Application of the Highway Investment Analysis Package

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The Highway Investment Analysis Package is a computerized benefit/cost and cost-effectiveness model developed by the Federal Highway Administration to aid state, regional, and local governments in making the best use of limited highway funds. During the past year, a project evaluation and programming study has been conducted by the Wisconsin Department of Transportation and a team of consultants to improve the department's evaluation and program development capabilities. As part of this study, the Highway Investment Analysis Package programs have been installed in Wisconsin and used in two major analyses. The applications and the resulting evaluation of the package for inclusion in the improved programming procedure are the topic of this paper. The Highway Investment Analysis Package programs were found to be extremely useful in the efficient estimate and display of many of the consequences of alternative highway improvements and investment policies.

The Wisconsin Department of Transportation and a team of consultants have recently completed a project evaluation and programming study aimed at improvement of the department's procedures for making highway investment decisions. The study was initiated by the department in 1977 in response to widespread concerns that the old programming process (where many decisions were made at the nine highway district offices) could not respond effectively or consistently to new policy directives. Central guidance and review had to be strengthened if increasingly scarce highway funds were to be spent wisely.

The project evaluation and programming study was conducted in three phases:

1. Several planning and programming aids potentially of use to state and district offices were assembled or developed;
2. The existing, refined, and new techniques were applied on a trial basis in the course of the development of a highway program for the years 1980 through 1985; and
3. The experience gained in the applications was used to establish an annual cycle of programming activities at the department.

Certain principles were established at the start of the study. The programming process had to consider a broad range of technical data (e.g., service and safety measures) and subjective data (e.g., community impacts) if the product was to be widely accepted. The assimilation of this much information, however, requires consistency among the data and criteria used to define deficiencies and evaluate alternative design solutions. A final principle was that alternative policies and programs be evaluated to provide top management with sufficient information to make informed choices about the development of investment programs.

As a result of these requirements, a range of data presentation and analysis techniques were considered for complementary roles in the overall process. Benefit/cost analysis was found useful for describing some important implications of alternative project designs and investment programs. A number of benefit/cost packages were reviewed at the start of the project. The Highway Investment Analysis Package (HIAP), recently developed under the sponsorship of the Federal Highway Administration (FHWA) (1, 2), was selected as best fulfilling the requirements of the Wisconsin Department of Transportation.

HIAP is a computerized benefit/cost and cost-effectiveness package developed to aid state, regional, and local organizations in making the best use of limited highway funds. The package consists of two basic modules: project evaluation and program development. The project evaluation module uses microeconomic theory to analyze alternative improvements to individual roadway sections or limited networks of roadway sections, called project sites. The physical, operational, and traffic characteristics of each existing, improved, or new section are used to estimate both (a) highway user performance measures (i.e., travel times, vehicle operating costs, and accidents) and (b) public performance measures (i.e., pollutant emissions and noise levels) for the no-build condition and for each alternative improvement to a project site over a planning period of 15-20 years.

Aggregate economic and effectiveness measures for the evaluation of an improvement are produced by a comparison of the improvement's performance measures to those of the no-build alternative. The effectiveness measures include changes in accidents, emissions, and noise levels. The economic measures include the total present (i.e., discounted) value of user benefits summed over the planning period, the net present value (i.e., total present benefits minus the present value of improvement costs), and the benefit/cost ratio. The HIAP user specifies the key parameters, such as values of time (used to convert time savings into dollar benefits) and the discount rate (used to assign consistent weights to present and future benefits) applied in developing the economic measures.

The program development module of HIAP uses the aggregate measures calculated for project alternatives at all sites to develop candidate investment programs for as many as four periods. The selection process uses marginal analysis to allocate a budget among the sites to achieve the best program possible under the funding limitations specified by the user; the choice of sites that receive funds and the project scale or design at each site are made concurrently. The funding limitations can include minimum levels of investment in different funding programs, functional classes, or jurisdictions as well as the overall budget limits. The project selection criterion (specified by the user) can be the maximization of either accident reductions or economic benefits per dollar invested. By varying the economic parameters, the selection criterion, and the funding constraints, the HIAP user can easily generate a number of candidate investment programs that meet different program objectives, revenue forecasts, and allocation policies. The decision makers receive evaluation measures for alternative programs that may be combined with other considerations not easily handled by benefit/cost packages.

In the course of the project evaluation and programming study, HIAP has undergone an intensive evaluation involving five basic steps:

1. Adapting the programs to Wisconsin—Accident rates and pavement deterioration tables were developed

from Wisconsin data to replace those distributed with the project-evaluation module. The formats of some reports were also modified.

