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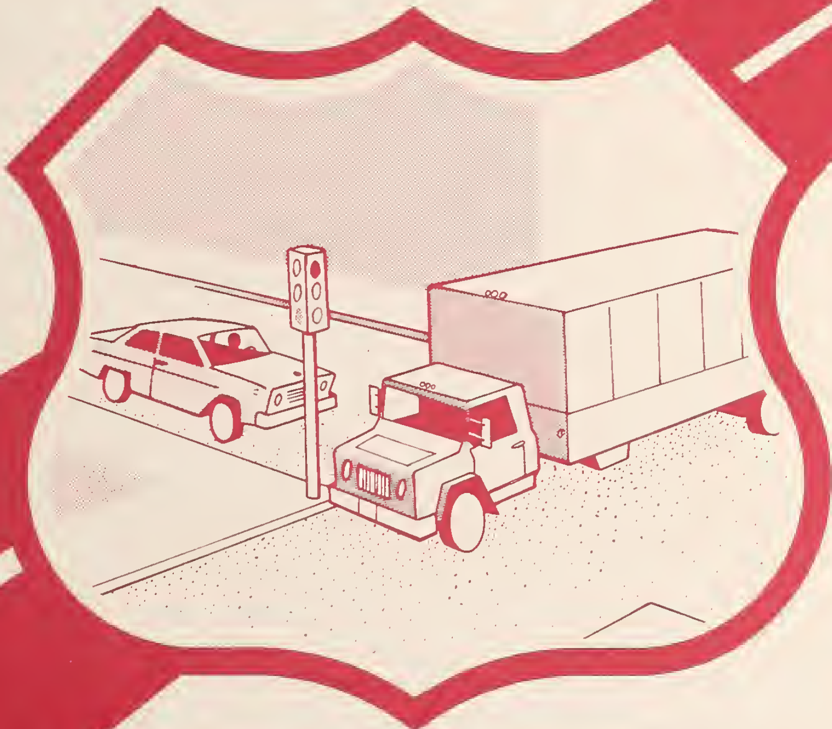
EFFECTIVENESS OF ALTERNATIVE SKID REDUCTION MEASURES

Vol. III. Users Manual
November 1978
Final Report



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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Environmental Division
Washington, D.C. 20590

FOREWORD

This report is part of a final report consisting of an executive summary and four volumes. The executive summary provides a synopsis of the research. Volume I describes the evaluation of accident rate-skid number relationships; Volume II describes the development of the benefit-cost model; Volume III presents the computerized benefit-cost model and instructions for its use; and Volume IV summarizes methods of measuring and achieving macrotexture. It will interest those concerned with pavement surface characteristics and the selection of accident reduction measures.

This research is included in Project 1H, "Skid Accident Reduction" of the Federally Coordinated Program of Research and Development. Mr. George B. Pilkington II is the Project Manager and Mr. Philip Brinkman is the Task Manager.

One copy of this report is being distributed to each FHWA regional office.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

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16. Abstract
A computerized benefit-cost model is presented for use by state highway departments in the selection of accident-reduction countermeasures to be applied to investigated sites. The model has capability to evaluate both surface modification countermeasures, which increase frictional supply, and geometric and traffic control countermeasures, which reduce frictional demand. The model considers the effectiveness of each countermeasure under both wet- and dry-pavement conditions. The model logic is described briefly to familiarize the program user with the type of analysis performed. The information needed by state highway department to use the model as a decision-making tool is presented in detail. Such information includes input requirements, input formats, output formats and interpretation of analysis results.

17. Key Words
Benefit-cost model, Skidding accidents, Skid number, Computer programs, Wet pavement, Accident countermeasures

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PREFACE

This users manual presents a computerized benefit-cost model developed by Midwest Research Institute for the Federal Highway Administration under Contract No. DOT-FH-11-8120. The mcdel development incorporates research results on the accident rate-skid number relationship obtained in Phase I of the contract. Mr. Charles P. Brinkman of the Office of Research, Federal Highway Administration was the Contract Manager.

The project benefited from the comments and suggestions of several other members of the staff of the Office of Research of FHWA including Mr. Ronald Giguere, Mr. George Pilkington, Ms. Julie Anna Fee, and Mr. Burton Stephens. In addition, the Data Systems Division of FHWA wrote all of the computer programs and made all computer runs for the project. We wish to thank Mr. William Mellott, Ms. Sandy Wallenhorst, Mr. Donald Clausen, and Mr. Dave Wood of that division for their invaluable contributions.

The model development was carried out in the Engineering and Economics and Management Sciences Divisions, under the administrative direction of Dr. William D. Glauz. Mr. Robert R. Blackburn, Manager, Driver and Environment Section; and Mr. A. D. St. John, Senior Advisor for Analysis, served as principal investigators for the study. Messrs. Blackburn and St. John, together with Mr. Douglas W. Harwood, Associate Traffic Engineer, were co-authors of this manual.

Present and past MRI staff members who contributed indirectly to the model development include: Mr. Duncan I. Sommerville, Ms. Cathy J. Wilton and Mr. Patrick J. Heenan.

Approved for:

MIDWEST RESEARCH INSTITUTE

A E Vandegrift

A. E. Vandegrift, Director
Economics and Management
Science Division

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METRIC CONVERSION FACTORS

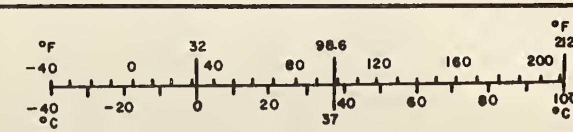
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286. Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



I. INTRODUCTION

This User's Manual is the third volume of a four-volume set prepared as the result of a multi year study of wet-pavement accidents. The project grew out of the increasing national concern over the hazards connected with driving on wet pavements. Under such conditions, the tire-pavement friction level is reduced--often dramatically. If vehicle maneuvers demand higher friction levels, skidding will occur, perhaps leading to an accident. Such accidents tend to be promulgated by higher traffic volumes and higher speeds. It therefore befalls the traffic engineering community to develop and implement countermeasures that will either increase the tire-pavement friction level or reduce the demand for friction.

The contract dealt with two aspects of this total problem. The first was to develop the relationships between pavement skid number and wet-pavement accidents for a variety of highway and traffic conditions. This work is documented in Volume I of the set.

The second phase of the study involved the definition of a range of alternative solutions to the problem of maintaining the frictional requirements of drivers during wet weather, and the development of a means to evaluate them on a cost-effectiveness basis. This was accomplished through a comprehensive, computerized, benefit-cost model. The details of the model and its development are given in Volume II.

A simplified version of the benefit-cost model was used to perform a benefit-cost analysis of alternative techniques for improving pavement macrotexture. The results of this analysis are presented in Volume IV, which is a guide to the role of pavement macrotexture in pavement skid resistance and accidents. This guide also contains a description of the methods of measuring pavement macrotexture, the methods of incorporating macrotexture in new pavements and the methods of restoring macrotexture in existing pavements.

This volume, the User's Manual, is meant for implementation. It shows how the user can apply the model, not just to wet-pavement accident reduction, but to an extremely wide class of benefit-cost evaluations of accident countermeasures. This capability exists because of two major reasons. First, the model is very comprehensive in that it embodies treatment of many types of present and future costs. Secondly, although it incorporates in detail the relationships between skid number and accidents (so that the effects on accidents of changing the skid number through resurfacing or other means can be predicted), it goes much further. It treats explicitly, via self-contained tabular data or user-supplied data, the effects of geometric and traffic control countermeasures on a variety of accident types. Thus, the user should find it to be a very useful aid in decision-making over the expenditure of always limited funds for accident-reduction countermeasures.

As explained in the next section, the manual is designed for two types of users: (a) highway engineers or administrators who need to understand the overall aspects of the model to use it effectively in decision making, and (b) engineers and other persons who need to prepare data and actually use the model. The computer programs, listing, etc. are available from FHWA's Data Systems Division, who performed the programming in accordance with the specifications and flow diagrams provided by MRI.

II. ORGANIZATION AND USE OF THIS MANUAL

The manual is structured such that the first sections provide general concepts that introduce the benefit-cost model to the reader; later sections go into more detail and provide specific instructions for using the computerized benefit-cost model and interpreting the output. Section III of the manual is an overview of the benefit-cost model and its associated computer program and support system. Sections IV and V describe the treatment in the model of major considerations such as capital costs, accident costs and accident rates. Section VI cites the sources from which much of the numerical data incorporated in the model was obtained. Section VII contains detailed instructions for running the computer program and Section VIII presents the output format and interpretation of benefit-cost analysis results. Instructions for updating the numerical values contained in the support system files are found in Section IX. Detailed input formats are presented in the Appendix.

The manual has been written primarily to serve two types of users--administrators, and engineers and other persons who need to prepare the data and run the program. In the following paragraphs, the probable interests of these user types are defined and appropriate sections of the manual that address these interests are identified.

It is assumed that the administrator wants to understand the model in sufficient depth to utilize the output in making management, scheduling and budgeting decisions. This administrator can obtain an overview of the model from Section III and the details of output interpretation from Section VIII. If the administrator wants to know how specific aspects of the benefit-cost analysis are handled, he can obtain this information from appropriate subsections of Sections IV and V. Special capabilities of the model are described in great detail in Section VII-A.

It is assumed that the engineer needs to assemble input values, employ the computerized model and interpret the output correctly. A majority of the manual is directed to this type of user, who should read most sections in sequence. The overview in Section III will prepare the reader for the additional details presented in Sections IV, V and VI. Subsection VII-A defines the types of input data required and the special capabilities of the model. Section VIII describes the output and output interpretation. After he is familiar with the model, the engineer should use Section VII-A to guide the organization of input data, with occasional references to Sections IV, V and VI for clarification of details.

Several items are included as quick references, especially for persons who may routinely prepare the actual data decks for computer runs. The Appendix presents in a simple form the format specification of each of the 26 possible types of data cards that may be used by the model. A summary description of input format requirements is in Section VII-B, and the deck organization is shown in Section VII-C. Error messages, which usually arise because of data errors or deck organization errors, are identified in Section VII-D.

All readers may have an occasion to refer to backup data or other information related to the application of the model. Section VI identifies the major sources of the data employed by the model, for example. Probably the major reference for the interested user is Volume II of this four-volume report. That volume contains the philosophy and reasoning behind the model features; equations, tables and figures depicting most of the numerical aspects of the model; detailed flow diagrams of the model subroutines; the subroutine heirarchy; the list of all major symbols used in the computer program, together with their definitions, subscripts, and other pertinent details; an extensive bibliography; and many other types of information related to the model. Volume I serves as a detailed reference to the user interested in the details of the accident rate-skid number relations in the model--the data collection, analysis and interpretation. Finally, the computer systems specialist is referred to FHWAs Data Systems Division for all program listings, and details of the support system, which is touched on only briefly in this manual.

III. PURPOSE, SCOPE, AND MAJOR CAPABILITIES OF THE COMPUTERIZED BENEFIT-COST MODEL

This section presents a brief description of the purpose and scope of the computerized benefit-cost model that has been developed for application by state highway departments. The section also describes the major features that have been incorporated to provide compatibility with the procedures and economics of individual state highway departments.

A. Purpose and Scope

The model is designed to be employed by state highway departments to evaluate the benefit/cost ratios afforded by accident-reduction countermeasures selected for potential application at a highway site. Although initially conceived as a means of evaluation of wet-pavement accident-reduction techniques, the model has proven to be much more versatile and is capable of broad applications to a variety of accident-reduction problems. The accident-reduction countermeasures to be evaluated are selected by the program user from a list that includes geometric, traffic control, and skid reduction types. The program user can also evaluate unlisted countermeasures by supplying the appropriate input data. The computer program proceeds to carry out a two-step process. First it evaluates economic feasibility by comparing each countermeasure with the "as is" or "as planned" condition; then, if necessary, it continues with the project formulation calculations by comparing economically feasible countermeasures, one against the other. The important results for each countermeasure are printed by the computer program for subsequent use in making budget decisions.

The highway site can be rural or urban, on a highway that is two-lane, multilane without access control, or multilane with access control. The site can be a highway section, non-intersection spot location, or at an intersection.

