ANALYSIS AND EVALUATION OF HIGHWAY PROJECTS AND PROGRAMS

by

William V. Ward
Sharon A. Barta
Jack H. Foster

Research Report Number 488-1F

Analysis and Evaluation of Highway Projects and Programs

Research Project 3-10-85-488

conducted for

Texas State Department of Highways
and Public Transportation

by the

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

November 1987

PREFACE

The allocation of funds and other resources for highway improvements among the many parts of Texas is a vitally important and continuing responsibility of the State Highway and Public Transportation Commission. Historically, the Commission approved planning and construction of highway projects and programs, in response to petitions from various interests, by considering the cost-effectiveness of competing projects and programs. Economic evaluation procedures and traffic operations analysis programs are tools used by organizations, such as the SDHPT, in the decision-making process of project selection and project priority setting. This report presents a review and appraisal of existing methods for project evaluation and selection.

ABSTRACT

This report presents the review and appraisal of existing methods for project evaluation and selection. Economic evaluation procedures currently used by the Texas State Department of Highways and Public Transportation are discussed, as are procedures from the Dallas area, New York, Alabama, Nebraska, and North Carolina. Emphasis was placed on computerized techniques, such as HEEM II, in order to facilitate the analysis of the large volume of projects submitted for consideration by the SDHPT. In addition, traffic operations analysis computer programs were also reviewed. Programs such as TRANSYT–7F, SOAP–84, PASSER II–84, NETSIM, and HCS make possible a more detailed analysis of projects and their potential effect on the transportation network. The results of reviewing these procedures and computer models will provide information necessary for the SDHPT to use in selecting a cost-effective and efficient highway program.

SUMMARY

Procedures that aid in the selection and priority setting of highway projects are tools that can be utilized by the SDHPT. Most of these economic evaluation procedures follow the methodology found in AASHTO's A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements– 1977. Most of the procedures were found to have numerous shortcomings for use by the SDHPT, but one computer program, called the Revised Highway Economic Evaluation Model (HEEM II), does contain a framework that would enable the SDHPT to more effectively analyze proposed highway projects. Traffic operations analysis models were also examined to determine whether they could be used by the SDHPT in evaluating complex proposed urban highway projects.

IMPLEMENTATION STATEMENT

This study has identified a computer program that is suitable for implementation by the SDHPT in project selection and project priority setting. HEEM II contains the necessary framework, although it does warrant some additional work in the generation of cost data appropriate to Texas and in its limited input format.

A lack of information on actual benefits resulting from highway improvements was also identified. It would be extremely valuable for the SDHPT to initiate a series of before-and-after studies in order to evaluate the economic impact of various types of improvements.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

The allocation of funds and other resources for highway improvements among the many parts of Texas is a vitally important and continuing responsibility of the State Highway and Public Transportation Commission. This responsibility for facility improvements must be managed at a time of intense competition for available tax resources and increasing system service demands. It is important, then, that the Commission be dependably advised as to the value and public benefits of competing individual highway projects and programs of highway projects in order to allocate funds and resources in a credible and cost-effective manner. To better and more expediently advise the Commission as to the selection and setting of priorities of projects and programs, it is desirable to provide improved methods and procedures for analyzing and evaluating highway projects and programs.

Study 488 was conceived to develop economic analysis methods to assist the Commission in its mission of cost-effective and efficient project selection. The study was planned to be directed by a Steering Committee chaired by an Assistant Engineer Director with four Administrative Division Directors as members. The purpose of the Steering Committee was to interact with the findings of the study team and therefrom provide the counsel and guidance as appropriate to continue the study. The general method of this research, however, was not to redefine or develop a new methodology for performing economic evaluations, but rather to review techniques currently used by those practicing in the field and to determine their utility for highway project and program selection in Texas. The work plan of this research project involved a review and appraisal of existing methods for project evaluation and selection. The results of the reviews and appraisal were periodically presented to the Steering Committee for their consideration.

CHAPTER 2. REVIEW OF PAST AND CURRENT EVALUATION TECHNIQUES

Historically, the Commission approved highway projects and programs for planning and construction in response to petitions from various interests, by considering the relative value of competing projects and programs. Beginning in 1976, the Commission established a policy of periodically selecting and approving a program of projects designed to meet, within the projected availability of funds, the State's future highway needs for a period of twenty years.

The SDHPT, in forecasting needs and selecting and setting priorities for projects, has relied on locally stated perceived highway needs as well as traditional tools of traffic operations analysis and economic evaluation. The Department has also participated in numerous research projects designed to improve the tools of project analysis and evaluation and to generally enhance the quality of programming.

DEFINITIONS

Before presenting the economic analysis techniques and models, it is appropriate to define terms commonly used in economic analyses in order to establish a basis for comparison of the techniques. The American Association of State Highway and Public Transportation Officials has a publication entitled A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements–1977 (Ref. 1) which provides a definitive source for the terminology used in transportation-related economic evaluations. For this discussion we will focus on highway economic evaluations as opposed to transit economic evaluations; however, transit improvements contain similar elements.

Improvement Costs

Improvement costs include the investment costs (or owner, provider, and construction costs), maintenance costs, and highway user costs (operating costs, travel time costs, and accident costs). These costs are those directly related to the cost of the highway improvement for each alternative improvement studied.

1. Investment costs – these are costs associated with bringing the proposed improvement into service; such as preliminary engineering, right of way acquisition, construction, and traffic control devices.
2. Maintenance costs – these are costs associated with keeping the highway improvement at some minimum serviceability level, including such operating costs as traffic signal operation and lighting.
3. Highway user costs – these are the sum of the following costs:
   a. vehicle operating costs – mileage-dependent costs of operating a vehicle on the highway, including the expenses of fuel, oil, tires, insurance, maintenance, and depreciation.
   b. travel time costs – costs (value) of vehicle operator's travel time, are dependent on the type of vehicle.
   c. accident costs – costs (value) of traffic accidents, are usually a function of the accident rate attributable to the type (classification) of transportation facility being analyzed.

User Benefits

User benefits are the monetary equivalents of the benefits derived by the user through the use of one particular transportation facility over another facility. These benefits are usually measured as a decrease in user costs.

Incremental Cost

The incremental cost is a relative measure (net change) of the cost of one alternative over another alternative transportation facility. These incremental costs, therefore, can be either negative or positive and involve only future costs.

Present Value

The present value (PV) is the conversion of a series of future costs (or benefits) of a transportation facility into a single amount at a specific time (usually the present). It sometimes is referred to as present worth. An associated concept is net present value (NPV), which is the net cumulative present value of a series of costs and benefits derived over the analysis period (usually the life of the project).

Discount Rate

The discount rate is the interest returned on an investment equal to the expenditure for the transportation improvement. The discount rate is increased to allow for inflation if future benefits and costs are to be reckoned in current dollars. Sometimes the discount rate on future benefits is increased to allow for the risk and uncertainty inherent in making forecasts and predicting trends.