2. Acquainting senior staff with the program's capabilities—One-day orientations were conducted for over 70 senior district and headquarters staff to explain the operation of HIAP and the interpretation of its results. The first session was an overview of HIAP for potential users of its results; the second was a more detailed presentation for project managers who would be using HIAP to develop and analyze alternative project designs.

3. Applying HIAP to specific studies—Two major applications of HIAP were performed using data collected largely by district offices. The reports of these studies received wide distribution within the Wisconsin Department of Transportation.

4. Assessing the role of HIAP in the planning and programming process—The reactions of many study participants to HIAP's capabilities and usefulness were compiled to evaluate HIAP and determine its appropriate role in the continuing programming process.

5. Developing an applications guide—A workbook of instructions and guidelines for future users of the programs was assembled to supplement the more detailed user's guide distributed by FHWA (1).

APPLICATIONS OF HIAP

HIAP was applied in two major studies. The first application was an analysis of 13 reconstruction and 10 resurfacing projects under consideration as additions to the 1979 highway improvement program. Because of time constraints, only one improvement was considered at each site. Seven candidate programs were generated from these projections: one that used a base set of economic parameters developed by project staff (as shown below) and three pairs of programs in which the values of time, discount rate, and costs of accidents were alternately raised and lowered. The final selection of projects for the supplementary 1979 investment program was based on summaries of deficiency data for the three sites and a methodical view of existing conditions as shown on the department's photolog, together with the benefit/cost results obtained from HIAP.

Parameter	Amount
Value of time ($/vehicle-h)	
Automobile	3.20
Single-unit truck	7.00
Multi-unit truck	10.00
Accident cost ($/accident)	
Fatality	122 000
Injury	7 550
Property damage	600
Discount rate (%)	7

The more extensive application of HIAP was the analysis of alternative improvements at 30 sites where major investments had been proposed for the highway program in the years 1980-1985. The sites represent a good cross section of the major highway projects proposed for the state. In general, data were readily available for alternative improvements to the sites and a particular improvement had not yet been selected. Six of the sites were urban, 9 were suburban, and 15 were rural. Eleven of the sites included the improvement or construction of a bypass or a beltway.

The district offices supplied data on the 30 proposed alternative sites, which project staff then compiled and edited. Results of preliminary runs of a HIAP benefit/cost analysis of those data were distributed and discussed at the second HIAP orientation meeting. Besides providing measures of the proposed alternatives, the preliminary HIAP results indicated sites where additional, generally lower-cost, alternatives should be considered. Where improvements were proposed for more than one highway section, the HIAP results also indicated which sections should be the first step in a staged investment. The districts used this information to correct any data inconsistencies and to develop new alternatives for some of the sites. Essentially, the initial runs helped district staff clarify assumptions, make trade-offs, and propose better second-round alternatives. Final analyses considered a total of 107 project alternatives at the 30 sites and used both the project-evaluation and program-development components of HIAP.

In the project evaluation phase of the analysis, the performances of all existing highways and each improvement were examined over a 21-year planning period (specifically, years 1980, 1986, 1991, and 2001) under the assumption of generally increasing traffic conditions. The values shown in the preceding table were applied to translate time and accident savings into dollars so that these terms could be added to cost changes in vehicle operations and highway maintenance to form measures of total benefits. In calculating savings in travel time, a maximum speed of 90 km/h (55 mph) was used to reflect current state and federal policies. Except in special cases, specific accident rates were used for each existing section, and statewide averages by highway type were used for improvements.

HIAP performs its benefit and cost calculations in constant dollars. The assumption is made that all components to which dollar values are assigned will inflate uniformly in the long run, so an inflation rate need not be estimated. The discount rate of 7 percent given in the table measures the public's preference for present over future benefits, exclusive of inflation. In the analysis, 1977 cost values were used and a factor of 1.55 was applied to the 1969 vehicle operating costs internal to HIAP (3). This factor considered changes in fleet characteristics and fuel economy as well as increases in factor prices (e.g., cents per liter of gasoline).