The current model examines individually countermeasures and does not evaluate feasible combinations of countermeasures that might be implemented together. Exceptions are signal-turn lane combinations that are treated as one countermeasure, and combinations whose characteristics are assembled and supplied by the model user.

The computerized benefit-cost model utilizes auxiliary data files that supply standard values for such items as countermeasure costs and accident reductions, and the distributions of accident severities and accident costs. A support system of computer program provides procedures for a state highway department to incorporate and update the values of these items. In addition, the user in the highway department is given the option of supplying overriding values in individual calculations. Figure 1 shows the elements involved when the benefit-cost model is executed.

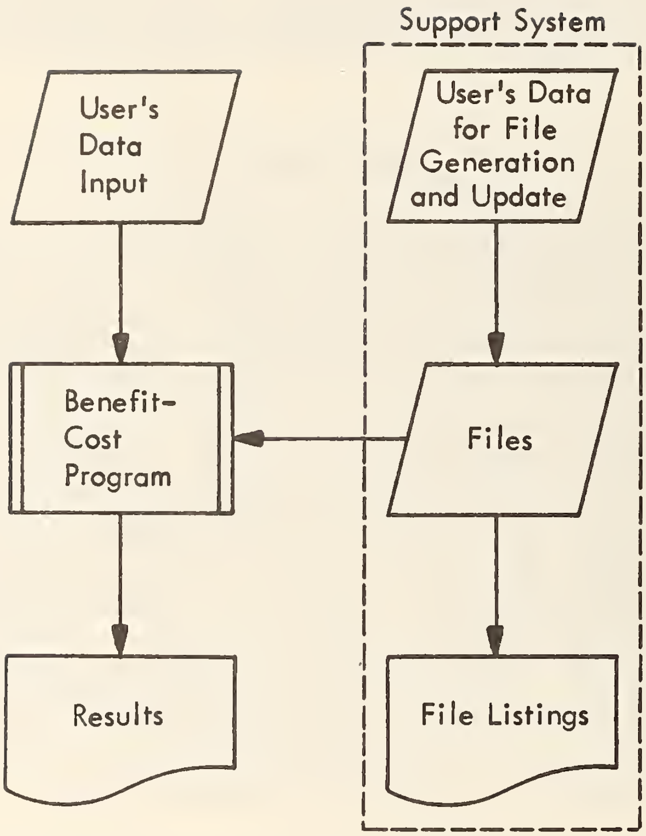


Figure 1 - Benefit-Cost Program Operation

B. Compatibility with Current Practices of Individual Highway Departments

The computerized benefit-cost model retains the capability to utilize the user's professional judgement; recognizes that costs and other characteristics of countermeasures are likely to vary between states or even between regions within states; and accounts for potentially important economic considerations that frequently are neglected in simple models. The following subsections describe these features.

1. Engineering judgement is required to select for evaluation those countermeasures that are appropriate for the site and the accident experience (if available). Also, if the program user judges that a countermeasure will be less or more effective than normal at the particular site, the normal accident reduction assessment contained in the support system files can be overriden by program input. Combined economic-engineering judgement can also be employed by overriding, through program input, the standard costs or life of a countermeasure.

2. Normal costs, lives, and characteristics of countermeasures are contained in the support system computer files where they can be updated periodically. Also, since the costs, effectiveness, etc. of a countermeasure may vary between states or regions within a state, the program logic employs a state and region code to identify the costs and characteristics' files to be used.

3. Prior decisions, future actions and future changes can have a pronounced influence on benefit/cost ratios. However, when faced with manual calculations the analyst may not appreicate their potential importance, or else may consider the calculations to be unduly complicated. In the computerized model the effects of prior decisions, future actions, and future changes are treated explicitly.

A frequent important prior decision is to resurface the site analyzed.* Because the analysis takes place before the prior decision is carried out, alternative surface courses could be considered and, if judged to be a better investment, be applied. When an alternative surface source is evaluated as a countermeasure for wet-pavement accidents, the resurfacing budget previously accepted should be treated as a sunk investment. In effect this then reduces the capital cost of the alternate surface. However, if a geometric or traffic control countermeasure is evaluated for the site, its cost is not reduced by the prior decision to resurface. Instead, the geometric or traffic control countermeasure is evaluated at the site as if the newly planned surface course were in place. Both the economic and skid number consequences of these interactions are included in the computerized model.

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* Most resurfacing projects are done to improve rideability and to safeguard the integrity of the pavement structure.

The model also accounts for the consequences of future highway department actions. For example, the normal effective life of a countermeasure may be shortened by future resurfacing or rebuilding, or by abandonment of the facility. The model employs the user's forecasts of these future actions to calculate benefits and costs that are both complete and fair.

The model accepts projected traffic volumes in any of three forms including linear growth, exponential growth, or year-by-year values. The linear and exponential forms are convenient since ADT projections frequently take these forms. The year-by-year specification of ADT provides the flexibility needed to account for step changes that frequently accompany actions such as the opening of contiguous sections or parallel facilities.

4. Right-of-way costs may need to be considered in conjunction with some geometric countermeasures such as added turn lanes or reconstruction of horizontal curves and intersections. Right-of-way generally has a longer life (amortization period) than other highway elements and its actual final worth frequently remains high. For those countermeasures that may require it, the model permits the right-of-way cost, life and final worth to be supplied independently of the other values for the countermeasure. The model performs separate economic calculations for the right-of-way and then combines the results appropriately with other countermeasure costs. The user-supplied input can also be used to account for special situations such as right-of-way that is planned for future acquisition, but for countermeasure purposes must be acquired at an earlier date. The details for appropriate input are described in Section VII.

5. Output printed by the computer program includes the user-supplied input, and the important results generated in the two steps of the calculation process--economic feasibility and project formulation. This output is designed for use in making budget decisions. It is recognized that budget decisions involve competition between sites that are candidates for remediation. Also, the initial capital outlays and the future budget commitments need to be considered in addition to the benefit/cost ratios.

IV. DESCRIPTION OF MODEL FEATURES

The benefit-cost model was designed to be implemented as a computer program. Thus, unless specifically stated otherwise, references to the model apply equally to the program and vice versa.

This section begins with a discussion of the fundamental construction of the model. Then a number of important features are described, together with user options where applicable. The major subject of countermeasure effectiveness in reducing accidents is treated in Section V.

A. Overall Program Logic

The major routines of the benefit-cost computer program are shown in the flow diagram of Figure 2. The notes in the figure describe the general course of computations.

One pass through the logic diagrammed in Figure 2 completes the benefit-cost analyses of all requested countermeasures at one highway site or section. The early routines read input information, obtain data from the support system files, and set initial values for variables. The next routines calculate for each requested countermeasure its applied life, its final capital worth, and capital costs at the highway site analyzed.

The principal measure of effectiveness used in the model is the benefit/cost ratio. Using this ratio, an analysis is performed in two steps. In the first step each countermeasure is compared with a base condition, which is the "as is" or "as planned" condition for the facility. Countermeasures that provide a B/C ratio of one or more are judged to be economically feasible. These calculations are performed in routine EFEAS.

If more that one countermeasure is judged economically feasible, a second step is undertaken to identify the best of the feasible countermeasures. This step is called project formulation or incremental analysis and employs routine PFRM. The first operation for this step is to rank the economically feasible countermeasures in order of increasing capital costs. Then, the first-ranked countermeasure (lowest capital cost) is taken as the base and the next ranked countermeasure is taken as a challenger. If the resulting (incremental) B/C ratio is equal to or greater than one, the challenger is accepted and becomes the base countermeasure in a calculation with the next ranked countermeasure. On the other hand, if the ratio is less than one, the challenger is discarded, and the base countermeasure is retained for comparison with the next ranked challenger. This process continues until each economically feasible countermeasure has challenged and has either been accepted or discarded.

C DURING BENEFIT-COST PROGRAM EXECUTION ALL SYSTEM FILES ARE AVAILABLE IN SEQUENTIAL FORM

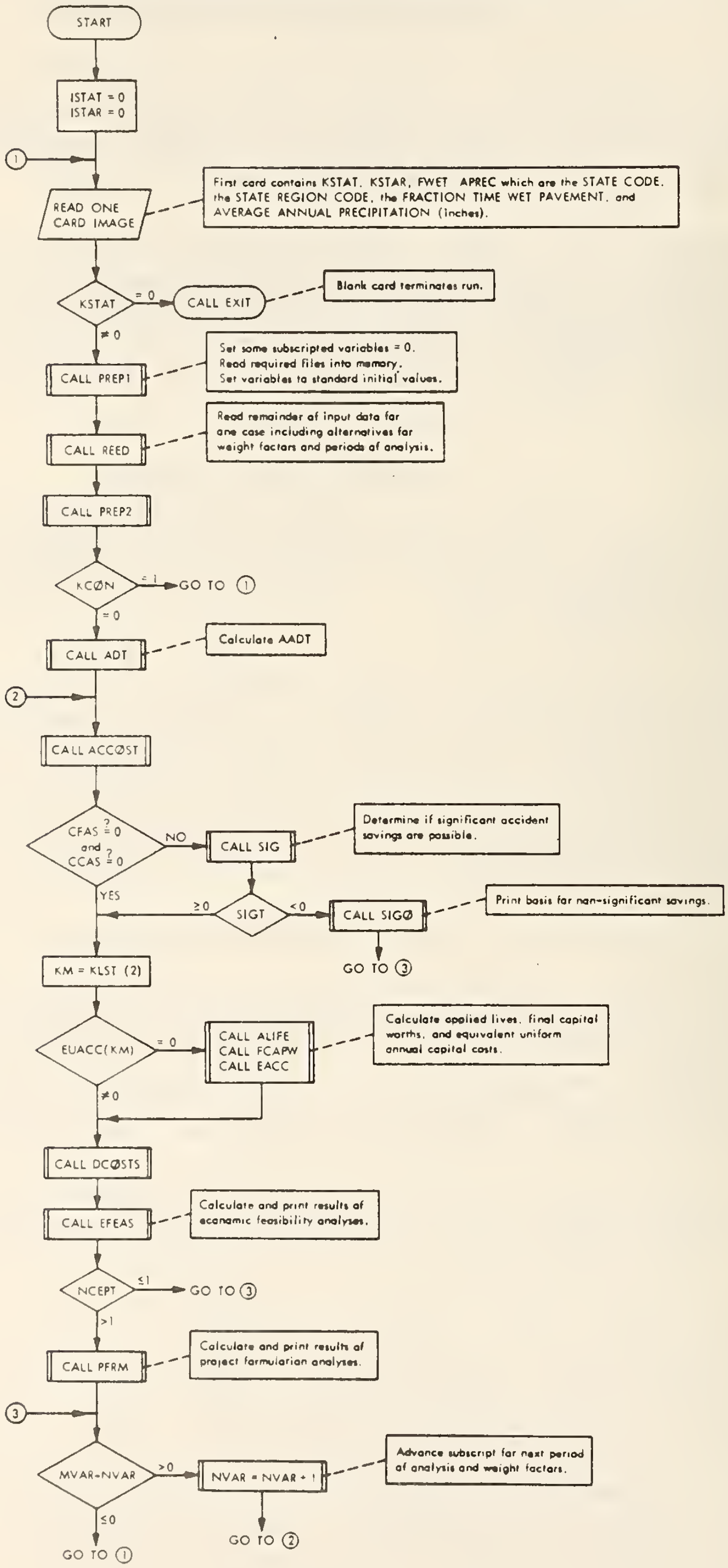

Figure 2 - Benefit-Cost Flow Diagram

Because the form of the calculations and the results are similar in the two steps, the same headings and print formats are used for both. The only difference is in the main heading. Also, each calculation involves three elements: a base condition, either a countermeasure or a challenger, and differences reflected in the benefit/cost ratio (and other measures). These three elements lend themselves to three lines of printed output for each calculation.

The test on MVAR-NVAR is part of an option to repeat the analyses at the same site, using the same countermeasures but with a different period of analysis and/or different accident cost values.

The program does not make final decisions for a highway department. Since, realistically, budget constraints are usually present, a final decision rests with the management and administration of the highway department. The cost-benefit program provides information useful in reaching that decision. Therefore, each calculation of both the economic analysis and the project formulation (if needed) is printed as an aid in decision making and subsequent review.