Analysis Period

The analysis period is the time period (beginning at the end of construction of the transportation facility) over which the benefits/costs are being calculated. It is usually the usable life of the project but it can be any future date desired for study.

Residual or Salvage Value

The residual or salvage value is the value of the transportation facility investment remaining at the end of the analysis period. If, for example, the analysis period were the same as the usable life of the project, then the residual value would be zero.

CURRENT SDHPT ECONOMIC EVALUATION PRACTICES

The current SDHPT economic evaluation practice for project selection is to rank or compare projects of similar characteristics according to their hierarchical indices. These indices are sometimes in the form of warrants such as those developed for traffic signals and grade crossing protection and are sometimes labeled sufficiency ratings. These indices are influenced by factors such as project cost, project length, traffic volume, traffic characteristics, geographical location, detour length, highway functional category, special purposes, system gaps, source of funds, previous commitment, commercial development potential, design standards, and safety. Projects are categorized according to their primary purpose, within each program of work or system of highways, to effect some special outcome such as to enhance safety, extend the usable service life by rehabilitation, increase highway capacity by adding lanes or providing a new facility, provide railroad grade crossing protection to enhance safety, and replace certain bridges because of functional or physical obsolescence. These categories are applied to each highway system, such as the interstate, farm-to-market, urban, etc. The categories for which indices have been developed are

1. upgrade to standards
2. added capacity
3. new location
4. rehabilitation
5. safety
6. railroad grade crossing protection
7. bridge replacement
8. traffic signals
9. highway lighting
10. rest areas

For this research, we focused on these highway project categories: new location, upgrade to standards, and added capacity.

SUFFICIENCY RATINGS

In the SDHPT Twenty-Year Plan, a sufficiency rating is assigned to two types of projects– upgrade-to-standards and added-capacity. The sufficiency rating for upgrade-to-standard projects is based on the highway's present average daily traffic, present truck average daily traffic, whether or not it is classified as a principal arterial, a point system based on its functional classification, crown width deficiency, roadway alignment deficiency, geometric deficiency gap, and condition of existing pavement. For added-capacity projects, the sufficiency rating has a slightly different basis: present average daily traffic, projected average daily traffic, present truck average daily traffic, whether or not it is classified as a principal arterial, a point system based on its functional classification, and geometric deficiency gap. In these two types of sufficiency ratings, no consideration is given to the relationship between user benefits and provider costs.

CONGESTION INDEXING

Another technique used by the SDHPT, which does take into account a project's cost in relation to the project's traffic service, is the development of two indices for added-capacity projects. The first congestion index, Index 1, is a function of the present average daily traffic exceeding "tolerable" flow conditions on the existing facility multiplied by the project length in miles and divided by the project cost in thousands of dollars. The second index, Index 2, is a function of the projected average daily traffic exceeding "tolerable" flow conditions on the existing facility multiplied by the project length in miles and divided by the project cost in thousands of dollars. Again these indices do not address user cost benefits per vehicle and often can be misleading. For example, a project with a small cost on a highway with high average daily traffic may appear to be more beneficial than a project with a high cost on a high-volume roadway.

COST PER VEHICLE–MILE RATING

Another technique used by the Commission is to rate proposed projects on a project cost per vehicle-mile basis. The cost of the proposed project is divided by the product of the average daily traffic and the length of the project in miles. Again, this technique does not indicate the economic benefit to the highway user of the proposed project.

OTHER SDHPT RATING AND EVALUATION TECHNIQUES

One important system of fund allocation the Department is in the process of implementing is the Pavement Management System. The PMS is designed to allocate, in a cost-effective manner, funds for pavement maintenance, resurfacing, rehabilitation, and reconstruction. The Department also administers a Bridge Replacement Program designed to allocate bridge replacement funds in a cost-effective manner. These two programs of fund allocation are, however, only part of the Department's overall responsibility of fund allocation, and the Chairman of the SHPT Commission had expressed a desire that the Department continue to review, coordinate, and improve its practices and procedures in project and program evaluation, selection, and priority setting, which led to the current research.

The SDHPT Highway Design Division's Operations and Procedures Manual has an appendix which deals with the use of economic analyses for evaluating design choices. The three types of cost evaluation contained therein are for (1) overall project design, (2) stage construction, and (3) design of particular elements of the overall project. The techniques used are from AASHTO, as described in A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements--1977. The Design Division's manual is used in conjunction with acceptable methods for producing traffic engineering estimates of vehicle delay, vehicle running and idling times, vehicle speeds, and traffic volumes and roadway and intersection capacities. The primary use of the Design Division's economic evaluation technique would be in screening project alternatives before development of a program of projects for a highway district. The primary disadvantage of this technique would be that it is inappropriate for the evaluation of a large number of projects, such as would be evaluated on a statewide basis by the SHPT Commission.

CHAPTER 3. REVIEW OF OTHER BENEFIT/COST TECHNIQUES

The basic purpose of benefit/cost analyses as applied to highway projects is to determine whether or not the benefits of reduced highway user costs (operating costs, travel time value, and accident costs) exceed the highway system costs (right of way, construction, utility relocation, operation, and maintenance) required to produce those benefits. In all cases, only direct economic effects to users are considered because the indirect effects to the community at large (the non-users) are difficult to quantify in monetary terms and may cause double counting when the non-users become users of the facility.

AASHTO BENEFIT/COST PROCEDURE

Most of the techniques found during this research project follow the basic procedures and scope outlined in the American Association of State Highway and Transportation Officials publication entitled A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements--1977 (called the Red Book). There are eight basic steps to the methodology set forth in the Red Book. A brief description of each step follows.

Update User Cost Factors

The Red Book utilizes running cost factor nomographs for two sizes of an "average" passenger car, a single-unit truck, and a diesel combination tractor semitrailer truck. Since it is necessary to update these factors periodically to insure accuracy of the economic analysis, a multiplier method is provided. These nomographs for the four vehicle types are based on the effect of speed on fuel, engine oil, tires, maintenance, and vehicle depreciation costs. Additional effects of grade, horizontal curvature, and speed change cycles are also provided.

Select Basic Parameters

The basic parameters for the economic analysis, i. e., discount rate, unit values of time, analysis period, and study years to be calculated, need to be set. The discount rate represents the opportunity cost of capital and, as stated in the definitions section of this report, varies depending on the technique used to calculate the stream of project costs, i. e., whether they are in "constant" or "current" dollars. If constant dollars are used, the discount rate is a percentage which represents the real cost of capital and not the market rate of return, which would include an allowance for inflation. If current dollars are used, then a higher discount rate, which would include the full current market rate of interest would be used .

The unit values of time for automobile trips are usually tabulations of (1) standard values of time for an average trip type and (2) groupings of time saved and are based on an average hourly family income to facilitate adjustment based on local variations. To obtain person-time values instead of vehicle-time values a multiplying factor based on vehicle occupancy is used. For truck trips the value of time is based not only on the driver's time costs but on other time-related costs based on the market value of the goods carried; however, the driver costs are the most significant component.

