page is based on the total time span, i.e., January 1977 to December 1978.

Using the 100 projects monitored January-December 1977 as a base, an examination of the slippage experience by these same projects January-December 1976 shows an average of 5.11 months and a high for 12 projects in one regional office of 10.33 months. During the period January 1977-December 1978, the average slippage per project monitored was reduced to 2.45 months, a reduction of 53 percent.

If this slippage reduction is applied against the average inflation rate for January 1977-December 1978 of 10 percent per year on a total letting of monitored projects for the same period of $1364 million, the cost saving calculated is $30.0 million.

Another success factor is the support shown by higher-level management in the efforts of the Program-Project Management Section. Monthly status reports on the monitored projects were developed by the section and reviewed at regular monthly meetings with this management. At these meetings, decisions are made on those problems beyond the control of the project manager and action is taken to correct the situation. Although many other factors are involved in the measured success, without this visible follow-up to major delays, it is doubtful that the section would have achieved such results in the first two years.

Future Years

The future course of the matrix-project-management concept is dependent on recognition of the possible failings of the system: inability to identify the responsible person, the fostering of power struggles, being considered redundant during economic recession, and fear of high costs associated with the matrix organization. Recognizing and dealing with these and other problems associated with the matrix approach can improve the group's chance of future success. Continuing on course without acknowledging some of the possible failings of the matrix organization would be shortsighted.

Over the past two years, the major area of concentration of the Program-Project Management Section has been on the highway mode; there has been only minor emphasis on other modes of transportation. From projected trends, however, it is apparent that, in the future, more of the activity of the section will be given to the various other modes.

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Abridgment

Suggested Criteria and Procedures for Setting Highway Priorities

David Curry and Guillaume Shearin

A practical system for setting the priorities of highway projects for the California Department of Transportation has been developed. This includes formula and rating instructions for setting priorities based on project merits for 12 of the 15 highway capital-outlay programs and guidelines for the remaining three maintenance programs. The general technique for rating projects consists of calculating a benefit/cost ratio or a cost-effectiveness index closely related to project objectives. The numerator of the ratio or index represents the benefits of the project, measured either in dollars or in weighted rating scales; the denominator is the project cost. This ratio or index is then used to rank projects within each program area. The project ranking is then subject to technical, financial, legal, scheduling, and political considerations that are not addressed by the formula. This priority-setting system, which has been used for a year with only minor adjustments to formulas and weights, is a major step toward rational spending of highway monies that are projected to cover only 25 percent of the anticipated need for improvement over the next six years.

In the study described in this paper, a practical system for rating and ranking improvement projects in each of the 15 components of the highway capital-outlay program of the California Department of Transportation (Caltrans) was developed. The capital-outlay program has a budget of $2.4 billion over the next six years, an expenditure rate that will meet only 25 percent of the anticipated need for highway improvements. New highway construction is the largest of the program components, constituting 53 percent of the total budget. Seven maintenance and rehabilitation components constitute about 20 percent of the budget, and six operational-improvement components and a very small (0.4 percent) bicycle facilities component constitute the remaining 27 percent. Even among the maintenance programs, the available funds will meet less than half the anticipated need, which thus emphasizes the need for careful project selection.

The technique for rating projects varies by program component, but the general approach is that intensity-of-impact variables [such as highway-user time saving per vehicle or decibels of noise reduction (each derived from project objectives)] are multiplied by breadth-of-impact variables (vehicle kilometers or number of affected housing units) to give impact ratings. Different impacts can be weighted if they are not all measurable in dollars. (A typical weighting and scoring system is described below for the HB33—safety roadside rest areas—program component.) The sum of the project impacts or ratings is then divided by the project costs to give either a benefit/cost ratio (when impacts are measured in dollars) or a cost-effectiveness index. This ratio or index serves as the criterion by which projects are ranked to determine their formula priority.

The formula priorities are only advisory, because additional considerations (such as financial, legal, scheduling, and political) are introduced in the process of developing the annual state transportation improvement plan (STIP). Also, there are some types of projects for which criteria were not developed in this study, usually either because they are legislatively mandated, are reaching completion within the present STIP, or would require excessive data or analytical cost. Even for projects that are rated by this scheme, there will often be technical or cost considerations not covered by the variables in the rating formula that will make exceptions to the formula priority desirable. Because of such exceptions and because of the other considerations and constraints, not all projects will have final priorities corresponding closely to the formula priorities.