The program, written in FORTRAN IV, makes extensive use of subscripted variables. They are identified in the program and in the discussion as a symbol name followed by the subscript in parenthesis. Thus, FCW(KM) is the final capital worth of countermeasure KM, where KM identifies a specific countermeasure of a series being examined. The notation FCW( ) is used to signify the entire array of values of final capital worths.

B. Benefit/Cost Ratio

The ratio of benefits to costs is used as the main measure of countermeasure effectiveness. In general, it is defined as the fraction (using non-computer terminology):

$$B/C = \frac{AC_b - AC_c + MO_b - MO_c + UC_b - UC_c}{CC_c - CC_b},$$

where AC = Accident costs,

MO = Maintenance and operating costs,

UC = User costs,

CC = Capital costs, and

subscript b indicates the base condition, while

subscript c indicates the condition with countermeasure.

In the program formulation step, the subscript b refers to the base countermeasure and c refers to the challenging countermeasure.

C. Applied Life

According to normal economic practice, the life of a countermeasure would be the number of years that the principal capital cost items would last while serving their intended purpose. However, in the present application, it is necessary to recognize that additional factors may limit this time period. As a simple example, consider a highway section that is scheduled for resurfacing at the end of 2 years, to restore the riding qualities and weather-resisting properties. A surface treatment with a normal service life of 3 years could be applied now to improve skid number. However, the skid number improvement would be realized for a maximum of only 2 years. The phrase "applied life" has been adopted here to describe the period that the countermeasure capital item(s) will actually be employed for their intended purpose. Applied life may equal but not exceed normal service life. In this example, the applied life is 2 years.

The logic associated with applied life appears in subroutine ALIFE where the applied life of each countermeasure is calculated for the site under study. However, the program user may specify the applied life of individual countermeasures and override the file values and logic normally used. To provide this option the subscripted values of applied life, LAF( ), are set equal to zero in subroutine PREPI; values supplied by the program user are read in subroutine REED; and subroutine ALIFE tests the LAF( ) values individually for user input before employing normal computational logic. Similar options are provided the program user for other quantities described subsequently, such as final capital worth and capital cost.

D. Period of Analysis

When two alternatives with unequal applied lives are compared, a period of analysis must be chosen and employed. The computer program uses the longer life as the standard period of analysis but provides the user with the option to request a second analysis that employs the shorter of the applied lives. Even if the analyses produce different results they will provide useful information for management decision making which can consider the confidence in projections used and the indicated burdens on current and future budgets.

The symbol JPER( ) is used as a code for selection of period of analysis. A code value of 1 selects the shorter period; the default value, 2, selects the longer period. MVAR, the largest subscript to be employed for JPER( ), is initialized at the value, 1. The range of subscripts, MVAR, can be increased to include other options for both JPER( ) and the weight factors for costs described in Section J, which also must be defined for the subscripts 1 to MVAR.

The subscripts for JPER( ) and the cost weight factors are part of an option to calculate benefit/cost ratios under more than one set of cost or time period estimates. When the subscript range MVAR is greater than one, separate sets of calculations are made for the same site and set of countermeasures. Each calculation set employs the JPER( ) and cost weight factors supplied by the user for the associated subscript.

E. Compound Interest Forms

The compound interest forms used in the model logic are based on year-end cash flows. That is, all payments, receipts, and benefits are treated as though they occurred at the end of each year. The discount factor $1/(1+i)^n$ is used to obtain the present worth of a single amount n periods (years) in the future with interest rate i (a decimal, such as 0.06). The capital recovery factor is $[i\ (1+i)^n]/[(1+i)^n - 1]$. It is used to convert a present capital worth (when the countermeasure is installed prior to the beginning of the first year) to the equivalent uniform annual capital cost over a life of n years at interest rate i .

F. Forms for Capital Costs and Benefits

Capital costs are expressed on an annual basis as the equivalent uniform annual capital cost, EUACC. It annualizes over the applied life, via the capital recovery factor, the initial capital outlay, reduced by the present worth of the final capital worth after the end of the applied life.

Thus, the capital costs have an intrinsic cost/year character; the equivalent uniform annual capital cost does not change with the period analyzed. One might be tempted to treat benefits in a similar fashion so that the equivalent uniform annual benefits for each alternative would be independent of the analysis period. But the benefits may be greater or smaller in later years compared with earlier years. Thus, when equivalent uniform annual benefits are evaluated for compared alternatives over different periods, the comparison may not be equitable. Consequently, the benefits must be evaluated for compared alternatives over equal time periods.

In summary, the equivalent uniform annual capital cost provides equitable valuations of capital costs even when applied lives of compared alternatives are not equal. But, to be equitable and comparable, benefits must be evaluated over the same time periods.

Unfortunately, when capital costs are transformed into equivalent uniform annual capital costs, the information about initial capital outlays is obscured. Therefore, initial capital outlays and applied lives appear in the printed output from the computer program. The capital outlay is calculated as the product of the number of units required, and the capital cost per unit for the countermeasure provided from the support system data file. An overriding value of the capital cost per unit can be supplied by the program user.

The final capital worth in the simplest case is the typical net salvage value. In other cases additional applied life may be realized by removing and reinstalling the capital cost items. Their final capital worth in the initial application is, of course, reduced by the cost for removal and reinstallation. Some capital items may have a final capital worth in place. An example is a surface course that is covered by resurfacing. The covered course may have structural value that persists and contributes to the life or load-bearing capabilities of the pavement.

The final capital worth is calculated based on data and codes in the support system data file. However, the final capital worth for each unit of countermeasure KM, FCW(KM), can be entered by the program user as input. If the applied life LAF(KM) is directly supplied by the user for KM, then a non-zero value of FCW(KM) <u>must</u> also be supplied in input. If the final capital worth is zero or negligible, that fact should be indicated by inputting a small positive value, e.g., $0.01.

G. Weight Factors for Certain Costs

Two types of cost and benefit data have strong influences on economic analyses of highways and traffic, yet are very controversial. They are the costs of injury and fatal accidents, and the value of time. The program employs standard values and costs in the data files, but also gives the user the option of assigning separate weight factors for each of the above in input. The weight factors can thus be used in sensitivity tests or to apply extra emphasis to the accident reduction aspects of countermeasures.

H. Accident Severities and Costs

Accident severities are classified as property-damage-only, injury, and fatal. The user is given the option of supplying the base year accidents by severity or total only. If the base year accidents are provided by severity, that distribution is employed for the precountermeasure condition. If only the total is supplied, default distributions are supplied by the model. The default distributions of severities are distinct for area type-highway type combinations. The area types are rural and urban; the highway types are two-lane uncontrolled access, multilane uncontrolled access, and multilane controlled access.

The costs per accident in each of the severity classes are part of the data files accessed by the computer program. If the model user specifies weight factors for accident costs (other than the 1.0 default values), those factors are applied in the computer program. The costs used are those published by NHTSA in 1972.

When the model treats accident reductions, the injury and fatal severities are combined. This approach is consistent with the accident reduction data and the small sample problems that attend fatal accident reductions. It should, however, be recognized that the initial (precountermeasure) distribution employs injury and fatal severities separately so that accident costs in the baseline and in the countermeasure conditions correctly reflect the accident costs at the site analyzed.

I. User Costs

The model incorporates user costs arising from construction associated with the countermeasures. The costs are due to increased delay (vehicle-hours/year) and excess fuel consumed (gallons/year) in years when construction occurs. The costs are incurred in the baseline year and periodically in future years if the countermeasure is replaced in the period analyzed. The cost per vehicle-hour and per gallon of fuel is part of the data file, so that current values will be available from updated files.

The delays considered are those due to queuing and to depressed speeds at the construction zone. The added fuel consumptions considered are due to idling in queues, speed change cycles, and depressed speeds. The delays and the fuel consumption depend on the area type, the normal highway configuration, the construction zone configuration, the zone length, the ADT, the daily schedule for construction zone configuration, and the number of calendar days required.

J. Maintenance and Operating Expenses

The model incorporates maintenance and operating costs as the algebraic sum of two components. The first component is the normal average cost per mile, which is dependent on area type and highway type. The second component is the change or increment in maintenance and operating costs arising from the countermeasure.

The individual countermeasures influence maintenance and operating expenses in one of two ways. Those countermeasures that add equipment (signing, markers, lights) or new pavement (turning lanes, climbing lanes, widened traveled way) or other structures increase maintenance and operating expenses. On the other hand, those countermeasures that renew, replace or protect the existing surface course change the sequence of yearly expenses and have a tendency to reduce these expenses in the near future.

K. Traffic Volumes

The measure of traffic volume used by the model is the Average Daily Traffic (ADT). The model considers three types of sites: intersection sites, non-intersection sites and highway sections. The model has the capability to handle traffic volumes for either one or two facilities at each site. At an intersection site, one of the intersecting roadways is designated as the major facility and the other is designated as the secondary facility. In this case, the user must supply traffic volume estimates for both facilities. For highway sections and non-intersection sites, traffic volumes are needed for only the major facility.

The user can specify traffic volumes by either of two alternative methods: (1) by directly identifying the ADT year-by-year for the entire analysis period, or (2) by specifying the ADT for the year when implementation of the countermeasure is planned and the rate of ADT growth. The growth rate can be either linear or exponential (compounded).

The model uses the same projected traffic volume data in the analysis of all countermeasures. It assumes that none of the countermeasures has an effect on the traffic volume at the site during the analysis period.

L. Skid Numbers

An in-depth examination of the factors that determine skid numbers made it clear that they depend on the aggregate mineralogy, initial shape, size grading, binder or cement characteristics, emplacement practices, and various wear and weathering processes after emplacement. Therefore, it is currently impractical to establish numerically defined values for skid numbers that will be appropriate for widespread application. Instead, the subtle variations in mineralogy, binders and emplacement practices, and the regional variations in wear and weathering combine to make skid number prediction a strictly local necessity.

The computerized model contains a simple analytical form for skid number as a function of accumulated vehicle passages. The form is known to be applicable to pavements with polishing aggregate and it appears to be suitable for nonpolishing aggregate as well. It requires as input data, the initial skid number, a coefficient representing the logarithmic rate of change and an ultimate skid number.

V. ACCIDENT RATES AND COUNTERMEASURE EFFECTS

The computerized benefit-cost model uses the results from project analysis of the relationships between skid number and accidents. It meshes these with previously published data on the accident reductions achieved through geometric and traffic control countermeasures. This combination gives the model the capability to evaluate the entire range of wet-pavement accident countermeasure types. The analysis of the combined forms also indicates that the effectiveness of geometric and control countermeasures is not independent of skid number.

This section of the report presents the results from the analyses that are directly applied in the model. The relationship of these results to countermeasure effectiveness is shown. The relations employed in the model are presented in brief and their implications discussed. The incorporation of geometric and control countermeasures is described. The influence of ADT on accidents is presented together with the model's overall handling of accident rate calculations.

A. Results From Analyses of Skid Number and Accident Rates

Three major findings are incorporated in the model. First, there is the general finding that the wet-pavement accident rate is correlated with skid number in the anticipated way. That is, the wet-pavement accident rate is decreased for higher skid numbers. The exact relationships are dependent on the area type and highway type, and these relationships are well defined by available data only for rural areas, where sample sizes are largest.

The second major finding is that the relationship between the <u>wet-pavement</u> accident rate and skid number is strongly dependent on the <u>dry-pavement</u> accident rate. This finding is illustrated in Figure 3 where the rate of change of the wet-pavement accident rate with skid number is plotted against the dry-pavement accident rate for all rural highway types. The magnitude of the rate of change is indicative of the relative sensitivity of wet-pavement accident rate to skid number.

In the model, it is assumed that the wet-pavement and dry-pavement accident rates prior to application of a countermeasure are known. These initial estimates will be based on historical experience at the site or, in the case of new or rebuilt facilities, on professional judgement considering similar facilities. Then, if a change in skid number is contemplated as a remedial measure, the rate of change of the wet-pavement accident rate with skid number can be estimated.