The analysis period for transportation improvements should usually be the length of their economic life and the same length of time for each alternative. However, accommodation can be made for different economic lifetimes or staging of improvements through the use of residual values (refer to definitions section) and the inclusion of rehabilitation costs for the shorter-lived projects.

The selection of study years is based on the representativeness of the years selected to calculate benefits or costs and requires the estimation of traffic data. Usual practice would be to have the following study years: the first and last years of the analysis period, and an intermediate year if a significant change in user benefits is anticipated.

Setting of Project Characteristics and Estimation of Project Costs

To assure accuracy and representativeness of project estimates, the project and alternatives should be broken into sections with uniform characteristics (cross section, traffic, etc.). Then an estimate is made of the project costs (including construction, maintenance, and operating costs) for each alternative and for each study year.

Calculate Unit User Costs

This step in the methodology calls for the estimation of user costs on a per unit of traffic (vehicles or trips) basis to enable application to various levels of traffic (hourly, daily). These unit costs are based on both the build and no-build condition of each alternative. The unit user costs are the sum of the time value, vehicle running costs, and accident costs per vehicle-mile or per person-trip. To these costs are added the additional user costs of speed changes between sections and at traffic control devices.

Calculate User Benefits

The user benefits are defined as the difference between the user costs for any two alternatives. Another way of saying this is that the user cost differences result in an incremental user benefit based on a savings in vehicle operating costs, travel time costs, and accident costs with each proposed alternative. In order to accommodate induced and diverted traffic, the basic user benefits calculation is a function of the difference between the user cost per unit of traffic with and without the improvement times the average of the traffic volume with and without the improvement.

Conversion to Annual User Benefits

Since incremental user benefits as calculated in the previous step are usually in hourly or daily terms to insure greater accuracy, it is now necessary to aggregate this data to a yearly basis to cover the life of the project. The conversion from hourly or daily traffic is straightforward; i. e., obtained by multiplying peak and off-peak benefits by their respective number of hours in the day and then multiplying the daily benefits by 365.

Estimation of Residual Value

In cases where the analysis period is less than the useable life of the project, a residual value calculation will need to be made. This calculation should include the cost of conversion, if any, of the project to other uses and the value is counted as a negative benefit decreasing any residual value.

Determination of Present Values and Economic Desirability

The final step is to compute the stream of user benefits over the life of the project and compare this with the project costs to determine the economic benefit of the project. In order to convert the stream of user benefits calculated for each year (or representative years) of the project to a present value, the Red Book utilizes standard economic analysis procedures. Benefits and costs are multiplied by present worth factors determined from tables of compound interest based on the discount rate selected in an earlier step and summed to determine net present value (costs sign being negative and benefits sign being positive). For projects with a NPV greater than one, the project can be said to be beneficial from an economic standpoint but this should be only one of the considerations in determining the future of the project. Another technique for analyzing the effectiveness of a project is to calculate the ratio of the present value of the stream of benefits to the present value of the stream of costs. This ratio is known as the benefit/cost ratio and can be calculated for each project alternative. A project with a value greater than one can be said to have an economic benefit and projects can be ranked based on this ratio.

The Red Book methodology has been incorporated into some more recent procedures which have made their own adaptations of the basic technique, i. e., computerizing the process, inputting location-specific default values, etc.

STATE OF ALABAMA ROAD USER COSTS PROCEDURE

The State of Alabama Road User Costs procedure (Ref. 2) is based on the Red Book. Road user cost curves were developed for gasoline powered passenger cars at four levels of gasoline prices, namely $1.25, $1.50, $1.75, and $2.00 per gallon. User costs for freeways and arterials can be found by entering the curves with the average vehicle speed and the annual vehicle mileage. The costs are based on March, 1980 price levels and can be updated to current prices by using the Consumer Price Index Detailed Report, published by the Bureau of Labor Statistics of the U. S. Department of Labor.

The curves contained in the Alabama Road User Costs procedure are composed of several factors, including vehicle operating costs, vehicle travel time costs, and vehicle accident costs. The vehicle operating cost is the total cost of the following components: gasoline costs, lubricating oil costs, tire wear costs, maintenance and repair costs, and depreciation of new car costs. The travel time cost is the cumulative dollar value of the vehicle occupants' time as the vehicle moves along a highway at a given speed. The vehicle accident cost is based on the total dollar value of all fatality accidents, injury accidents, and property damage only (PDO) accidents that occur on all Alabama highways divided by the total annual vehicle mileage on all Alabama highways for that year. These costs are shown separately, along with the total user costs, for both freeways and arterials in the curves on a cents per vehicle mile of travel in relation to the vehicle speed. The vehicle speed is the average running speed for freeways and the average overall travel speed for arterials.

The Alabama procedure is simple to use, requiring very little input data, but this simplicity has various disadvantages. The procedure considers only passenger vehicles; no trucks or other vehicle mix can be examined. The procedure is manual and therefore not useful when large numbers of complex projects are analyzed. Finally, the costs are not based on Texas data, which could lead to inaccurate analysis of Texas projects.

THE NORTH CENTRAL TASK FORCE PROCEDURE

The technique used in Dallas by the North Central Task Force (NCTF) to perform a cost-effectiveness analysis for corridor alternatives is a combination of the Red Book and the State of Alabama Road User Costs procedure. Using an indexing method based on the Consumer Price Index (CPI), the cost data in the AASHTO and Alabama studies were updated to 1985 dollars. The NCTF procedure (Ref. 3) compares a no-build or existing situation to a build alternative. The procedure uses tables, nomographs, and formulas to compare the benefits of the reduction in road-user costs to the cost of engineering design, right of way acquisition, construction, maintenance, and operation. The input data requirements are

1. roadway corridor daily VMT and speeds for each year of the analysis period and for each alternative.
2. roadway facility types in the corridor for each alternative.
3. timing of construction and time frame of analysis period.
4. construction, ROW, engineering, maintenance costs.
5. additional data for the following items:
    a. discount rate or rates assumed over the analysis period
    b. gasoline price
    c. Consumer Price Index updating value

The output of the calculations used in the NCTF procedure provide the following measures of economic desirability of the improvement:

1. net present value (NPV)
2. benefit/cost ratio (B/C)
3. payback period
4. internal rate of return (ROR)

These calculations are based on two equations, one for NPV and one for B/C. Internal to the NCTF procedure are data regarding vehicle operating costs, vehicle travel time cost, and accident costs. The difference in user cost between the build and no-build alternatives then becomes the user benefits. To calculate the investment costs, the method utilizes the input data regarding design, ROW, and construction costs and combines it with historic maintenance costs. For projects with a life span longer than the analysis period, a residual value is also calculated to indicate the additional value remaining for the project.

