offers some proof to this claim. Almost no data in the depth and form needed to make meaningful cost effectiveness studies in any facet of highway maintenance were found either in the literature or in the records of highway agencies (3). Actually, more meaningful data have been presented at this workshop or have been developed by the agencies making presentations here than were found in all the past literature. So real progress has begun!

CLASSES OF COST EFFECTIVENESS STUDIES

Techniques for making cost effectiveness studies might be put into three general classes as follows:

Class 1—Those situations where a standard of quality or quantity has been fixed by higher authority and where no differences in or factors affecting capital investments are involved. In this case, comparisons based on cost per unit of accomplishment will be appropriate. For example, for patching a bituminous surface, the man-hours and materials per square foot or square yard of patching might be proper units, or both items might be converted to a dollar cost per unit area. This approach would be appropriate whether the aim is to measure the actual performance of a given crew against a standard or to make comparisons between the effect of crew size or some other variable on productivity (this would be true as long as equipment costs are not a factor in the comparison).

Class 2—Those situations where a standard of quantity or quality has been fixed by higher authority, but where capital investments as well as annual expenditures are involved. These investments may be in materials, machines, or facilities any of which may have different costs, performance characteristics, or useful lives. In this case, an economic comparison (economic study) must be made. The most favorable alternative will be the one that had the lowest cost in the long run. Results may be expressed in the following forms: (a) lowest equivalent uniform annual cost, (b) lowest present worth of costs for a specific number of years, or (c) the highest rate of return on the total and also on the last viable increment of investment. An example of a situation where this approach is required would be a comparison of the present method of mowing the roadside with several other machines and procedures.

Class 3—Those situations where the standard of quality of maintenance is subject to question and where, in addition, alternative procedures may or may not be followed to accomplish the different standards. In this case, as in Case 2, an economy study ap-

proach is required. Results may be stated as indicated in Case 2, or also as the benefit-cost ratio on total and last viable increment of investment. Case 3 differs from Case 2 in that, for Case 3, a money value for the good or benefit that this particular maintenance operation brings to the public at large must be included in the analysis or the decision. An example of this form of cost effectiveness study would be a determination as to how often, at what height, and how far from the edge of the roadway to mow the roadside.

PROBLEMS WHEN MAKING ECONOMY STUDIES

The purpose of economy studies is to apply fundamental economic principles to making engineering and management decisions. All too often, however, engineers and administrators have assumed that these principles are self evident or that they merely represent an extension of accounting procedures or financial calculations. An added factor is that only about one-third of the civil engineering curricula offer these principles among their subject matter. It is, then, small wonder that many highway economy studies contain fundamental errors. Unfortunately, also, the highway literature is crowded with formulas and solutions to economic problems that are entirely wrong.

The principles underlying economy studies are too complex to be presented here, but it is essential that those involved in cost effectiveness studies understand them thoroughly. The book by Grant and Ireson is a classic; early next year, Robley Winfrey's book devoted entirely to highway economics will be available (5). In addition, most of the papers sponsored by the Committee on Highway Engineering Economy of the Highway Research Board in the last ten years are fundamentally sound. Although these papers are not primarily concerned with maintenance problems, the parallels are close enough to be helpful to one who wishes to develop competence in highway economy.

As indicated above, past highway economy studies have often been in error. Among the more common mistakes are the following:

1. Failure to clearly define the available alternatives and their consequences.
2. Mixing economics, which is the use of resources, with finance, which relates to sources of funds. Decisions on economy and finance are separable; they should be made separately, one following the other.
3. Using accounting data such as book value or allocated costs in economy studies. Neither of these have a place in an analysis of the future consequences of alternate courses of action.
4. Including a factor for inflation in future costs or benefits.
5. Making comparisons involving future costs, gains, or both without using compound interest to reflect the time value of money. Another form of the same error is to adopt the bare cost of borrowed money as the interest rate.
6. Counting the same cost or benefit more than once. This is called "double counting." (A common error is to include the tax on motor fuel when computing vehicle operating costs.)
7. Using the physical life rather than the anticipated service life of a highway element in cost comparisons.

This list of errors is far from complete, but it may be useful as a means for running a rough check on formulas now in use or that are being proposed to solve maintenance economy problems.

DIFFICULTIES IN SETTING STANDARDS AND EVALUATING THEIR BENEFITS

Earlier in this paper it was stated that highways are constructed, operated, and maintained with public funds for the public good. It can be concluded, then, that standards for maintenance should, insofar as possible, reflect the public's wishes when determining how maintenance funds should be used. Cost effectiveness is one measure, but it is also clear that the public has desires that cannot be evaluated in money terms.

To date, few, if any, formal attempts have been made to measure public preferences as to the level of maintenance standards. Neither have public desires been explored systematically in terms of the importance or the various aspects of maintenance, for example, surface maintenance vs litter collection. Of necessity, and for want of legislative or other direction, highway engineers in each agency have aopted standards that, in their opinions, seemed reasonable. These standards have, of necessity, been elastic in order to fit the available resources of money, manpower, and equipment. If the available resources were in short supply, standards were selectively relaxed.

Recently a statement of policy entitled "Criteria for Maintenance of Multilane Highways" was prepared by the Committee on Construction, Maintenance, and Operation of Highways of the American Society of Civil Engineers (6). Among the objectives of the statement was the following: "To promote a uniformly high level of maintenance by the various state and local agencies." This statement presumes that the public wants or demands this high level of maintenance. It also assumes that the public wants this high level across the board, rather than being selectively applied to say, the roadbed but not the roadside.

In some instances, the statement of policy indicates that standards should be lower where traffic volumes are lower; in others, it does not. For example, it recommends that corrective measures to bring skid resistance to a particular level be developed on all roads, regardless of traffic volume. Yet, accident expectation and accident costs should be less on roads carrying lower volumes.

The question being raised here is how, if at all, cost effectiveness and other measures of the public's wishes can be applied to standards for highway maintenance. One possibility is to use modern sampling and polling methods to test public reaction, as has been done in an exploratory way in other public works fields. In any event, since standards are at the crux of all decision-making on highway maintenance, this subject deserves immediate and concentrated attention.

CONCLUSION

This paper has attempted to take a preliminary look at how cost effectiveness can be applied to decisions on highway maintenance. It also has briefly explored the forms that analyses to measure cost effectiveness will take and the problems that will be encountered in carrying them through. In addition, it has examined the question of giving decisions regarding highway maintenance greater sensitivity to the wishes of the public that pays the bill. In sum, it has looked at cost effectiveness as an advanced and valuable aid to decision-making and as a fruitful area for research and development.

REFERENCES

1. Glancy, D. M. Utilization of Economic Analysis by State Highway Departments. Highway Research Record 77, 1965.
2. Miller, G. A. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. The Psychological Review, Vol. 63, p. 81-97, March 1956.
3. Oglesby, C. H. and Altenhofen, M. J. The Economics of Design Standards for Low Volume Rural Roads. Final Report on Contract HR 63-2-6 of the National Cooperative Highway Research Program.
4. Grant, E. L. and Ireson, W. G. Principles of Engineering Economy. Fourth Edition, The Ronald Press, 1960.
5. Winfrey, Robley. Highway Engineering Economy. International Textbook Co. (in press).
6. Criteria for Maintenance of Multilane Highways. Journal of the Highway Division, Proc. ASCE, p. 43-60, June 1968.