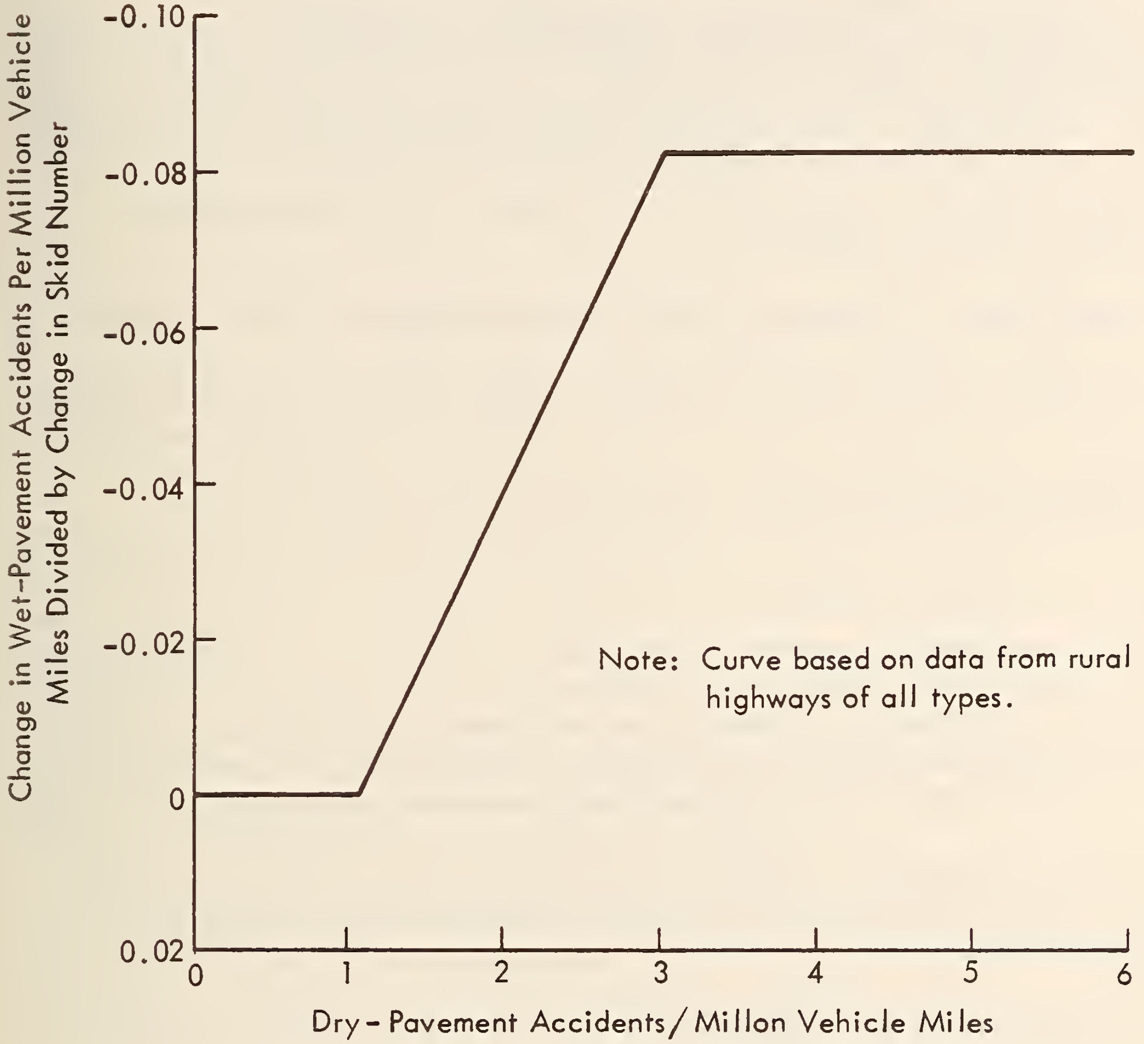

Figure 3 - Sensitivity of Wet-Pavement Accidents to Dry-Pavement Accident Rate

Although the data on urban sections were not extensive enough to establish separate relationships, statistical tests indicate that the sensitivities for urban areas are likely to be different than the rural values. However, the general character of the relationships should be similar. Lacking definitive data, the rural relationships are applied in the model to urban sites as well as best available estimates.

The third major finding incorporated in the model is the set of regression results that relate dry-pavement and wet-pavement accident rates. Regression equations were obtained separately for each combination of area type and highway type. The relations between wet-pavement and dry-pavement accident rates and the sensitivity of wet-pavement accident rates to skid number were combined in the computerized model. The final forms used are presented in the next section.

B. Basic Equations Depicting Skid Number-Accident Rate Relationships

The incorporation of the skid number-accident rate relationships employs several simple concepts. First, the overall accident rate on a facility is approximated as a linear combination of the rates under wet- and dry-pavement conditions:

$$r = f_w r_w + f_d r_d ,$$

where r = Overall accidents per MVM,
f_w = Fraction of time pavement is wet,
r_w = Accidents per MVM under wet-pavement conditions,
f_d = Fraction of time pavement is dry, and
r_d = Accidents per MVM under dry-pavement conditions.

Second, the wet-pavement accident rate is expanded as the sum of a part correlated with the dry-pavement accident rate and a part containing the skid number sensitivity:

$$r_w = b_o + b_1 r_d + \frac{\partial r_w}{\partial S}(S - \bar{S}) ,$$

where b_o and b_1 are coefficients provided by the model. S is the skid number measured at 40 mph (64 km/hr); and $\bar{S}$ is the average (40 mph or 64 km/hr) skid number for which $r_w = b_o + b_1 r_d$.

In addition, in agreement with Figure 3, a three-segment representation for $\frac{\partial r_w}{\partial S}$ is employed where each segment has the form

$$\frac{\partial r_w}{\partial S} = a_o + a_1 r_d$$

where the coefficients, a_o and a_1 , provided by the model, depend on the dry-pavement accident rate.

These equations can be combined to form the basic equation:

$$r = f_w \left[b_o + b_1 r_d + (a_o + a_1 r_d) (S - \bar{S}) \right] + f_d r_d \ .$$

This is the basic relation that, together with its differential form and the tabulated coefficients, is used by the model in assessing the change in total accidents with skid number. Clearly, the impact on accidents will be most pronounced if the pavement is wet a large fraction of the time (large f_w). In addition, skid number changes will be most effective if the dry-pavement accident rate is large, as is reflected in Figure 3. In fact, if r_d is less than about one accident per million vehicle miles, the accident rate will be totally independent of skid number.

The model contains an option to specify skid resistance by means of pavement texture parameters rather than skid numbers. This option can be used when conventional skid test results for a highway pavement are not available, but microtexture and macrotexture measurements are. Microtexture is represented in the model by the British Portable Number (BPN) and macrotexture is represented by the mean texture depth (milli-in.) determined by the sand patch method.

It is also important to appreciate how countermeasures that do not change the skid number impact accidents. First of all, geometric or traffic control countermeasures aimed at reducing wet-pavement accidents also, aside from a few special situations, reduce dry-pavement accidents. (The following is true even for the special situations.) The resultant change in total accidents is dependent in a somewhat involved manner on skid number. In essence, the dependency applies to sites in the midrange of dry-pavement accident rates (roughly one to three per million vehicle-miles). In that range, such countermeasures are most effective for low skid numbers, and when f_w is relatively large.

The skid numbers and the fractions of time that pavements were wet during countermeasure evaluations will affect the results of those evaluations. The basic equation for overall accident rate can be applied to determine a factor to correct the evaluated percent reduction to the percent that can be expected in application. That capability is in the model.

Spot-site accident rates are also treated by model. However, the data and analyses in the project dealt with accident rates (accidents/MVM) on sections of highway, whereas at spot sites it is conventional to use accidents/MV. In the model, it is postulated that the spots in question have higher than average accident rates, so that the sensitivity to skid number should be equal to or greater than the sensitivity observed in highway sections. It is assumed that each spot site analyzed has an initial accident rate that is equivalent to the section rate at the upper end of the middle range of Figure 3. Using this assumption the precountermeasure (year zero) accident numbers are used to calculate a pseudo length for the spot. The modifications and adjustments to accident rate are then handled by the same logic employed for sections.

C. Accident Rates Associated With Geometric and Traffic Control Countermeasures

One of the most useful features of the model is its ability to compare the effectiveness of geometric and traffic control countermeasures with the effectiveness of countermeasures that involve modification of pavement surface characteristics. Although the state-of-the-art of accident reduction effectiveness estimates for geometric and traffic control countermeasures is limited, those estimates that are available from previous research have been incorporated in the model. The user has the option of replacing the effectiveness estimates taken from the literature with estimates more appropriate to a particular region or a particular site. In addition, countermeasures other than those explicitly incorporated in the model can be evaluated using user-supplied effectiveness estimates.

Table 1 presents the accident reduction effectiveness estimates from the literature that are incorporated in the model. These estimates are expressed as percent accident reductions which are applied to the accident experience for the site under analysis. The effectiveness estimates found in Table 1 were obtained from the User's Manual in NCHRP Report 162. The estimates in Table 1 are the most reliable that are currently available. However, as more reliable estimates become available in the future, the estimates currently incorporated in the model can be replaced.

The following discussion describes the use of each type of information described in Table 1.

1. Selection of countermeasures for analysis: The user may select one or more countermeasures that are appropriate for a given site by specifying the countermeasure numbers given in Table 1. The user must exercise judgement in selecting the countermeasures to be analyzed. The burden is on the user to decide whether each potential countermeasure is warranted and feasible.

Many of the countermeasures in Table 1 are applicable to all highway types and area types, but the estimates for some countermeasures are only applicable to certain specified area types or highway types. For example, the accident reduction effectiveness estimate for installation or improvement of edge markings, the first countermeasure shown in Table 1, is only applicable to rural, two-lane highways. If the user specifies this countermeasure for use with any other highway type or area type, an appropriate message will be printed to warn the user. However, since appropriate effectiveness estimates for other highway types and area types are often not available, this message does not prevent the program from performing the analysis of the countermeasure, because the estimate, however inappropriate, may be the best available.

TABLE 1

GEOMETRIC AND TRAFFIC CONTROL COUNTERMEASURES INCORPORATED IN THE MODEL

Countermeasure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 1 - ROUTE SECTIONS																				
Countermeasures which do not require additional right-of-way																				
22	Install/improve edge marking	1	1	0.13	14	17	12													
23	Install right edge lines	1	2	0.13	2															
24	Install right edge lines	2		0.13	2															
25	Install double-yellow median line			0.13	5															
26	Install reflectorized raised pavement markers			0.13	5															
27	Upgrade signs			0.20				20	10	0	0	0	0	0	0	0				
28	Install/improve warning signs	1	1	0.13	36	32	38													
29	Install/improve warning signs	1	2	0.13	18	2	27													
30	Install/improve warning signs	2	1	0.13	14															
31	Install/improve warning signs	2	2	0.13	20	26	17													
32	Install overhead warning signs			0.20				0	20	0	20	20	0	0	0	0				
33	Install overhead lane signs			0.20				0	10	20	0	0	0	0	0	0				
34	Eliminate parking	2	2	0.13	32	3	46													
35	Increase sight distance			0.20				20	0	0	20	20	0	0	0	0				
36	Shoulder stabilization	1	1	0.13	38	46	33													
37	Relocate fixed objects																			
38	Grooving																70	0		

TABLE 1 (continued)

Countermeasure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 1 - ROUTE SECTIONS																				
Countermeasures which may require additional right-of-way																				
95	Add painted/raised median	2	2	0.13	12															
96	Widen shoulder-no dimensions given	1	1	0.13	-2	7	-7													
97	Widen traveled way-no dimensions given	1	1	0.13	38	30	43													
98	Widen traveled way from 9-ft lanes	1	1	0.13	38	16	51													
99	Widen traveled way from 10-ft lanes	1	1	0.13	5															
100	Modernization to design standards	1	1	0.13	10															
101	Modernization to design standards	1	2	0.13	15	22	12													
102	Reconstruct roadway			0.20				20	10	0	0	0	0	0	0	0				
SITE TYPE 2 - HORIZONTAL CURVES																				
Countermeasures which do not require additional right-of-way																				
39	Install delineators	1	1	0.13	2	16	-6													
40	Install delineators	1	2	0.13	46	-10	61													
41	Install reflectorized guide markers			0.13	30															
42	Install/improve warning signs	1	1	0.13	57	71	23													
43	Install/improve warning signs	1	2	0.13	52	40	59													
44	Install warning signs and delineators	1	2	0.13	22	41	12													
45	Install warning signs and delineators	2	2	0.13	20	-27	42													
46	Install curve warning arrows			0.13	20															
47	Install advance curve warning sign with advisory speed			0.13	20															
48	Install special curve warning			0.13	75															
49	Install advance warning flashers			0.13	30															
50	Grooving																70	0		