The output, as noted earlier, are values for net present value, benefit/cost ratio, payback period, and internal rate of return, which are standard cost effectiveness measures. The format of the output provides information concerning the year-by-year benefits and costs and a running computation of NPV and B/C.

The disadvantages in using the NCTF procedure are that it does not consider indirect costs and benefits, such as stimulated business activity and deflated property values, and it does not easily handle a variety of alternatives without a significant amount of preprocessing of traffic and other data. The North Central Task Force procedure by itself could not handle efficiently a large volume of projects that a highway program would encompass but would be adequate for specific problems within a city or a small district. It would also require updating and revision to a more current Texas-based transportation cost data base.

The advantages of the procedure are that it gives a year-by-year breakdown of the benefit/cost measures, has fairly simple input requirements, allows a rather straightforward analysis of the two alternatives simultaneously, and allows variance of the parameters to fit specific situations.

THE NEW YORK STATE BENEFIT/COST PROCEDURE

The New York State Benefit/Cost procedure (Ref. 4), like the two preceding procedures, uses nomographs to estimate operating and time costs for a given highway improvement project. A benefit/cost ratio can then be calculated using the total of the operating and time costs divided by the estimated construction cost of the project. The only input needed are the posted speed, average running speed, traffic (with some estimate of vehicle mix), and highway section length, for both the before and after conditions. The nomographs use posted speed and average running speed as equivalents to facility type and congestion; the operating cost per vehicle-mile travelled (VMT) relationship between those speeds is then obtained from the nomographs. That cost multiplied by the VMT on the selected project yields the operating cost. Similarly, the travel time costs are estimated. The New York procedure does allow for the vehicle mix to be included by providing four nomographs– 100% automobiles, 100% trucks, and 90/10 and 80/20 auto-to-truck ratios.

Accident costs are not included in the procedure because the New York State Department of Transportation (NYSDOT) considers these costs to be site specific and therefore less amenable to generalization. The procedure is manual and was set up by the NYSDOT to be a "first-cut filter" for project selection.

Since one of the prime arguments against the preceding procedures was the inability of these procedures to handle as large a set of data as would be found in Texas' Statewide and district-wide programs, large mainframe computer programs were also investigated as a part of this research effort.

THE NEBRASKA PROGRAM

The Highway Economic Analysis Computer Package (Ref. 5), known hereafter as the Nebraska Program, was developed at the University of Nebraska. It is an interactive program that performs an economic analysis for various highway improvement alternatives. The program was written in FORTRAN to run on a VAX 11-750 mainframe computer. The program is interactive in that it is menu driven. The user is presented with a choice as to which program to run, for example the stop signed intersection program; each program has either one or two screens to which data must be input. The user selects the last choice, END SESSION, to enter the construction cost data.

The general methodology of the Nebraska program, like that of the Alabama Road User Cost procedure and the NCTF procedure, is derived from the AASHTO Red Book. Highway segments and intersections can be analyzed for each highway alternate. There are four intersection programs to choose from and they are signalized intersections, stop signed intersections, railroad intersections, and intersection accidents.

User costs on highway segments are categorized as vehicle operating costs, travel time costs, discomfort and inconvenience costs, and accident costs. Vehicle operating costs are composed of tangent running costs, grade costs, curvature costs, and speed change costs. Tangent running costs accumulate to a vehicle operating at the average running speed on a tangent level highway segment.

Grade and curvature costs are additional operating costs that accumulate as a vehicle travels along a route. Speed change costs are also additional operating costs and accumulate as a vehicle decelerates to a reduced speed and then accelerates back to the running speed.

The Nebraska program uses operating cost data from a study (Ref. 6) that reported on 1980 costs. Tangent running costs, grade costs, and curvature costs are based only on the vehicle type, while speed change costs are dependent on the level of congestion measured by the volume to capacity (v/c) ratio. The speed change cost is a linear function for v/c ratios less than or equal to one. A non-linear function is used for v/c ratio's greater than one; this rationale is taken from the Red Book and reflects the instability in traffic flow for oversaturated highway segments.

The value of time used by the Nebraska program in computing time costs is based on a vehicle occupancy of 1.56 persons per vehicle (Nebraska data). The user cannot input the average occupancy into the program but the occupancy can be manipulated by inputting the appropriate value of time.

Discomfort and inconvenience costs are computed by the program and these are a function of the v/c ratio. As congestion increases, so do the discomfort and inconvenience costs.

The Nebraska program uses data from the state for accident costs due to fatal, injury, and property damage only accidents.

The Nebraska program will calculate the costs associated with vehicle delay at an intersection. Vehicle delay is divided into three components, namely, deceleration delay, stopped or idling delay, and acceleration delay. Deceleration delay is the length of time needed for a vehicle to decelerate from the approach speed to a stop. Stopped or idling delay is the time that a vehicle is stopped at an intersection. Acceleration delay is the time needed for a vehicle to accelerate back to the approach speed from a stop.

The vehicle delay at an intersection adds to the operating and time costs. As vehicle delay increases, so do the operating and time costs; similarly, a reduction in delay will lower the operating and time costs. The Nebraska program calculates the additional costs deceleration delay, stopped delay, and acceleration delay to operating and time costs for signalized intersections, stop-signed intersections, and railroad crossings.

Intersection accident costs are based on fatal, injury, and property damage only accidents that have been converted to Equivalent Property Damage Only (EPDO) accidents, which are then multiplied by the average cost of property damage accidents. The program is able to estimate the reduction in accidents resulting from a safety improvement to an intersection, such as the addition of a protected left turn phase.

The segment cost part of the Nebraska program provides a single screen to input the necessary data. The input data needed are facility type, area type, segment length, capacity, volume, speed, accident reduction, vehicle mix, value of time, percent grade, surface quality, and curvature. Default values are provided for capacity and operating speed (posted speed needs to be input).

The Nebraska program calculates the net present worth and benefit/cost ratio of each alternate. The output of the program for each alternate consists of an echo print of the first and last years of the analysis period, and the economic analysis, i.e., the NPW and the B/C ratio. The program can analyze up to ten alternates at a time, with each alternate including up to 999 segments and 999 intersections.

The Nebraska program allows for easy data entry with its menu-driven format. Unfortunately, that is the only strong point about the program. There are numerous problems, some minor, but most are major in the Nebraska program. The data used within the program are not completely documented. One of the key tables used in determining user cost, the operating speeds as a function of the V/C ratio, is an example of this. In another instance, the data in the program seem to be in error. The default accident cost data for an undivided, four-lane roadway is listed as $1.69 per 1000 vehicle-miles, a figure which is inconsistent with a cost of $15.34 per 1000 vehicle-miles for a painted-median, four-lane roadway and $7.38 per 1000 vehicle-miles for a divided, four-lane roadway. Also, the source of the default accident cost data is not given.