Analysis of Project Evaluation Results

The preliminary analysis of improvements to the 30 major project sites focused on the results of the project evaluation phase of HIAP. At project sites where only one improvement was analyzed, the evaluation was simple. A positive net present value indicated that the improvement was worthwhile; a negative net present value indicated that it was not. At sites where more than one alternative had a positive net value, incremental analysis was used to evaluate the alternatives. For example, Table 1 lists the summary evaluation measures for the three alternatives analyzed for project site A. The alternatives are listed in order of increasing cost, which in this case is also the order of increasing benefits and net present value. The least-expensive alternative ($6.5 million) upgrades part of the existing route and replaces the remainder with a new expressway. This alternative yields $43.9 million in benefits, a ratio of 6.8. The additional or incremental cost of replacing the entire route with a new expressway is $3.3 million. This alternative yields $11.2 million in additional benefits, so the benefit/cost ratio of the incremental investment is 3.4. This incremental ratio, not the total ratio of 5.6, determines that the alternative is a worthwhile investment. Similarly, an incremental benefit/cost ratio of 2.1 can be calculated for the freeway alternative. This indicates that the additional investment needed to construct this alternative is also a worthwhile investment. Note that the incremental benefit/cost ratio is always greater than 1.0 if the net present value is increased by the additional investment.

From an economic perspective and in the absence of any budgetary constraints, the freeway alternative is the best investment at the site because it produces the highest net present value. If funds were limited and could be invested at other sites to produce benefits at a consistent rate of at least 3:1, however, the expressway alternative would be the best investment at site A.

At many sites none or few of the initial alternatives emerged as being economically worthwhile or competitive for limited program funds. At site B, for example (see Figure 1), the four-lane freeway initially proposed did not produce significant net benefits until the 1990s, when its additional capacity would be better used. Consequently, the alternative two-lane designs shown in Figure 1 were proposed for construction during the next six years. At site C (also shown in Figure 1) a lengthy bypass of two rural towns produced significant service improvements only on portions of its route. In this case revised alternatives that combine shorter bypasses with spot improvements to the existing roadway were developed to concentrate smaller investments at the problem areas.

In the final HIAP analyses, a total of 107 alternatives were examined at the 30 project sites. At only 3 of the sites did no alternative yield a positive net present value. Two of these were highways with few deficiencies, which carry low to moderate traffic volumes; the third could not be improved at a low cost because of the poor conditions of the existing roadway. At a fourth project site, where the upgrading of a four-lane expressway to a six-lane freeway was analyzed, the results showed an increase in net present value if the improvement was deferred beyond 1985 despite a benefit/cost ratio of 2.7. In this particular case most of the benefits occurred late in the planning period and were not lost by the deferral.

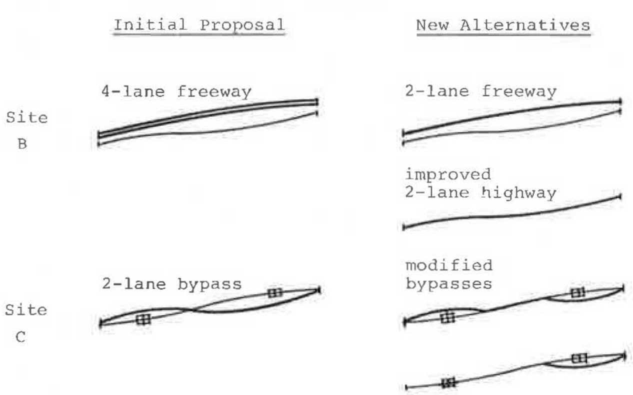
Analysis of Program Development Results

After new and revised alternatives had been developed, the program development module of HIAP was applied to the project evaluation results for the 107 alternatives.

Table 1. Site A analysis results.

Alternative	Capital Cost ($000 000s)	Total Benefits ($000 000s)	Net Present Value ($000 000s)	Incremental Benefit/Cost Ratio
Partial four-lane expressway	6.5	43.9	37.4	6.8
Four-lane expressway	9.8	55.1	45.3	3.4
Four-lane freeway	11.5	58.7	47.2	2.1

Figure 1. Development of new alternatives.



Several candidate investment programs were generated for different assumptions about budget levels and project selection criteria. These programs illustrated many of HIAP's capabilities in this area and provided information useful for the development of the 1980-1985 highway program.

Without Budgetary Constraints

Earlier we noted that, if sufficient funds were available, the project alternative at each site with the highest positive present value would be the best to implement from an economic perspective. A program of these alternatives forms an upper bound on worthwhile investment in the 30 sites (assuming the values of the economic parameters shown in the in-text table). In this benchmark program, $478 million would be invested in 27 of the sites to yield $2 billion in benefits—an average return of $4.20 on each $1.00 invested.