TABLE 1 (continued)

Counter-measure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 2 - HORIZONTAL CURVES																				
Countermeasures which may require additional right-of-way																				
103	Reconstruct curve	1	1	0.13		89	96													
SITE TYPE 2 - GRADES																				
Countermeasures which do not require additional right-of-way																				
51	Install centerline striping at crests	1	1	0.13	64															
Countermeasures which may require additional right-of-way																				
104	Add climbing lane	1	1	0.13	0															
SITE TYPE 2 - MEDIAN OPENING																				
Countermeasures which do not require additional right-of-way																				
52	Close median opening			0.20				100	50	50	100	100	0	0	0	0				
SITE TYPE 2 - BRIDGE																				
Countermeasures which do not require additional right-of-way																				
53	Install delineators	1	1	0.13	47	-8														
54	Install delineators	1	2	0.13	53															
55	Install reflectorized guide markers			0.13	40															
56	Install new safety lighting			0.13															50	0
SITE TYPE 2 - UNDERPASS																				
Countermeasures which do not require additional right-of-way																				
57	Install delineators	1	1	0.13	47	-8														
58	Install delineators	1	2	0.13	53															
59	Install reflectorized guide markers			0.13	40															
60	Install new safety lighting			0.13															10	0

TABLE 1 (continued)

Counter-measure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 2 - RAILROAD CROSSING																				
Countermeasures which do not require additional right-of-way																				
61	Install flashing beacons			0.13	80															
62	Install new safety lighting			0.13															60	0
SITE TYPE 3 - INTERSECTIONS																				
Countermeasures which do not require additional right-of-way																				
63	Install 4-way STOP signs	2	1	0.13	68	67	68													
64	Install minor leg STOP control (at locations where angle accidents exceed 50% of all accidents)	1	1	0.13	65	89	51													
65	Install minor leg STOP control (at locations where angle accidents exceed 50% of all accidents)	2	1	0.13	48	71	37													
66	Install minor leg STOP control (at locations where angle accidents exceed 50% of all accidents)	2	2	0.13	38															
67	Install YIELD sign	2	1	0.13	59	80	49													
68	Install YIELD sign	2	2	0.13	-46															
69	Install STOP AHEAD sign	1	1	0.13	47	96	18													
70	Install advance warning flashers			0.13	30															
71	Install flashing red-yellow warning beacons			0.13	50															
72	Install 4-way flashing red beacons			0.13	75															
73	Install new traffic signals (at locations where angle accidents exceed 60% of all ac-	1	2	0.13	29	50	17													

TABLE 1 (continued)

Countermeasure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 3 - INTERSECTIONS																				
Countermeasures which do not require additional right-of-way																				
74	Install new traffic signals (at locations where angle accidents exceed 60% of all accidents)	2	2	0.13	29	50	19													
75	Install new traffic signals			0.13	27															
76	Remove existing traffic signal			0.20				0	90	0	0	0	0	0	0	0				
77	Improve signals at 4-leg intersection	1	2	0.13	42	45	40													
78	Improve signals at 4-leg intersection	2	1	0.13	31	35	29													
79	Improve signals at 4-leg intersection	2	2	0.13	-2	10	-8													
80	Improve signals at T intersection	2	2	0.13	57	57	57													
81	Modifty signals			0.13	27															
82	Install 12-in. signal lenses			0.20				0	10	0	0	0	0	0	0	0				
83	Install optically programmed signal			0.20				20	10	10	10	0	0	0	0	0				
84	Install left-turn phase			0.20				0	10	0	0	50	0	0	0	0				
85	Improve signal timing			0.20				0	10	0	10	10	0	0	0	0				
86	Actuate signals			0.20					10	20	10	10	0	0	0	0				
87	Install pedestrian signal phase	2		0.20				0	0	0	0	0	0	0	60	0				
88	Add left turn signal without left turn lane	2	2	0.13	39	57														
89	Improve timing, install 12-in. lens, install turn phase and actuate signsl			0.20				0	20	10	20	20	0	0	0	0				
90	Prohibit left turns	2	2	0.13	40	39	40													
91	Improve pavement markings			0.20				0	0	20	10	10	0	0	10					
92	Install rumble strips at non-signalized intersections	1	1	0.13	27															
93	Install safety lighting			0.13															75	0
94	Upgrade safety lighting			0.13															50	0

TABLE 1 (continued)

Counter-measure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 3 - INTERSECTIONS																				
Countermeasures which may require additional right-of-way																				
105	Add left turn lane without signal	1	2	0.13	-6	-16	-1													
106	Add left turn lane without signal	2	1	0.13	19	80	-9													
107	Add left turn lane without signal	2	2	0.13	6	54	-17													
108	Add left turn lane without signal at T intersection	2	1	0.13	79															
109	Add left turn lane without signal at T intersection	2	2	0.13	51	62	46													
110	Add left-turn lane without signal at Y intersection	1	1	0.13	33															
111	Add left-turn lane with raised/curbed island at non-signalized intersection	1		0.13	60															
112	Add left-turn lane with raised/curbed island at non-signalized intersection	2		0.13	70															
113	Add left-turn lane with painted island at non-signalized intersection	1		0.13	60															
114	Add left-turn lane with painted island at non-signalized intersection	2		0.13	15															
115	Add left-turn lane and signal	1	2	0.13	43	58	35													
116	Add left-turn lane and signal	2	2	0.13	27															
117	Add left-turn lane and signal at T-intersection	1	2	0.13	-42	-28	-49													

TABLE 1 (concluded)

Countermeasure Number	Countermeasure	Area Type	Highway Type	Fraction of Time with Wet Pavement	Percent Reduction All Accidents	Percent Reduction by Severity: Fatal and Injury	Percent Reduction by Severity: Property Damage Only	Percent Reduction by Accident Type: Head On	Rear End	Side Swipe	Right Angle	Left Turn	Parking Related	Fixed Object	Pedestrian	Other	Percent Reduction by Pavement Condition: Wet	Dry	Percent Reduction by Light Condition: Night	Day
SITE TYPE 3 - INTERSECTIONS (concluded)																				
Countermeasures which may require additional right-of-way (concluded)																				
118	Add left-turn lane at signalized intersection without separate left-turn phase			0.13	15															
119	Add left-turn lane at signalized intersection with separate left-turn phase			0.13	36															
120	Add left-turn lane, signal and illumination	2	2	0.13	46	76	32													

Key

Area Type: 1 = Rural
2 = Urban

Highway Type: 1 = Two-Lane, Uncontrolled Access
2 = Multilane, Uncontrolled Access

Blank area type and highway type designations indicate that the effectiveness estimate for that countermeasure can be applied to any area type or highway type without generating an error message.

Blank percent reductions indicate that the accident breakdown is not used for that countermeasure unless specified by the user.

Negative percent reductions are interpreted as percent increases.

Similarly, the computer program will compare the actual site type with the site type appropriate for each countermeasure specified by the user. If any discrepancies are found a message will be printed to warn the user that the accident reduction effectiveness for the countermeasure he has specified may not be appropriate for the type of site under analysis, but the program will still complete the analysis of the countermeasure.

2. Countermeasure effectiveness estimates: The program will automatically use the effectiveness estimate contained in Table 1 for a countermeasure unless the user provides another estimate for one or more of the selected countermeasures. It is mandatory only that the user supply an effectiveness estimate for those countermeasures that are not included in Table 1 or that have no effectiveness estimate shown there. An error message will be printed if the user does not provide an effectiveness estimate for a countermeasure which requires one. The countermeasure in question will not be analyzed, but analysis of the remaining countermeasures will continue.

The accident reduction effectiveness estimates used by the model are expressed by one of five methods:

- Percent reduction by accident severity
- Percent reduction by accident type
- Percent reduction by pavement condition
- Percent reduction by light condition
- Percent reduction for all accidents

Several methods have been used because the effectiveness estimates are presented in the literature in a variety of forms. The five methods are listed above in priority order as used by the program.

The countermeasure evaluations in the literature may have been performed under wet-pavement exposure and skid number conditions different from the analysis site. As noted above, a correction factor is used in the model to make the effectiveness estimates applicable to the wet-pavement exposure and local skid number of the analysis site.

3. Calculation of accidents remaining after countermeasure implementation: The user must provide the value of AALL , the total number of accidents expected to occur in the zeroth year if no countermeasure is implemented. If the only available effectiveness estimate for the countermeasure being evaluated is the percent of all accidents reduced, then the expected number of accidents remaining after implementation of the countermeasure is determined directly by the model, and distribution of these accidents is based on tabulated averages within the model.

If for any countermeasure, Table 1 contains percent accident reduction by one of the four accident breakdowns, these values will be used rather than the percent reduction for all accidents. The accident totals to which these percent reductions are applied for each category of the accident breakdown used are obtained by the model in one of two ways; either (1) the total number of accidents is separated into components by use of typical accident distributions available in the model, or (2) the user supplies the actual number of accidents in each category. This option gives the model great flexibility, since the user can perform a benefit-cost analysis using estimates when very little accident data are available or he can use detailed accident data for the site.

D. Influence of ADT on Accident Rate

The analyses in the project showed that ADT had an influence on accident rates for some area type-highway type combinations. However, the information obtained was not sufficient to quantify the effects of the moderate changes in ADT likely to occur from year to year on an analyzed facility. Consequently, the model employs the regression results developed by Fee.* The adjustment is contained entirely within the model, and requires no additional user data.

E. Sequence of Processing Accidents and Accident Costs

The model requires that the analyses at any site begin with the average number of accidents at the site for the year prior to installation of a countermeasure (the "zeroth" year). The zeroth year estimate can be based on historical data or on the program user's professional judgement. The estimate can consist of total accidents or, separately, the property-damage-only accidents and the injury-plus-fatal accidents.

The subsequent processing dealing with accident numbers or rates always employs fractional or incremental changes. This logic preserves the influence of rates or proportions at the analyzed site that may be markedly different from the average for sites with similar area and highway types.

The first step is the calculation of two average costs. One is for property-damage-only accidents; the other is for combined injury-plus-fatal accidents. The calculations employ the costs of a fatality, an injury,

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* Fee, J. A., "Interstate System Accident Research Study-1," U.S. Department of Transportation, 1970.

and the per vehicle property damage. The calculations also employ the average numbers of fatalities, injuries and vehicles involved per accident type, which are a function of area type and highway type. The proportions of fatal and of injury accidents also depend on area type and highway type. All these factors are obtained from system files. The cost calculations also employ the separate cost weight factors for fatalities, injuries and property damage supplied by the user. The above calculations and results are independent of countermeasures and the subsequent course of events at the site. All calculations that follow depend on individual countermeasures or on the future of the base condition.

The next major step is to calculate the zeroth year accidents with the countermeasure incorporated. (If the base case includes a prior decision to modify the surface and consequently skid number, this change will be included.) A cost per accident average over all accident severities is then calculated for subsequent use. Also, the remaining accident number is converted to a rate. At this point, a calculation is made for additional zeroth year accidents associated with countermeasure construction, if any. If the countermeasure construction requires lane closure, the costs of accidents due to that construction are entered as part of accident costs associated with the countermeasure, even though they occur in the zeroth year.

The next major step, still for the zeroth year, is to adjust the accident rate for the change in skid number. Skid number will change in the zeroth year for countermeasures that change the surface, or for the base case if there has been a prior decision to modify the surface. After adjustment for skid number the accident rate is the rate that would have occurred in the zeroth year if the countermeasure being processed had been installed and operating for the entire year. Also available is the average cost per accident with the countermeasure installed.

Subsequent processing of accidents and accident costs deals with 1 year at a time for future years 1, 2, etc., through the final year of the period of analyses. For each year the accident rate in the preceding year is the starting point. The rate is adjusted for the effects of change in ADT. Then it is incremented for the change in skid number. Finally, the accident rate, the ADT, the site length, accident increases due to countermeasure construction during the year, and the average cost per accident are combined to obtain the accident costs for the year. These costs are subsequently discounted using economic equations and assembled to provide the equivalent uniform annual accident costs with the countermeasure analyzed.