Another problem with the Nebraska program is that the cost data are based on different years. The operating costs per vehicle type are from 1980, but the speed change costs are from 1984, as are the time costs and the accident costs. The default capacity values used by the program are not available to the user except by running the program or digging through the program structure.

Finally, there are problems in running the "user friendly" program. If a mistake is made in choosing a program, say the signalized intersection program is picked when the stop signed intersection was intended, there is no way to correct the program except by aborting the entire session and beginning again. In addition, there is no way to correct an incorrectly entered bit of data once the user moves to the next data screen. This poses serious problems when the user is inputting extensive alternatives made up of numerous segments and intersections.

THE REVISED HIGHWAY ECONOMIC EVALUATION MODEL (HEEM II)

The Revised Highway Economic Evaluation Model (Ref 6) is a computerized model which calculates the benefit/cost ratio and a measure of mobility for each highway project or system of projects. In addition, HEEM II can evaluate the relative importance of the projects for the purpose of programming them for construction or select the best design or budget alternatives. HEEM II is also equipped with some optimization techniques for evaluating proposed highway projects. The program can optimize the construction year of the if-build alternative so that the maximum benefits are realized. The expansion year for a staged project can also be optimized or HEEM II can optimize both the construction and expansion years. These techniques can aid the user in determining the scheduling of projects so that the greatest benefit is derived from the project costs. The following is a list of the input data requirements for the HEEM II:

1. corridor ADT for current and two projected years (including dates for projected years)
2. characteristics of existing, proposed, alternate and expanded highway segments:
   a. number of lanes
   b. technical and safety factors (difference in percent between proposed design and a typical design for shoulder and lane widths, vertical and horizontal alignment, and percent trucks)
   c. length in miles
   d. facility type (60+ varieties)
3. construction and expansion years
4. construction and ROW cost of improvements

Options for the noted input data can be accommodated if the user does not choose to use the default values for percent trucks, speed limit for conventional highways, vehicle occupancy rates, percentage of vehicles using HOV bypasses, diversion route speed, length of planning horizon, value of time for cars and trucks, HOV inconvenience costs, construction cost escalation rates, inflation rate, and discount rate. Additional HEEM II analysis refinements include corridor segmentation, staging of construction, and optimization of staging of construction/expansion, use of which would require varying amounts of input data.

The HEEM II model then calculates traffic allocated to each route under analysis, average daily speed, delay savings, operating cost savings, accident savings, incremental maintenance cost savings, net present value of benefit, net present value of capital costs, benefit/cost ratio, internal rate of return, and mobility measures in miles per hour and daily vehicle miles. The program is run in a batch format and has specific card formats which are filled out on forms for later input and processing.

The output produced by HEEM II is provided for each segment (if divided this way) of the problem itself and for the system (if applicable) and covers the items noted under calculations and includes a printout of the input data. The output includes tabulations and graphical presentations of the results. The basis for decision making would be the three measures of effectiveness: net present value, benefit/cost ratio, and internal rate of return. These three measures are all related to one another but the output does allow some flexibility in how one looks at the selection of projects for implementation.

HEEM II was written in FORTRAN and runs on an IBM 3081-D mainframe computer. Input is loaded in a batch format for subsequent running of the program. The batch format is time consuming because care must be taken in placing the appropriate data in the correct column. The user must keep track of the spacing between data entries as there is no labelling system format. The program does not execute as data is entered (as is the case with the Nebraska program), so input errors can be identified and corrected before the program is run.

The HEEM II model was designed for the SDHPT, and therefore would be very useful and very appropriate for project and program evaluation by the Commission. The advantages are its great flexibility in types and sizes of projects it can analyze. The only disadvantages would come from how the variables are selected (such as percent trucks, etc.), the difficulty of keeping the default values and assumptions up-to-date and site specific (for greatest validity and accuracy), and the use of daily (rather than hourly) traffic (or the development of data that more accurately reflect the relationship between speed and volume).

DELAY SAVINGS MODEL

The Delay Savings Model (Ref. 8) calculates the delay savings that results from a capacity improvement to an existing highway. The model calculates only the delay savings realized by a highway improvement since the reduction in delay to the road user is the single largest component of the project benefits. Using only delay savings allows for comparison of projects on a similar basis. Required data input was kept to a minimum to allow for quick runs of a large number of projects. The absence of detailed data input means that the computer model's calculations are best viewed as providing a planning level of evaluation of the relative magnitudes of projects and not as a detailed summation of the absolute benefits of a project.

The delay savings model is written in FORTRAN and will run on IBM mainframe computers. However, the program is not very sophisticated, and it would be possible to put it on a microcomputer without losing much time in program execution. The data are input in batch format, like the HEEM II.

Input data for the delay savings model are divided into two categories, required and optional. Required data include the current year, current ADT, construction cost and location, highway type, number of lanes, and section length for the existing and proposed facilities. The user can also input data to override the default values for percentage trucks, value of time for cars and trucks, discount rate, planning horizon, projected ADT for the planning horizon, and percentage persons using the proposed facility. Additional optional data are the speed limit, shoulder information, left turn median information, number of traffic signals per mile, and category of area development for both the existing and proposed facility.

The delay savings model calculates the delay savings based on the ADT anticipated in the future. This projected ADT can either be input by the user or the program will project ADT by using a growth factor based on the category of area development. Development categories are low, medium, and high, with medium being the default category. Yearly ADT is figured for each year between the current and projected years. Next, the ADT for each year is converted into hourly volumes by using K-factors supplied by the program.

Average speeds are then calculated for each hourly volume. The speed is influenced by the type of highway (either undivided, divided, freeway, or busway) and also by the presence of shoulders and left turn medians. The delay savings model is different from the other programs in that it will form queues for v/c ratios greater than one, and the average speed will decrease as the queue length increases. The queue is carried over to successive hours until it dissipates. The delay cost is then calculated from the speeds on both the existing and proposed facilities with the difference becoming the delay savings.

The output begins with an echo of the input data along with any default values used in the analysis. All of the projects are ranked in decreasing order of delay savings ratio. The delay savings ratio is the discounted delay savings divided by the construction cost. The cumulative construction cost of the projects is also listed. The program can process up to 9999 projects at one time.

The delay savings model has some features that are an improvement over the HEEM II. ADT volumes are converted into hourly volumes before average speed is calculated instead of using ADT to directly calculate average speed as HEEM II does. The delay savings model also handles queues, which more accurately reflects actual traffic flow on congested facilities. Unfortunately, this attention to calculating the traffic characteristics is not carried throughout the program. The way the program uses the influence of shoulders and left turn medians to calculate average speed and the unsophisticated manner in which projected ADT volumes are derived reduce the level of accuracy in the model's results. But, the delay savings model was not intended to be anything more than a planning tool or first-cut technique that requires little data entry and delivers a faster execution time than the HEEM II. Table 1 lists the various features of the economic analysis procedures.