Alternative Funding Levels

HIAP's program development module was used to apply total six-year program budgets of $50 million, $100 million, $150 million, and $200 million (in 1977 dollars) to the 30 project sites. A summary of the results is given in Table 2. A major impact of the budget restrictions was to decrease the number of project sites at which investments are made. In addition, the scale of the project changed at 3 of the sites. At site A, for example, the three alternatives listed in Table 1 were funded in the $100 million, $150 million, and $200 million programs, respectively. The changes in project scale emphasized the need to examine a range of project alternatives when funding limitations exist. Essentially, no best alternative can be selected at any site on the basis of an independent project evaluation. The appropriate alternative design always depends on program funding constraints and on the merits of alternative projects at other sites in competition for the funds. Had more alternatives been examined at some site, additional changes in scale might have occurred as program funding increased from $50 million to $200 million.

Incremental Increases in Funding

Not all of the budgets listed in Table 2 could be spent because of the large incremental costs typical of highway investments. An examination of optional HIAP reports also indicates that, in choosing the last alternative in each of the programs in Table 2, except the unconstrained program, desirable projects that would just exceed the budget limit have to be skipped. In other words, when most of the available funds have been allocated, small investments with lower incremental benefit/cost ratios are selected to use up the remaining budget. For example, a 1 percent increase in the $50 million budget would allow a four-lane highway to be funded at project site E in place of widening part of site F to four lanes. The additional $1.4 million spent yields an increase of $9.1 million in the net present value of the program. The most striking change occurs when the $100 million budget is increased by 2 percent—the additional $2.5 million invested yields a $20 million increase in program net present value.

This analysis of small variations in program specification effectively compensated for HIAP's selection rules, which may select a low-cost project that produces only moderate benefits to complete the budget at the end of the selection process. In the major project application, a low-cost improvement at site G appeared in most programs generated because it had a relatively low cap-

Table 2. Impact of budget constraints.

Program Funding Level ($000 000s)	Number of Project Sites Funded	Program Cost ($000 000s)	Program Net Present Value ($000 000s)
50	6	49.1	730
100	12	98.7	1005
150	16	148.9	1225
200	22	199.7	1304
Unlimited	27	478.3	2025

ital cost and thus was a convenient budget filler. In view of this characteristic of the selection process, the $102 million program was probably a better preliminary program than the strict $100 million program. The uncertainties of cost and revenue estimates are probably significantly higher than the 1-2 percent variation examined here; larger variations in budget level should be considered to determine the impacts of these factors.

Allocation of Funds to Categories

HIAP allows the user to control the distribution of funds among categories by specifying minimum funding levels in each. To demonstrate this feature, we specified that at least 25 percent of the budget be spent in each of the urban, suburban, and rural categories at program funding levels of $100 million and $150 million. At both budget levels, funds were shifted to urban projects from at least one of the other categories; the greater shift occurred in the $100 million program. The shifting of funds to less beneficial projects decreased the net present values by $26 million for the $100 million program and by $7 million for the $150 million program. The size of the decrease provides a measure of the cost of the allocation policy.

Variation of Economic Parameters

The economic parameters used in the analysis are another realm of uncertainty. Additional programs were generated for budget levels of $100 million and $150 million (the most likely range of six-year investment in the 30 sites) to test the sensitivity of the investment program to changes in these key parameters. In two tests the discount rate was varied to 4 percent and 10 percent (i.e., future benefits were given more and less weight, respectively, than they received using the base set of economic parameters). In two other tests the values of time used to calculate automobile-user benefits were lowered and raised by 25 percent. In the latter test, truck values of time were also raised by 50 percent.

On the whole, the variation of the economic parameters had little effect on program composition; most sites were unaffected. At the lower budget level, the decrease of the discount rate to 4 percent or the automobile value of time to $2.40/h had no impact on program composition. The results of varying the parameters indicate that the sites and alternatives consistently selected by HIAP represent good investments.

Developing Programs with Alternative Criteria

Programs were generated at the $100 million- and $150 million-funding levels using accident reductions as the selection criteria. One program at each budget level considered all accidents and a second considered only serious accidents (i.e., fatality- and injury-producing accidents). With these selection criteria, HIAP uses the ratio of accidents saved by implementing an alternative to the capital cost of the alternative as a benefit/cost ratio, although no dollar value is assigned to the numerator, and future savings are not discounted. At both funding levels, there were significant changes in both project scale and project sites selected.

Synthesis of Programs

The various programs generated show that budgetary constraints and selection criteria affect the program development process. As a first step toward development of a final program, the staff grouped the project sites, alternative project designs, and specific improvements within projects on the basis of consistency of selection in the various $100 million and $150 million programs. This information, as well as deficiency summaries, scheduling constraints, and community and environmental considerations, was used in the development of the 1980-1985 highway program.