VI. SOURCES OF NUMERICAL VALUES USED IN THE BENEFIT-COST PROGRAM

Three types of numerical data are used in the benefit-cost program: user-supplied input data, data from support system files and numerical values incorporated in the program. Numerical values that depend on the practices, specifications and costs used by individual states are supplied as user-specified input or support system file data. These can be altered using procedures explained in Sections VII and IX of this manual. The numerical values incorporated in the program cannot be changed except by rewriting the appropriate program statements. The purpose of this section is to explain which numerical values are incorporated in the program and what their sources are.

A. Accident Rate-Skid Number Relationships

The relationships between accident rate and skid numbers used in the model are based on those results from Phase I of this project that are described in Volume II of this final report. The numerical values used in these relationships are a fixed part of the computer program logic. The results of Phase I also indicated that the effectiveness of geometric and traffic control countermeasures may be influenced by skid number. This influence has been quantified and is also incorporated as a fixed part of the computerized model.

B. Skid Numbers Associated with Surface Courses and Traffic Wear

In the computerized model, the skid number for a pavement surface is calculated as a constant plus (or minus) a coefficient times the natural logarithm of the accumulated number of traffic passages. A provision is made for a limiting value of skid number when accumulated traffic is large. The basic equation and logic used were developed from Interim Report KYHPR-64-24, HPR-1(8), Part II, Kentucky Department of Highways, June 1972. However, the numerical values are to be supplied from the system files maintained by the state and reflecting the properties of the surface materials used locally.

The user may elect to specify the current skid resistance of a pavement by means of pavement macrotexture and microtexture values, if conventional skid test results are not available. The program converts the pavement texture values to a skid number using a relationship developed by Penn State University. The relationship between skid number and pavement texture is discussed in Volume II of this report.

C. Geometric and Traffic Control Countermeasures For Accident Reduction

Although all of the data pertaining to the geometric and traffic control countermeasures are in the support system files, to be maintained by the users, the programming logic uses an ordered arrangement of these data associated with the subscripting. The subscripting requirements are described in Section VII.A.3.a.

D. ADT - Accident Rate Relations

In the computerized model, the effect of ADT on accident rates is expressed in the form of a cubic function of ADT. The coefficients, which depend on area type and highway type, are obtained from the system files. These coefficients are based on regression results reported by J. A. Fee in "Interstate System Accident Research Study - 1," U.S. DOT., 1970.

E. User Costs

The model has the option to include user costs for delays and excess fuel consumed due to countermeasure construction. The vehicle hours of delay and the excess gallons of fuel consumed have been calculated with a separate model. The results obtained with this model have been incorporated in the computerized benefit-cost model in the form of polynomial relationships. Numerical values for the polynomial coefficients are provided with the model for two work-site configurations and provisions are made for four additional configurations that can be quantified by similar manual calculations. The relationships are described in Volume II of this report.

The cost per hour of vehicle delay and the cost per gallon of fuel are obtained by the program from the support system files.

F. Costs Per Accident

The cost per accident is assembled in the computerized model from the basic values such as:

- Cost per vehicle involved in PDO accidents,
- Cost per injury, including property damage,
- Cost per fatality, including property damage,
- Number of vehicles involved per PDO accident,
- Number of injured per injury accident,
- Number of fatalities per fatal accident, and
- The distirbution of accidents by severities.

These seven values are represented within the computer program by symbols whose values are normally obtained from the system files. The numbers of vehicles, injured, etc., involved depend on the area type and highway type. The distribution of severities depends on the same factors. The file values for these quantities are derived from data obtained from the states of California, Michigan and Washington for a 4-year period on their entire state highway systems.

The costs per vehicle, injury and fatality supplied with the model were obtained from "Societal Cost of Motor Vehicle Accidents, Preliminary Report," published by NHTSA in April 1972. It is anticipated that individual states will update these data and use sources consistent with their policies.

G. Capital Costs and Normal Lives of Countermeasures

The computerized model obtains the values for capital costs and normal service lives from the system files. The program user may override these values with input data. Because these values vary with time, from state to state and even between regions of the same state, no attempt has been made to supply these values to the user.

The capital costs in the system file are for one unit of the countermeasure. The number of units for a site are mandatory input to the model, so that total capital outlays can be calculated.

Several other types of countermeasure data are also obtained from the system file. They are: the final worth of one unit of capital item, its vulnerability to future resurfacing or rebuilding, the cost for removal and the fraction of remaining value that could be recovered. Values for these variables are also left to the discretion of individual states.

H. Maintenance and Operating Costs

The maintenance and operating costs are assembled in the computerized model as an average cost for the site plus the changes associated with countermeasure installation. The average for the site is dependent on area type and highway type. The cost components are obtained by the computerized model from the system files. These costs vary between states. Their values are left to the discretion of individual states.

VII. INSTRUCTIONS FOR RUNNING THE BENEFIT-COST PROGRAM

This section presents instructions needed by the user to run the benefit-cost analysis program. Section A, which presents the input requirements for the program, is of interest both to the general reader who wants to become familiar with the input data and to the program user who needs to determine the value of each input variable. The remaining sections provide detailed information addressed primarily to the program user. Section B presents the card formats for the input data and Section C discusses the organization of the input card deck. Section D presents error messages that may be generated during program execution and Section E discusses running time requirements for the program.

A. Input Requirements

Input for the benefit-cost program is obtained from two sources--user-supplied input variables and support system files. The maintenance of support system files is discussed in Section IX of this manual. The following discussion is concerned solely with the input that must be supplied by the user each time the program is run. The input variables are presented and discussed to the extent necessary for the user to determine their values. A brief discussion of the manner in which the variables are used in the program is found in earlier sections of this manual.

Three types of input variables must be specified by the user:

- General input variables that are printed in headings and control the type of analysis to be performed,
- Variables that describe characteristics of the analysis site, and
- Variables that describe the countermeasures to be evaluated.

Table 2 identifies the input variables in all three categories. The table indicates whether each of the input variables is mandatory or optional. Many of the optional items are included to give the user an opportunity to change the value of a variable from the support system files without disturbing the long-term system value. The comment column of the table provides detailed information needed by the user to select values for the input variables. Each of the three categories of input variables shown in the table is discussed below.

Table 2

INPUT FOR BENEFIT-COST PROGRAM

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
General Input Data				
Sequence Number for Analysis		Mandatory		Assigned by user.
Date of Analysis		Mandatory		Assigned by user (e.g., 01 31 1977)
Date Zeroth Year Ends		Mandatory		The last day of the year in which the countermeasures will be implemented (e.g., 12 31 1977 = December 31, 1977).
Decimal Interest Rate	V	Optional		User-specified interest rate will replace standard rate obtained from file. Rate is expressed in decimal form (e.g., 0.06).
Subscript for Five Items Which Follow	NVAR	Optional		If NVAR = 1 values are read in; they will write over default values of 1.0 for all cost factors and two for JPER (1). MVAR is largest NVAR used; it could be read in or established by testing NVAR input. If JPER ( ) = 1, logic selects period of analysis as shortest of applied lives of two compared alternatives. If JPER ( ) = 2, period of analysis is longest of the applied lives of two compared alternatives.
Weight Factor for Prop. Damage Only Accident Costs	FPD ( )	Optional	(6)	
Weight Factor for Injury Accident Costs	FIA ( )	Optional	(6)	
Weight Factor for Fatal Accident Costs	FFA ( )	Optional	(6)	
Weight Factor for User Time Delay Costs	FUTC ( )	Optional	(6)	
Code for Period of Analysis	JPER ( )	Optional	(6)	
Upper Limit on Number of Years to be Used in Any Period of Analysis	MXYR	Optional		If read in, will write over default value of 20.
Coefficient for Fraction of Accident Costs Saved in Test for Significant Savings	CFAS	Optional		CFS and CCAS are intended for use in Subroutine SIGØ, which may be added to the model at a later date. They have default values of zero. When both CFAS and CCAS are zero, subroutine SIGØ is by-passed.
Coefficient for Amount of Accident Costs Saved in Test for Significant Savings	CCAS	Optional		
Site Characteristics				
Site Description		Mandatory		Assigned by user; maximum of 40 characters on each of two lines.
Numerical Code for State	KSTAT	Mandatory		Assigned by user.
Numerical Code for Region in State	KSTAR	Mandatory		Assigned by user.
Area Type	IATYP	Mandatory		1 = Rural; 2 = Urban

TABLE 2 (Continued)

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
Highway Type	IHTYP	Mandatory		1 = Two-lane, Uncontrolled Access 2 = Multilane, Uncontrolled Access 3 = Multilane, Controlled Access
Site Type	ISITE	Mandatory		1 = Highway Section 2 = Nonintersection Location 3 = Intersection
Site Length (miles)	TLGH	Mandatory		Enter length of facility (in miles) affected by countermeasure (i.e., length of facility for which accident data are gathered). For intersections use length of major facility.
Fraction of Time Pavement is Wet	FWET	Mandatory		
Average Annual Precipitation (Inches)	APREC	Optional		Value specified by user appears on printed output; not currently incorporated in other program logic
Normal Remaining Life of Facility (Years)	LIFF	Mandatory		
Scheduled or Estimated Years Until Resurfacing	LIFRS	Mandatory		If site is being resurfaced in zeroth year as result of prior decision to resurface or rebuilt, this entry should be the estimated life of the new surface.
Scheduled or Estimated Years Until Rebuilding	LIFRB	Mandatory		If site is being rebuilt in zeroth year as a result of prior decisions, this entry should be estimated interval between rebuildings.
Prior Decision to Resurface	IRS	Mandatory		0 = Prior decision to resurface immediately 1 = No prior decision to resurface immediately
Job Number for Prior Decision		Optional		Assigned by user
Number of Units of Surface Course Which is Planned as Result of Prior Decisions	UN (1)	See comment		Input is mandatory if resurfacing or rebuilding in zeroth year is a result of prior decisions.
Final Capital Worth per Unit of Surface Course Which is Planned as a Result of Prior Decision	FCW (1)	See comment		Same as above.
Current Skid Number	SNYØ	Optional		If skid number is available. If user does not enter SNYØ, and AMDYØ and BPNYØ were not supplied, the program will use SBAR (IATYP) as default value.
Current or Planned Type of Surface Course	KSW	Optional		User may specify the countermeasure number (KM ≤ KMS) for the type of surface presently in place or planned as a result of a prior decision. Default value = 1.
Current Mean Texture Depth (milli-in.) of Surface Course	AMDYØ	Optional		In the absence of SNYØ if AMDYØ is supplied it will be used with BPNYØ to calculate current skid number (prior to as planned changes).
-- Tester Number	BPNYØ	Optional		Must be supplied if AMDYØ is.