The approach used in developing a priority index in the 15 program components was influenced by the current Caltrans priority methods. However, in some programs, there was a general lack of familiarity with or even a dislike of an economic or benefit/cost approach. Some distrust of computerized quantitative methods also existed, especially at the district level, and even the existing computer-based data and project indices were not always used in setting priorities. On the other hand, most Caltrans staff were familiar with deficiency- or sufficiency-factor methods. Some program components either had invested or were investing significant time in developing a priority method based on deficiency factors, generally without considering project cost.

The resulting criteria and rating scales are therefore very much a joint Caltrans-consultant product, based on applying engineering economy and scoring principles to the diverse requirements of each program component. A benefit/cost approach was found to be better suited to HA1, maintenance lands and buildings; HA3 and HA22, resurfacing and roadway reconstruction and restoration; HA4, protective betterments; HB1, safety improvements; HB4, traffic operations improvements; and HE1, new highway construction. For HA21, bridge reconstruction, a sufficiency-rating approach is most appropriate, and HA25, highway planting restoration, uses a combined benefit/cost and cost-effectiveness criterion. Cost-effectiveness is used by the other six program components: HB33, safety roadside rest areas; HA26, safety roadside rest-area restoration; HB32, highway planting; HB34, vista points and roadside enhancement; HB31, noise attenuation; and HE3, new bicycle facilities. Interim use of deficiency factors was recommended for HB32, HA1, HA22, and HA3 until the suggested preferred approach can be developed, because time did not permit completion of the recommended approach for those program components during this contract. Also, the use of a simplified form and rating procedure was recommended for calculating the community-impact index in HE1, new highway construction, until more detailed procedures can be tested and refined. Some technical assistance or added staff, similar to the financial analysis and assessment staff office that has been introduced at the Ontario Ministry of Transportation and Communications in Ontario, Canada, was thought necessary to develop the suggested refinements for HA1, HA22, HA3, and HE1.

Caltrans has used the procedures described below to develop a recommended STIP for 1980. For example, 290 projects have been ranked out of the 500 projects submitted for HE1, new construction. The six-year budget is sufficient to fund the first 110. Only minor adjustments were made in the rating weights and formulas during this first year. In subsequent years, project ratings will be updated based on any new data and on any rating system refinements.

HB33: SAFETY ROADSIDE REST AREAS

The HB33 program component funds designs and contracts for improved and additional safety roadside rest areas at acceptable standards of comfort and spacing. Caltrans' objective is a maximum of 96 km (60 miles) distance between rest areas in nonmetropolitan areas. The incidence of climate problems (such as rain and high winds) and existing roadside rest deficiencies are additional priority considerations. The cost-effectiveness (C-E) criterion for safety roadside rest areas is

$$\text{C-E index} = \text{AADT score} \times (w_1 \text{ alternative stops} + w_2 \text{ climate} + w_3 \text{ deficiency reduction}) \div \text{project costs} \quad (1)$$

where

AADT score = average annual daily traffic translated to a 0-to-1 scale on which 1 = 250 000 AADT (both linear and logarithmic scales are available) and

w_1, w_2, and w_3 = percentage weights.

Costs are in millions of dollars. The variables themselves—alternative stops, climate, and deficiency reduction—are each rated on a 10-point scale and $w_1 + w_2 + w_3 = 100$; thus, the potential total score in the numerator is 1000 points.

HA4: PROTECTIVE BETTERMENTS

The HA4 program funds construction to prevent damage to or loss of service on state highways. The program work categories are

1. Drainage and slope stabilization,
2. Earthquake restraint,
3. Truck scales,
4. Loss of lateral support (shoulder drop-off), and
5. Pavement edge drains.

Benefit/cost (B/C) methods can provide an excellent basis for determining HA4 priorities, but only the first work category has a sufficient backlog of projects to warrant implementation of this method. A B/C criterion for this category is described by Equation 2.

$$\text{B/C index} = 100 \times \text{probability of loss of service and damage} \times (\text{user costs from loss of service} + \text{Caltrans' cost of repairing damage}) \div \text{project cost} \quad (2)$$

This criterion approximately maximizes the expected project savings in loss of service and damage costs for a given budget by accounting for the uncertainty involved.