Table 1. Economic analysis procedures

	ALABAMA USER COSTS	N. CENTRAL B-C	NY STATE B-C	NEBRASKA	HEEM II	DELAY SAVINGS
Computerized procedure		●		●	●	●
Texas-based data					●	●
OUTPUT						
Average delay savings	●		●	●	●	●
Accident savings	●	●		●	●	
Operating cost savings	●	●	●	●	●	
Maintenance cost savings		●		●	●	
Net present value		●		●	●	
Benefit-Cost ratio		●		●	●	
Delay savings ratio						●
Residual value		●				
Internal rate of return		●			●	
Mobility measure					●	
Project ranking						●
Traffic allocation					●	
Discomfort and incon. costs				●		
Tangent running costs				●		
Grade costs				●		
Curvature costs				●		
Average vehicle delay				●		
Idling and stppg. time costs				●		
Idling and stppg. op. costs				●		
Payback period		●				
Optimum construction year					●	
Optimum expansion year					●	

NORTH CAROLINA TECHNIQUE

A procedure, called Transportation Project Evaluation Using the Benefits Matrix Model (Ref. 9), was developed for the North Carolina Department of Transportation to aid State officials in setting priorities of proposed highway projects. The procedure was also intended to provide guidelines for local officials to use for urban projects. The North Carolina technique utilizes a benefits matrix model that consists of several elements to evaluate projects. The elements are user benefits, costs, economic development potential, environmental impact, and relationship of the project to the State arterial system.

The benefits matrix model uses a 20-year planning horizon to compute the reduction in user costs, i.e., the user benefits, due to savings in vehicle operating costs, travel time costs, and accident costs. The vehicle operating costs, based on a composite vehicle (from a 1981 vehicle mix for Charlotte, North Carolina, containing medium and heavy trucks and various automobile classes), are calculated by averaging the existing and projected last year ADT over the 20-year horizon. The cost data are developed for freeways, arterials, and collectors. A table is entered with the expected average speed to determine the running cost for a particular facility.

The travel time cost savings is computed using an average 1981 hourly income from the county where the proposed project is to be built. This hourly income is multiplied with the average vehicle occupancy multiplied by the amount of time spent on the facility.

Accident cost savings are also based on North Carolina data. The model uses 1981 average costs for fatal, injury, and property damage only (PDO) accidents to determine the savings in accident costs by improving a highway facility. The user enters graphs with VMT to estimate the accident rate for a given accident type on a highway facility. The costs are multiplied by a factor of 1.33 to account for the underreporting of PDO accidents.

The procedure uses a computer program to calculate the user benefits resulting from vehicle operating cost savings, travel time cost savings, and accident cost savings. The costs associated with a highway improvement include construction, right-of-way, maintenance, operation, and administrative costs, but the North Carolina technique considers only construction and right-of-way costs.

The third variable in the benefits matrix model is the economic development potential. This variable is included to reflect the impact that highway improvements have on economic growth in the area. The model asks for a probabilistic estimate of a highway improvement's influence on stimulating growth in the immediate area and in the adjacent area. The following probabilities are suggested for the evaluation of economic development potential: excellent is 1.00, very good is .75, good is .50, fair is .25, and poor is .00.

The environmental impact of a project is also considered in the benefits matrix model. Environmental factors are divided into three major categories: (1) economic, (2) physical, and (3) social/cultural. The economic environmental factors are evaluated in the economic development potential variable, but 13 physical and social/cultural factors are identified by the procedure. Physical environmental considerations are air quality, soils and geology, water resources, wildlife, and vegetation. Neighborhoods, noise, churches, park and recreational facilities,educational facilities, public health and safety, historic sites and landmarks, and aesthetics are social/cultural considerations. These factors are evaluated, like the economic development potential, by utilizing a probability estimation. The model evaluates the effects on each of the 13 factors caused by the proposed project and the aggregate probability is determined for both the positive and negative aspects. The importance of the project to the State arterial system is evaluated by determining the average daily through trips on the proposed facility in the design year.

Transportation officials can select which highway projects to implement by examining the five criteria in whatever combination they deem important based on the particular priorities of that area. Projects may be chosen because they return the highest user benefits or because they have the lowest cost. Similarly, local officials may use the benefits matrix model to find those projects that will positively influence the economic development in the area while contributing to the State arterial system. The negative impact of a proposed project on the environment can also be identified by the model so that transportation officials may strive to reduce the magnitude of the negative impact in order to make the project more attractive.

The benefits matrix model has some drawbacks to its use. The determination of average operating speeds is left to the user of the model. This means that the most critical element in calculating user costs is to be estimated by the user in some manner. The lack of a mechanism within the model to calculate average operating speeds can severely limit the worth of the model's output if different users of the model use different techniques to determine the average operating speed. Another problem is that the model does not discount future user benefits. This must be kept in mind when evaluating the user benefits because, while comparisons between projects is not a problem, using the user benefits as an absolute value is not recommended. The model does take into account the effects of highway projects on economic development and environmental factors but the limitations of doing such is apparent. Assigning values to these impacts is very subjective and can be considered only a minor part of the evaluation procedure. Since the examination of the five evaluation criteria of the benefits matrix is based on the specific area's transportation priorities, care must be exercised so that this procedure is consistently applied or at least carefully documented so that the model's results will be equitable. Finally, the model includes only construction and right-of-way costs. These are the major portion of the cost in a highway project, but the continued maintenance cost of the facility is not unsubstantial and should be included in the decision making process.

CHAPTER 4. REVIEW OF NON-BENEFIT/COST TECHNIQUES

The manual procedures and computer programs discussed in this report deal with the economic analysis of proposed highway improvements. The way in which they handle the traffic characteristics is very simplistic and therefore yields only a planning level of analysis. Programs that perform a more rigorous analysis of traffic characteristics are desirable for assisting the SDHPT in setting priorities among complex urban projects.

Several computer programs, all of which are maintained and supported, were evaluated for this research study. They cover a wide range of capabilities, from the type and level of analysis to the ease in data entry ("user friendliness").

Computer programs that analyze traffic operations do so under a variety of methodologies. The ways that the programs model traffic flow fall into two categories. Programs that represent a stream of vehicles (or platoon of vehicles) in terms of average speed, flow rate, density, etc. are called macroscopic models; Microscopic models treat each vehicle as a separate unit. Microscopic models may be more accurate in representing traffic flow on facilities, but they also require more input and take more computing time than macroscopic models. Also, because microscopic models are more detailed, the underlying assumptions that drive the program must be examined closely, or the credibility of the results may be questionable.

Computer programs are also differentiated by the type of modelling they do. Most programs are designed to optimize a given situation related to traffic operations. For example, an arterial street with multiple signalized intersections may be modelled so that the program will produce the signal timing parameters necessary to minimize traffic delay. Optimization programs seek to produce the best solution, while simulation programs allow only the evaluation of a system. Simulation programs are designed to reproduce the given situation as accurately as possible, with the result being an evaluation of the system using measures of effectiveness, such as fuel consumption, delay, stops, etc.