TABLE 2 (Continued)

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
ADT of Major Facility in Zeroth Year	TIM	Mandatory		
ADT of Secondary Facility in Zeroth Year	TIS	See Comment		Mandatory for intersections; optional for other site types.
Percent Compounded Growth Rate of ADT for Major Facility	TMGC	Optional		User must specify ADT growth by one of three methods: Option 1 Site Types 1 and 2: Specify TMGC or TMGL. Site Type 3: Specify TMGC or TMCL and TSGC or TSCL. Option 2 Site Types 1 and 2: Specify ADTM ( ) for each year of the analysis period. Site Type 3: Specify ADTM ( ) and ADTS ( ) for each year of the analysis period Option 3 Set TMGC = TMGL = TSCC = TSGL = 0 for constant ADT during entire analysis period.
Percent Linear Crowth Rate of ADT for Major Facility	TMGL	Optional		
Percent Compounded Crowth Rate of ADT for Secondary Facility	TSGC	Optional		
Percent Linear Crowth Rate of ADT for Secondary Facility	TSGL	Optional		
ADT of Major Facility for Each Year of Analysis Period	ADTM ( )	Optional	(20)	
ADT of Secondary Facility for Each Year of Analysis Period	ADTS ( )	Optional	(20)	
Total Number of Accidents Prior to Countermeasure Implementation	AALL	Mandatory		
Number of Fatal and Injury Accidents Prior to Countermeasure implementation	AFI	Optional		The user should provide values for both AFI and APDØ or for neither. They will be calculated from default values if neither is provided. AFI and APDØ must sum to AALL.
Number of property-damage-only accidents prior to countermeasure implementation.	APDØ	Optional		
Number of head-on accidents prior to countermeasure Implementation	AHØ	Optional		The user should provide all values for each of AHØ, ARE, ASS, ARA, ALT, APR, AFØ, APED and AØTH or for none of them. They will be calculated from default values if none of them are provided. These nine variables must sum to AALL.
Number of Rear-End Accidents Prior to Countermeasure Implementation	ARE	Optional		
Number of Side-Swipe Accidents Prior to Countermeasure Implementation	ASS	Optional		
Number of Right-Angle Accidents Prior to Countermeasure Implementation	ARA	Optional		
Number of Left Turn Accidents Prior to Countermeasure Implementation	ALT	Optional		

TABLE 2 (Continued)

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
Number of Parking-Related Accidents Prior to Countermeasure Implementation	APR	Optional		The user should provide all values for each of AHØ, ARE, ASS, ARA, ALT, APR, AFØ, APED, and AØTH or for none of them. They will be calculated from default values if none of them are provided. These nine variables must sum to AALL.
Number of Fixed Object Accidents Prior to Countermeasure Implementation	AFØ	Optional		
Number of Pedestrian Accidents Prior to Countermeasure Implementation	APED	Optional		
Number of Other Accidents Prior to Countermeasure Implementation	AØTH	Optional		
Number of Wet-Pavement Accidents Prior to Countermeasure Implementation	AWET	Optional		The user should provide values for both AWET and ADRY or for neither. They will be calculated from default values if neither is provided. AWET and ADRY must sum to AALL.
Number of Dry-Pavement Accidents Prior to Countermeasure Implementation	ADRY	Optional		
Number of Nighttime Accidents Prior to Countermeasure Implementation	ANIT	Optional		The user should provide values for both ANIT and ADAY or for neither. They will be calculated from default values if neither is provided. ANIT and ADAY must sum to AALL.
Number of Daytime Accidents Prior to Countermeasure Implementation	ADAY	Optional		
Countermeasures (The following input items apply to each countermeasure specified by the user.)				
Countermeasure Number	KM	Mandatory		Must be in appropriate range; see Section VII
Countermeasure Name		Mandatory		Assigned by user
Number of Units of Countermeasure	UN(KM)	Mandatory	(180)	Mandatory for each KM to be evaluated.
Specified Capital Cost Per Unit	SCAPC(KM)	See Comment	(180)	This input is mandatory for nonzero right-of-way costs which are assigned separate subscripts (KM + K2) for countermeasures that may require ROW. When initial base condition is "as planned" resurfaced or rebuilt condition, the cost for the surface course is input as SCAPC(1) per unit. This input is optional for other non-right-of-way unit costs. If used, the logic will employ SCAPC(KM) rather than CAPC(KM) from cost file.

TABLE 2 (Continued)

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
Applied Life (Years) for Countermeasure KM at Site Analyzed	IAF(KM)	See Comment	(180)	Input is mandatory for right-of-way. For non-right-of-way subscripts IAF ( ) is normally calculated and need not be input. However, if IAF ( ) is input, input value will be employed.
Final Capital Worth Per Unit of Countermeasure KM After IAF(KM) Years at Analyzed Site	FCW(KM)	See Comment	(180)	Above comments apply. Also, whenever IAF(KM) is input FCW(KM) must also be read in.
Average Annual Maintenance and Operating Expenses Per Unit of Countermeasure	SCMAØ(KM)	Optional	(180)	If SCMAØ(KM) is supplied by user, it replaces the value of CMAØ(KM) contained in cost files.
Annual Rate of Change of Maintenance and Operating Expenses Per Unit of Countermeasure	SSMAØ(KM)	Optional	(180)	If SSMAØ(KM) is supplied by user, it replaces the value of CCMAØ(KM) contained in cost files.
Upper Bound on Annual Maintenance and Operating Expenses.	SMAØM(KM)	Optional	(180)	If SMAØM(KM) is supplied by user, it replaces the value of CCMAØ(KM) contained in cost files. See explanation of CCMAØ(KM) in Section V.
Mean Texture Depth (milli-in.) Immediately After Wear In of Surface for Countermeasure KM	AMDR(KM)	See Comment	(180)	AMDR(KM) must be supplied as input when BPNR(KM) is supplied. When supplied they are used to calculate the initial skid number of the surface. The calculated value is used rather than SDØR(KM).
British Portable Tester Number Developed Immediately After Wear In of Surface for Countermeasure (KM)	BPNR(KM)	See Comment	(180)	
Time that Traffic Service is Reduced Due to Construction of Countermeasure on Length ZLGH(KM)	TDUR(KM)	Optional	(180)	Expressed in days. Set TDUR(KM) = 0 if construction of countermeasure KM does not involve reduced traffic service.
Type of Construction Zone Configuration	KZOW(KM)	See Comment	(180)	Mandatory if TDUR(KM) is nonzero. KZOW(KM) = 1 for two-lane two-way roadway reduced to one lane and shoulder; = 2 for two lane, two-way roadway reduced to one lane with alternating directions; = 3 for two unidirectional lanes reduced to one lane; = 4 for three unidirectional lanes reduced to two unidirectional lanes; = 5 for three unidirectional lanes reduced to one unidirectional lane; and = 6 for four lane roadway reduced to two-lane, two-way roadway.

TABLE 2 (Continued)

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
Length of Construction Zone (miles)	ZLCH(KM)	See Comment	(180)	Mandatory if TDUR(KM) is nonzero. ZLGH(KM) is the length of highway with reduced traffic service, which may be less than the site length if the construction is accomplished in several stages.
Code for Construction Schedule	KCSCD(KM)	See Comment	(180)	Mandatory if TDUR(KM) is nonzero. KCSCD(KM) is a code representing the portion of each construction day for which traffic service is reduced. KCSCD(KM) = 1 for 24 hr in urban areas; = 2 with peak hours excluded in urban areas; = 3 for daytime hours only between peak periods in urban areas; = 4 for 24 hr in rural areas; = 5 for daytime hours only between peak periods, rural areas.

(Note: The files contain default values for percent accident reduction for each countermeasure incorporated in the model. The user can override these defaults by specifying the variables given below for five accident breakdowns: all accidents, by severity, by accident type, by pavement condition or by light condition. The user should specify percent reductions for, at most, one of the five accident breakdown options shown below).

Description of Item	Symbol (If Diagrammed)	Optional or Mandatory	Estimated Dimensions	Comment
Percent Reduction for All Accidents	PRALL(KM)	Optional	(180)	Option 1 - Percent reduction for all accidents.
Percent Reduction for Fatal and Injury Accidents	PRFI(KM)	Optional	(180)	Option 2 - Percent reduction by severity.
Percent Reduction for Property Damage Only Accidents	PRPDØ(KM)	Optional	(180)	
Percent Reduction for Head-On Accidents	PRHØ(KM)	Optional	(180)	Option 3 - Percent reduction by accident type.
Percent Reduction for Rear-End Accidents	PRRE(KM)	Optional	(180)	
Percent Reduction for Side-Swipe Accidents	PRSS(KM)	Optional	(180)	
Percent Reduction for Right-Angle Accidents	PRRA(KM)	Optional	(180)	
Percent Reduction for Left-Turn Accidents	PRLT(KM)	Optional	(180)	
Percent Reduction for Parking-Related Accidents	PRPR(KM)	Optional	(180)	

TABLE 2 (Concluded)

Description of Item	Symbol (If Diagramed)	Optional or Mandatory	Estimated Dimensions	Comment
Percent Reduction for Fixed Object Accidents	PRFØ (KM)	Optional	(180)	
Percent Reduction for Pedestrian Accidents	PRPED(KM)	Optional	(180)	Option 3 - Percent reduction by accident type. (continued)
Percent Reduction for Other Accidents	PRØTH(KM)	Optional	(180)	
Percent Reduction for Wet-Pavement Accidents	PRWET(KM)	Optional	(180)	Option 4 - Percent Reduction by pavement condition.
Percent Reduction for Dry-Pavement Accidents	PRDRY(KM)	Optional	(180)	
Percent Reduction for Night Time Accidents	PRNIT(KM)	Optional	(180)	Option 5 - Percent reduction by light condition.
Percent Reduction for Daytime Accidents	PRDAY(KM)	Optional	(180)	

The units for input variables are indicated in Table 2, where appropriate. As explained in the Input Format discussion, many of the input variables are specified in FORTRAN F3.0 and F10.0 formats. These formats give the user the flexibility to specify input variables as precisely as necessary; i.e., the site length can be specified in fractions of miles and unit costs can be specified in fractions of dollars. The user must insert a decimal point at the appropriate position in the input field to indicate a fractional value. If no decimal point is indicated, the decimal point is presumed to be at the right edge of the field. Further details on input formats and input deck organization are provided later in this section.

1. General input variables: The general input variables perform two functions: (1) provide information to be printed in output headings and (2) control the type of analysis performed.

The sequence number, date of analysis and end date of the zeroth year are included because they appear in output headings. The decimal interest rate appears in the output heading, and is also used in the analysis to determine discount factors.

Variables FPD( ), FIA( ), FFA( ), and FUTC( ) are weight factors that can be used to modify the costs of accidents and user time delays incorporated in the model. JPER( ) is used to select the longer or shorter applied life for use as the analysis period, when countermeasures with different applied lives are compared. MXYR sets a limit on the length of the analysis period for all countermeasures considered. Finally, CFAS and CCAS are variables that are not presently used, but could be incorporated in a future version of the model.

2. Site characteristics: This portion of the input data contains several basic site parameters such as the site description, state and region, area type, highway type, site type, site length, fraction of time with wet pavement and average annual precipitation.

The user must specify whether or not a prior decision to resurface the facility in the zeroth year has been made and must estimate the remaining life of the facility and the remaining time period before the facility will be resurfaced and/or rebuilt. The user has the option of specifying the current skid number of the facility. However, default values of skid number are available from the files in the event that the user does not have this information available. Table 3 is an input guide provided to help the user assign values to the variables IRS, LIFF, LIFRB, LIFRS, SNYØ, UN(1) and KSW which concern surface course characteristics and expected lives including the effect of prior decisions.

The ADT of the facility in both the zeroth year and each subsequent year must be specified using one of the three options described in Table 2.

TABLE 3

INPUT GUIDES FOR SURFACE COURSE CHARACTERISTICS AND EXPECTED LIFE

Situation	Related Preparation and Input			
There are no prior decisions to change anything about the analyzed site. And the conventional surface course (subscript = 1) is currently in place.	Input	IRS	=	0, indicating there is no prior decision to resurface.
	Input the estimates for:			
		LIFF	=	Remaining life of the facility site (years)
		LIFRB	=	Years until site will be rebuilt
		LIFRS	=	Years until site will be resurfaced
	Input	SNYØ	=	Skid number in zero year, if available. (If SNYØ is not supplied, and AMDYØ and BPNYØ are not supplied, the program will use an average SN value for the in-place, conventional surface type until it is resurfaced.)
	Or			
	Input	AMDYØ	=	Current mean texture depth (milli-inches) of surface course.
	And			
	Input	BPNYØ	=	Current British Portable Tester Number
	Input	UN(1)	=	Number of units of conventional surface course required to resurface site. (If UN(1) is not supplied, the program will treat it as zero so that capital costs associated with future resurfacing in the base conditions will be omitted where they may otherwise play a role.)
	Do <u>not</u> input a value for KSW; no input causes the program to use subscript = 1 values for surface course skid numbers and subscript = 1 values for capital costs of future resurfacing.			
There are no prior decisions to change anything about the analyzed site. But, there is a nonstandard surface course (with characteristics subscript = KSW) currently in place.	Input	IRS	=	0
	Input	LIFF		Remaining life of the facility site (years)
		LIFRB	=	Years until site will be rebuilt
		LIFRS		Years until site will be resurfaced
	Input	SNYØ	=	Skid number in zero year, if available. (If SNYØ is not supplied and AMDYØ and BPNYØ are not supplied, program will use an average skid number for surface course subscript KSW until resurfacing.)