HE1: NEW HIGHWAY CONSTRUCTION

The HE1 program component, construction of new highway facilities, accounts for about half of Caltrans' capital outlay budget. Project types include upgrading substandard facilities, adding lanes, and providing new connections and cross-traffic improvements. New construction is planned "only when an adequate level of service cannot be provided by any other effective means". Previously, HE1 project priorities were determined by professional judgment supported by (a) a great deal of information on transportation benefits and on social, economic, and environmental impacts developed through a project report or an environmental impact statement (EIS); (b) public and local and regional government views, obtained through the same processes; and (c) sometimes, the calculation of delay or safety indices. These are benefit/cost ratios, multiplied by 100 to produce the index numbers, that show the values of expected travel-time savings and of accident cost savings, respectively, in relation to project costs.

A staged development plan is recommended in this study for future determination of HE1 project priorities. Four steps were suggested for the first year:

1. Refine the procedures for computation of the safety and delay indices.
2. Combine the delay and safety indices with a new community-impact index that uses simplified procedures for rating public acceptance, social, environmental, and economic impacts. The resulting priority formula is

$$\text{B/C index} = (\text{delay index})^{1/2} + \text{safety index} + \text{community-impact index} \quad (3)$$

3. Supplement the B/C index by obtaining narrative comments on any other considerations of potential importance to the priority of the project.
4. Test more-detailed procedures for rating community impacts on selected HE1 projects (those that have an EIS) to (a) refine the suggested procedures, (b) compare the refined procedures with the simple procedures suggested for immediate use, and (c) determine the extent to which the community-impact index affects the transportation benefit/cost index in typical projects.

Among the refinements suggested for the delay index are (a) a method for estimating the value of travel time as a function of the amount of time saved (time savings are not valued highly until they exceed about 5 min/trip) and (b) a pricing correction factor to adjust user benefits for the underpricing of highways and their consequent overuse (which creates undue or premature congestion and the associated tendency to overbuild). The pricing correction factor reduces user benefits as a function of the price elasticity of demand for highways, which is a measure of prospective induced travel—hence, urban highway improvements are more affected by this adjustment than are rural improvements. A parallel measure for new facilities, the tendency to induce residential growth in undesired locations, is included in the proposed community-impact index.

Among the variables considered for inclusion in one of the HE1 indexes, but eventually dropped, was fuel savings. In this case, the net effect will generally be too small to justify the necessary estimates and calculations.

In subsequent years, it will be necessary to decide whether to use the refined procedures for computing the community-impact index, either in general or for projects having an EIS available.

HB4: SYSTEM OPERATION IMPROVEMENTS

HB4 is the largest program component after new highway construction; it uses about 11 percent of the six-year highway capital-outlay budget. It entails increases in the efficiency and quality of traffic service through projects that reduce freeway congestion (such as climbing lanes, high-occupancy-vehicle lanes, priority ramp treatments, and fringe parking facilities), improve freeway traffic service (such as improved lane delineation and signs), and improve conventional highways and expressways (such as traffic signals, left-turn and passing lanes, and shoulder widening). Many of these types of projects have measurable and predictable effects on traffic flow or accident risks, so it is recommended that the delay and safety indices be calculated for all applicable projects and combined in a single criterion, the transportation benefit/cost index, as follows:

$$\text{Transportation B/C index} = \text{delay index} + \text{safety index} \quad (4)$$

For HB4 projects that do not have significant effects on traffic flow or safety, continuation of the present Caltrans effort to develop separate cost-effectiveness indices is recommended.

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Highway Funding: Arizona Case Study

Judson S. Matthias and Robert H. Wortman

During the summer of 1978, the highway funding situation in Arizona was reviewed and the alternatives for overcoming the anticipated future deficit were studied. Although a number of user, as well as nonuser, revenue sources are potentially available, the emphasis was placed on increasing user charges. Based on this study, it was recommended that revenues be increased by (a) staged increases in the fuel tax, (b) increases in registration fees, and (c) increases in third-structure taxes. In all cases, it was recommended that user taxes be tied to a consumer price index so that additional increases will offset the effect of inflation.

In January 1978, the Arizona Department of Transportation (ADOT) submitted the Biennial Statewide Transportation Needs Report to the state legislature in accordance with the law passed by the 31st legislature in 1974. This Needs Report represented the culmination of a comprehensive examination of the current estimates of future transportation needs in the state.

Basically, the report indicates that Arizona faces major problems with respect to the funding of the highway system over the next 20 years. Figure 1 illustrates the comparison between the anticipated needs and the funding available from current revenue sources and indicates a considerable deficit. Even though the results of the needs study are considered to be conservative estimates of the resources that will be required, it is expected that the deficit will be at least approximately