Each computer program evaluated for this study is presented here with information on the input requirements, the level of analysis performed, the output produced, and the hardware necessary to run the program.

TRANSYT–7F

TRANSYT-7F, TRAffic Network StudY Tool (Ref. 10), is a program originally developed in England that has been modified for use in the United States. The program treats traffic macroscopically and is an optimization model. TRANSYT-7F can analyze a network of up to 50 intersections (called nodes) with a maximum of 250 directional links. Input is divided into four categories that either are (1) common to the network, or (2) control the optimization process, or (3) detail signal timing, or (4) detail traffic data. The amount of input data needed to run the program is on a moderate level, depending primarily on the number of nodes and links in the network. TRANSYT-7F can optimize the offset of signals in a network to minimize stops and delay and also determine the optimum splits of individual signals. The output consists of an echo of the input, traffic performance tables, flow profile plots (optional), signal timing tables, and space-time diagrams. TRANSYT-7F will run on IBM, CDC, VAX, and Honeywell mainframe computers and has recently been formatted for use on the IBM personal computer.

SOAP–84

The Signal Operations Analysis Package, called SOAP-84 (Ref. 11), is an optimization program for isolated signalized intersections. SOAP-84 was developed by the University of Florida Transportation Research Center and can run on the IBM mainframe computer and IBM personal computer. The program will determine the optimum cycle length, phasing pattern, and left-turn configuration for an intersection. Input requirements are not demanding, with the program suppling numerous default values that may or may not be altered by the user. Instruction type cards supply the program with information on what to do, i.e., the level of output desired. Parameter type cards are optional and describe signal phasing patterns, left-turn behavior, and controller operating parameters. Data type cards supply volume and capacity information; headway, truck percentage, and minimum green time are some optional data that may be entered. SOAP-84 will design and analyze each intersection problem entered and can also evaluate alternative schemes, if requested. SOAP-84 produces 6 types of output– an input summary, a measure of effectiveness (MOE) report, design recommendations, intermediate calculations reports, comparison summaries, and diagnostic messages.

PASSER II–84

PASSER II–84 (Ref. 12) is an acronym for Progression Analysis and Signal System Evaluation Routine. The Texas Transportation Institute developed the program, which can run on numerous mainframe computers and also IBM personal computers. As its name implies, PASSER II–84 analyzes and optimizes signal timing progression along an arterial. The best cycle length, phasing sequence and offsets are determined, which results in the largest bandwidths in both directions. PASSER II–84 will choose those phase splits that minimize delay at each intersection. The input needed to run the program is simple to enter because of the "user-friendly" format. Information is needed for each intersection concerning the configuration, signal control, and traffic. The macroscopic model can handle up to 20 signalized intersections. Output consists of an echo of the input, guidelines for minimum and maximum cycle length for each intersection, the "best solution" for signal timing along the arterial, and a space-time diagram, if desired.

AAP

Recently, the Federal Highway Administration (FHWA) released software called the Arterial Analysis Package (AAP) (Ref. 13). AAP is TRANSYT-7F, PASSER II–84, and SOAP–84 bundled together with an input managing program to allow easier manipulation of data between the three programs. The software is available in two versions, either for a mainframe or an IBM personal computer.

NETSIM

A NETwork SIMulation model, called NETSIM (Ref. 14), allows the user to explore existing and proposed urban network alternatives. NETSIM is the latest version of a program that was originally developed by Peat, Marwick, Mitchell and Co. for FHWA. Virtually any urban network configuration up to 99 nodes, 160 links, and 1600 vehicles can be evaluated by NETSIM. Since NETSIM is a microscopic model, data input is very extensive, being entered in a batch format. The program does not optimize traffic flow in the network, and it can only simulate traffic behavior, but it does allow the user to examine an urban network on a detailed level. Output is in five formats, beginning with an echo of the input, a summary of MOE over the simulation period, intermediate statistical reports, fuel consumption and vehicle emission report, and various supplementary reports, such as bus performance in the network. NETSIM, like most of the other traffic modelling programs is available for both a mainframe and an IBM personal computer. Table 2 lists the features of the traffic operations analysis computer models.

HCS

One other program that should be mentioned is the Highway Capacity Software (HCS) (Ref. 15). This software was developed by FHWA and is a computerized version of the 1985 Highway Capacity Manual (HCM). HCS covers calculation procedures in all of the chapters in the HCM, such as Signalized Intersections, and Ramps and Ramp Junctions. Data is fairly simple to input, depending mainly on the particular type of analysis desired. Output is similar to the results given in the HCM. HCS will run on an IBM personal computer.

Table 2. Traffic operations analysis computer models

	TRANSYT-7F	SOAP	PASSER II-84	NETSIM
Simulation model	●			●
Optimization model	●	●	●	
Macroscopic traffic flow	●	●	●	
Microscopic traffic flow				●
Intersection analysis	●	●	●	●
Arterial analysis	●		●	●
Network analysis	●			●
OUTPUT				
Vehicle delay	●	●	●	●
V/C ratio or saturation	●	●	●	●
Percentage stops	●	●		●
Maximum queue length	●	●		●
Fuel consumption	●	●		○
Optimum cycle length		○	○	
Optimum phase patterns		○	○	
Optimum splits	○	○	○	
Optimum offsets	○		○	
Time-space plots	○		○	
Flow profile plot	○			
Efficiency			●	
Attainability			●	
Vehicle emissions				○
O-D vehicle patterns				○
Bus performance				○
Intermediate reports	○	○		○
Summary report	●	●	●	●

○ – Optional

CHAPTER 5. CONCLUSIONS

The principal shortcoming of using warrants, indices, ratings, etc., as currently used by the Department to evaluate or rank expenditures, is that they do not reflect the value of a project or program to the user or client whose tax money may be paying for the project or program. Another disadvantage is that proponents, planners, and designers of projects do not directly use these same indices in deciding planning and design issues. There are also questions about the sensitivity of the indices to such input variables as project length which may be subject to broad interpretation, as in the instances of incremental construction and highway and railroad grade separation projects. Consequently, those who are responsible for ranking projects and those responsible for proposing the development of projects may use different yardsticks for evaluating projects.

Indices may not reflect project characteristics that relate to the time span during which users and maintenance costs are incurred. Indices such as the sufficiency ratings, which express desirability as the least cost per vehicle mile traveled within the limits of a project or, its inverse, the most miles traveled per unit of cost, would tend to favor least first cost along with the possibility of higher maintenance costs. The final result of project selection on this basis may be higher overall annual costs. Indices are also difficult to apply when the effect of future demands for service and future construction costs as applied to staged construction are being considered. Change in demand, over time, and the rate of change may vary considerably and may have substantial effect on the present value of future benefits. Indices that reflect only daily traffic volumes do not provide any insight into traffic congestion, which is a function of peak hour demand, which can vary substantially as a proportion of a given daily traffic volume and direction.