EVALUATION OF HIAP

Comments were solicited from district and central office staff who had reviewed and used the results of the two HIAP applications. Many responses dealt with assumptions made in the analyses, such as the values of key economic parameters, the uses of detailed and statewide accident rates, the definition of maintenance costs, and the definition of the no-build alternatives—all of which were addressed in the development of the applications guide. Other concerns, such as the use of nationally derived daily traffic distributions, suggested the possibility of a staff effort to develop new tables from Wisconsin's automatic traffic recorder data.

Still other concerns pointed to the need for additional research at the national level and the incorporation of the results in a revised version of HIAP. These concerns include the development of current vehicle operating cost tables (an effort currently sponsored by FHWA); the development of more refined traffic flow equations, which relate speed change and stop cycles to both congestion levels and a highway's physical characteristics; the explicit handling of recreational vehicles; the provision of greater flexibility for specifying alignment, profile, and cross-sectional characteristics, particularly of rural two-lane roads; and the development of improved techniques for estimating the impacts of pavement type and condition on the highway user, making HIAP more useful in the analysis of alternative resurfacing and reconditioning policies.

On the whole, HIAP was viewed as an efficient means for consistent quantification and display of many of the consequences of alternative highway improvements. It provides planners and designers with measures for evaluating alternative solutions to a specific problem or set of problems, and gives top-level staff measures for comparing among projects in developing investment programs. HIAP's ability to generate candidate investment programs quickly, using different criteria and parameters, proved particularly useful in the development of highway investment programs.

HIAP's roles in the ongoing programming process at the Wisconsin Department of Transportation will include

1. The early and continuing analysis of candidate projects to assist in the design of the most appropriate scales of improvement;
2. The periodic review of candidate projects for which significant cost changes, changes in alternative design, or delays or problems in project development have occurred; and
3. The annual review of the six-year investment program to determine the best responses to changes in

budget levels or allocation policies and to provide guidelines on appropriate scales for projects in the preliminary design stage.

In all cases, HIAP will be used as a design aid and not as a substitute for making decisions. This subservient role for the model was well received at the department of transportation during the trial applications—many had feared that benefit/cost analysis would be proposed and used as the final criterion for decision making. In fact, a major use of benefit/cost analysis in the project was in the identification of new alternatives. The need for professional judgment in preparation of data for HIAP and in analysis of the model results also became apparent in the applications. Once experience with the model was gained, HIAP became a very powerful tool for professional engineers and planners in the department.

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New York State's Approach to Highway Jurisdictional Realignment

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The New York State Department of Transportation is currently undertaking a study of the jurisdictional realignment of state and local highway systems based on functional classification. This paper describes the approach that is being taken. The current approach is based largely on the desire to correct existing misassignments of highway jurisdiction to the extent practical and is largely shaped by several recent efforts to accomplish realignment. Application of this procedure to many other states appears feasible. This paper briefly summarizes past highway jurisdictional realignment efforts within New York, outlines a series of short-term objectives and long-range goals for the study effort, highlights the present status of this effort, and discusses the preliminary observations and conclusions that may be drawn from study efforts.

In the past few years, state and local transportation officials have become aware that in the near future they will be unable to address a substantial portion of identified highway needs due to declining resources (in terms of real dollars) for both highway capital construction and maintenance. This has led to significant changes of emphasis in philosophy and program planning at the state and local levels. By necessity, many elements of transportation plans developed in the late 1960s and early 1970s are now being postponed, reduced in scope, or totally abandoned. Capital construction programs are now being redirected to recondition existing facilities rather than to plan for the development of new facilities. Such an approach increases the emphasis on the preservation of past investments and reduction of the cost of maintaining the existing highway system. Even at the federal level, which has traditionally emphasized new capital construction and reconstruction investments rather than aid for rehabilitation and operations, the tide seems to be changing.

This new direction has also drawn increased attention to a somewhat related area—highway jurisdiction. In some states the existing assignment of responsibility for maintenance and improvement of the public highway network may no longer be entirely logical or equitable. As a result, a number of states either have recently completed or are now undertaking studies that reexamine the validity of current jurisdictional assignments. In addition to eliminating inconsistencies, most states also hope that such an effort will result in potential cost savings through increased efficiencies. The New York State Department of Transportation is currently undertaking such an effort, via a somewhat unique yet straightforward approach.