Indices can be adjusted to reflect differences in input variables and project characteristics by assigning "weights" to the various factors used in calculating the index. However, the assessment of the weights to be used, if not assigned subjectively, may eventually be as difficult to appraise and utilize with other methods of evaluation.

In general, indices are most useful for comparing and ranking projects of similar characteristics. They provide no guidance in comparing improvements that are dissimilar. Examples would be the comparing of (1) a rehabilitation project to one that increases capacity and (2) rest areas to bridge replacement projects. It is often said that one cannot compare apples to oranges. In fact, it is done all the time in making transportation project decisions. However, the usefulness of such comparisons is indeed uncertain unless the value of apples and oranges can be quantified in a common currency. It is important to policy makers and administrators to be able to compare apples and oranges in order to allocate funds among disparate and competing projects. The chief concern, however, is the credibility and validity of such comparisons.

Comparisons are more credible when the value of an expenditure is expressed as a function of the value of that project to the client or user. If such comparisons were easy, there would be no tendency to use indirect methods of evaluating projects. Obviously, identifying and quantifying user benefits is difficult and is much more honored in the promise than in the breech. The AASHTO manual, which is a basic and authoritative reference work on economic analyses, and Appendix E of the Department's

Highway Design Division's Operations and Procedures Manual furnish good general examples of how to conduct economic evaluations of highway projects. These sources contain a good deal of average default operational and user costs which may or may not be appropriate for a particular project at a particular location. It is recognized that the values given for this default material may vary widely with place and time and lack conviction of similar data that are more timely and relevant. This lack of up-to-date and relevant operational and user costs also inhibits the use of fundamental economic analysis.

Economic analysis is essentially the evaluation of alternatives, including the "do-nothing" alternative. Each alternative design can be very extensive and require a great deal of effort to produce construction cost estimates, analyze traffic operations, assess environmental effects, and assign and estimate user costs. Each candidate highway project is usually considered to be custom designed and thus sufficiently different from other candidates that, in order to produce a credible estimate of project benefits and costs, each economic analysis may also be required to be custom designed.

For whatever reasons sufficient resources have not been made available to develop the necessary techniques and materials needed to make it attractive, except rarely, to apply accepted economic principles analysis in ranking highway projects. All of which may explain why economic analysis has not been widely used by highway administrators and policy makers for ranking projects. Nevertheless, there are techniques available which can be utilized in project evaluation. HEEM II provides perhaps the best framework of the techniques reviewed. HEEM II follows generally accepted practice in determining the economic effects of highway improvements, it is computerized, and it is maintained and supported by the Texas Transportation Institute.

During the course of the study the Department experienced the most turbulent turnover in personnel during the entire 70 year history of the Department. The Department lost about 1000 senior employees due to retirement , each having about 29 years of experience, which included a large part of the senior and middle management. Because of the many retirements of key personnel the make-up of the steering committee changed before each of the three committee meetings which interfered with the continuity of the study and necessarily limited the amount of time the committee members could spare for the study. These stressful conditions could not have been predicted when the study was originally conceived and the priorities of managing the Department during the period of intense personnel changes were such that the committee members did not have the opportunities ordinarily available to devote to the study.

CHAPTER 6. RECOMMENDATIONS

It would be extremely valuable for the Department to initiate a series of before-and-after studies in order to evaluate the economic impact of various types of improvements. Similarly, it would be useful to compare the traffic projections made on various urban highway networks with ground counts. The Department has been systematically preparing traffic forecasts for over 25 years and it would be educational to compare predictions with history. There is much to be learned about projecting traffic growth and assignments, which is problematical at best, and it would be enlightening for planners to be able to learn from these comparisons. Credible traffic projections are fundamental to credible economic analysis. Economic analysis, which is usually based on a limited data base of traffic characteristics, operations, and costs, together with many suppositional conditions, is often viewed with suspicion. Intuitively speaking, many highway improvements are asserted to be very cost-effective investments, but documentation is lacking to support the magnitude of such assertions. Before-and-after studies of improvements providing for changed travel patterns and operating conditions would be particularly valuable since the degree and scope of impact of such improvements are difficult to assess.

Improvements need to be made to HEEM II to make it a more effective and credible tool. The data from which the cost curves are generated need to updated, particularly with Texas data. The program should be converted for use on microcomputers and the format for entering input should be interactive, using a menu format.

REFERENCES

1. American Association of State Highway and Transportation Officials. A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements--1977, Washington, D. C., 1978.
2. Bureau of Urban Planning. Road User Costs, 1980, State of Alabama Highway Department, Montgomery, Alabama, October 1980.
3. North Central Task Force Consultant Team. North Central Project Technical Memorandum: Cost-Effectiveness Analysis, Dallas, Texas, September 1985.
4. Lemmerman, John H. "A Quick Benefit/Cost Procedure for Evaluating Proposed Highway Projects," Transportation Analysis Report No. 38, New York State Department of Transportation, Albany, New York, December 1983.
5. Lima, Peter M. and James Reinhart. The Highway Economic Analysis Computer Package, University of Nebraska, 1985.
6. Zaniewski, J. P. et al. Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors. Texas Research and Development Foundation, Austin, Texas, 1982.
7. Memmott, Jeffery L. and Jesse L. Buffington. "Revised Highway Economic Evaluation Model (HEEM-II)," Research Report No. 225-28F, Texas Transportation Institute, Texas A&M University, November 1983.
8. Memmott, Jeffery L. and Jesse L. Buffington. "A Model to Calculate Delay Savings for Highway Improvement Projects," Research Report No. 327-1, Texas Transportation Institute, Texas A&M University, October 1983.
9. Poole, Marion R.. "Transportation Project Evaluation Using the Benefits Matrix Model," Technical Report 8, North Carolina Department of Transportation, January 1983.
10. Wallace, C. E. et al. TRANSYT-7F User's Manual, Prepared for the Federal Highway Administration, Office of Traffic Operations, Contract No. DTFH61-80-C-00072, February 1981.
11. Signal Operations Analysis Package, Volumes 1--4, Transportation Research Center, University of Florida, prepared for the Federal Highway Administration, Implementation Package 78-4, 1978.
12. Chang, Edmond C.-P., Carroll J. Messer, and Blair G. Marsden. "Analysis of Reduced Delay and Other Enhancements to PASSER II--80 -- PASSER II--84 -- Final Report", Research Report No. 375-1F, Texas Transportation Institute, Texas A&M University, April 1984.
13. Arterial Analysis Package User's Manual, Transportation Research Center, University of Florida, prepared for the Federal Highway Administration, Implementation Package 86-1, March 1986.
14. Traffic Network Analysis with NETSIM -- A User Guide, Federal Highway Administration, Washington D.C., Implementation Package 80-3, January 1980.
15. Highway Capacity Software User's Manual, Federal Highway Administration, Washington D.C., January 1987.