TABLE 3 (Continued)

Situation				Related Preparation and Input
	Or			
	Input	AMDYØ	=	Current mean texture depth (milli-inches) of surface course
	And			
	Input	BPNYØ	=	Current British Portable Tester number
	Input	UN(KSW)	=	Number of units of surface course KSW required to resurface site analyzed. (If not supplied, future capital costs for base case condition resurfacing will be omitted where they might otherwise play a role.)
	Input	KSW	=	Subscript of surface course currently in place. (Failure to supply KSW will result in program using skid number changes etc. for standard surface with subscript = 1.)
There is a prior decision, not yet carried out, to resurface or treat the site with a surface whose subscript is KSW. (KSW can be one if a standard surface is to be emplaced.)	Input	IRS	=	1
	Input	LIFF	=	Remaining life of the facility site (years)
		LIFRB	=	Years until the site will be rebuilt.
		LIFRS	=	LIFC (KSW) so that years until resurfacing is equal to normal life of the surface to be emplaced or obtained.
	Input	SNYØ	=	Skid number in zeroth year <u>prior</u> to "as planned" resurfacing or surface treatment.
	Or			
	Input	AMDYØ	=	Current mean texture depth (milli-in.) <u>prior</u> to "as planned" surface changes.
	And			
	Input	BPNYØ	=	Current British Portable Tester number <u>prior</u> to "as planned" surface changes.
	Input	UN(KSW)	=	Number of units of "as planned" surface course or treatment required at site analyzed. (Failure to input will cause "as planned" capital costs in zeroth years to be zero.)
	Input	KSW	=	Subscript of surface or treatment to be applied. (If KSW = 1, it does not need to be input.) (If KSW ≠ 1 and it is not supplied the program will use skid numbers for standard surface, and, for the base condition, whatever zero year costs are associated with number of units (UN(1).)

TABLE 3 (Concluded)

Situation	Related Preparation and Impact
There is a prior decision, to modify the site by incorporating accident countermeasures including some of a geometric or traffic control character.	Estimate the zero year accident reductions that result from "as planned" geometric and traffic control countermeasures and then use the adjusted zero year accidents for the zero year inputs required.
Prior decisions, if any, about the pavement surface have not been carried out.	The "as planned" surface conditions can be based on the situations described above and the inputs shown there should be used.

The user must also specify the expected total number of accidents per year for the facility in its present condition. The user may supply a more detailed description of the accident experience, but if additional accident data are not available, the required accident frequencies can be estimated using default accident distributions contained in the program.

3. Countermeasures: The user must specify one or more countermeasures for analysis by the program. Usually, the user will desire to compare several options for reduction of accidents at a given site. The only information that the user must supply concerning each countermeasure are the countermeasure number, countermeasure name and the number of units of the countermeasure to be installed. However, the user also has the option of replacing the values of applied life, salvage value, capital costs and maintenance and operating costs available from the files.

The model has the capability of including, in the economic analysis, the user costs for delay time and excess fuel consumption due to reduced traffic service during construction of the countermeasure. Four variables must be identified by the user to exercise this option: (1) the number of days when traffic service is reduced due to construction, (2) the type of construction zone configuration, (3) the length of the construction zone and (4) the hours of the day during which traffic service is reduced. This option can be bypassed by setting the number of days with reduced traffic service equal to zero.

The user can replace the percent accident reductions incorporated in the model (see Section V) by specifying the percent accident reductions for one of five accident breakdowns: all accidents, accidents by severity, accidents by accident type, accidents by pavement conditions or accidents by light condition.

a. Countermeasure numbers: The user specifies which countermeasures are to be evaluated by supplying the countermeasure numbers, KM. The countermeasure numbers used to specify geometric and traffic control countermeasures incorporated in the model are given in Table 1, presented in Section V of this manual. Countermeasure numbers for surface modification countermeasures will be assigned by the user in creating the support system files. Some countermeasure numbers are not preassigned to any of the countermeasures incorporated in the model; these numbers are available to the user to supply countermeasures that are not in the files.

The countermeasure number is used in the program as a subscript for all variables associated with that countermeasure. The program logic requires that certain subscripts, and therefore, certain countermeasure numbers be reserved for specific types of countermeasures. The boundaries of the reserved subscript ranges are defined by the variables KSM, KM2, KM3, K2 and KMAX in the following manner:

- The subscript 1 is reversed for the initial, base condition, i.e., the "as is" or "as planned" condition.

● Subscripts 2 through KSM are reserved for the countermeasures that involve modification of the pavement surface, such as surface courses, surface treatments and chip and seal coats.

. Subscripts (KSM + 1) through (KM2 - 1) are reserved for the geometric and traffic control countermeasures incorporated in the model (see Section VI.B) that do not require additional right-of-way.

. Subscripts KM2 through (KM3 - 1) are reserved for countermeasures that may require additional right-of-way, including both those incorporated in the model and those supplied by the user.

. Subscripts KM3 through (KM2 + K2 - 1) are reserved for geometric and traffic control countermeasures, supplied by the user, that do not require additional right-of-way.

. Subscripts (KM2 + K2) through (KM3 + K2 - 1) are reserved for right-of-way costs, lives, etc.

. Subscripts (KM3 + K2) through (KMAX - 1) are reserved for additional geometric and traffic control countermeasures, supplied by the user, that do not require additional right-of-way.

. Subscript KMAX is the largest subscript and is reserved for use with Subroutine SIGØ, which is intended to calculate whether significant accident reduction savings are possible at the analysis site. This subroutine is not included in the current version of the model, but could be added. Therefore, Subscript KMAX is not currently used by the program logic.

The specific values presently employed in the model for the variables that define the boundaries of the subscript ranges are:

KSM = 21
KM2 = 95
KM3 = 127
K2 = 42
KMAX = 180

These values result in the following ranges for the countermeasure numbers used currently:

Countermeasure Number	Type of Countermeasure
1	Initial, baseline condition.
2 - 21	Countermeasures involving pavement surface modification.
22 - 94	Geometric and traffic control countermeasures incorporated in the model that do not require additional right-of-way.

95 - 126	Geometric and traffic control countermeasures that may require additional right-of-way (numbers 95 through 120 are reserved for countermeasures incorporated in the model and numbers 121 through 126 are reserved for countermeasures supplied by the user).
127 - 136	Geometric and traffic control countermeasures supplied by the user that do not require additional right-of-way.
137 - 168	Right-of-way costs, lives, etc.
169 - 179	Additional geometric and traffic control countermeasures, supplied by the user, that do not require additional right-of-way.
180	Maximum subscript.

If more countermeasures are incorporated in the model in a future revision, the values of KSM, KM2, KM3, K2 and KMAX will be adjusted accordingly.

b. Countermeasures involving right-of-way acquisition: Special input procedures must be used for countermeasures that require the acquisition of additional right-of-way. These procedures apply only to geometric and traffic control countermeasures, because the program assumes that surface modification countermeasures do not require additional right-of-way under any circumstances.

Countermeasure numbers 95 through 126 are reserved for geometric and traffic control countermeasures that may require additional right-of-way. The user should specify such a countermeasure using the conventional procedure. If additional right-of-way is required, an additional input is required. The right-of-way data for countermeasure number KM ($95 \leq KM \leq 126$) is specified as if it were another countermeasure with countermeasure number (KM + K2). The value of K2 in the current program is 42, so the acceptable range of countermeasure numbers for right-of-way input is 137 to 168. For example, suppose the user wishes to install countermeasure number 103 and that installation of this countermeasure requires additional right-of-way; then the user must specify the standard inputs for countermeasure number 103 and the appropriate right-of-way inputs for countermeasure number 145 (note: $103 + 42 = 145$).

The right-of-way cost and life variables that must be specified in several common situations are explained in Table 4 which is an input guide for countermeasures that require additional right-of-way.

TABLE 4

INPUT GUIDES FOR COUNTERMEASURES INVOLVING RIGHT-OF-WAY ACQUISITION [a/]

Situation	Related Preparation and Input			
R-O-W must be purchased exclusively for countermeasure KM.	Input	LAF(KM+K2)	=	Life or amortization period for R-O-W [b/]
	Input	SCAPC(KM+K2)	=	Total acquisition cost per unit of R-O-W
	Input	UN(KM+K2)	=	Number of units of R-O-W required
	Input	FCW(KM+K2)	=	Final worth per unit of R-O-W after LAF(KM+K2) years.
R-O-W will be required NFYR years in the future for rebuilding The R-O-W must be acquired now for countermeasure KM, but the countermeasure will not be retained as part of the rebuilt facility.	Input	LAF(KM+K2)	=	NFYR which in this situation is the time period for which the countermeasure must be charged interest on the capital outlay for R-O-W.
	Input	SCAPC(KM+K2)	=	Total acquisition cost per unit of R-O-W
	Input	UN(KM+K2)	=	Number of units of R-O-W required
	Input	FCW(KM+K2)	=	SCAPC(KM+K2) in this situation.
R-O-W will be required NFYR years in the future for rebuilding. The R-O-W must be acquired now for countermeasure KM, but the countermeasure will be retained as part of the rebuilt facility.	Input	LAF(KM)	=	NFYR, the number of years until rebuilding.
	Input	FCW(KM)	=	The remaining, in-place capital worth per unit of the KM^{th} countermeasure NFYR years in the future when it is retained as part of the rebuilt facility.
R-O-W is available, or will be available in zeroth year without advancing schedule for acquisition.	No input is required with subscript (KM+K2) since the four variables listed in the preceding situations are set equal to zero as a first step in each case. The zero values will cause R-O-W capital costs to be zero, as they should be.			

a/ Countermeasures that may require R-O-W have identifying subscripts in the range greater than or equal to KM2 and less than KM3. Where the KM2 and KM3 are specific integers for the data files employed by a state.

b/ K2 is a specific integer for the data files employed by a state. KM is the identifying subscript value for the countermeasure being evaluated for application.

B. Input Formats

The input data for the program are entered on up to 26 different types of punched cards. Each card has a distinct format that is presented in this section. The arrangement of the cards to form an input deck is discussed in Section VII.C.

Columns 1-2 of each card contain a two-digit code identifying the card type. This card type code must be included on each input card, because it is used by the program to determine the format for the remainder of the card.

Columns 3-20 contain an 18-character alphanumeric designation corresponding to the card type code. This designation is included for the convenience of the user in identifying the information contained on each card.

Table 5 identifies the 26 card types, including the card type codes, suggested card type designations and whether the card is mandatory or optional.

The Appendix to this manual presents the details of the format for each of the 26 card types. The Appendix identifies the name of each input variable, its computer symbol, the card and column numbers for its assigned field and the FORTRAN format specification for the field. Each of the input variables is defined in Table 2. The table also identifies whether the variables on each card are mandatory or optional if the card is used. Most of the cards contain a maximum of six variables in addition to the card type code and designation. These variables are usually presented in six ten-column fields (Columns 21-30, 31-40, 41-50, 51-60, 61-70 and 71-80). The user should not need a special form to code the data, since most standard coding forms are ruled with ten column divisions.

The user should use the FORTRAN format designations presented in the Appendix for coding the input cards. Many of the input variables are coded in fields with FORTRAN format designations F3.0 and F10.0. Decimal values must be indicated in such fields with the decimal point coded in the appropriate column. If no decimal point is indicated, the program will assume a decimal point at the right edge of the field.

TABLE 5

SUMMARY OF CARD TYPES

Card Type Code (Columns 1-2)	Card Type Designation (Columns 3-20)	Mandatory or Optional
01	STATE AND REGION	Mandatory
02	GENERAL INPUT	Mandatory
03	SITE DESCRIP ONE	Mandatory
04	SITE DESCRIP TWO	Mandatory
05	SITE CHAR	Mandatory
06	PRIOR DECISION	Mandatory
07	FACILITY LIFE	Mandatory
08	ACCIDENT DATA	Mandatory
09	ADT MAJOR FACILITY	Mandatory
10	ADT SCDRY FACILITY	Mandatory for Site Type 3 [a/]
11	JOB NUMB PRIOR DEC	Optional
12	WEIGHT FACTORS	Optional
13	COEFF FOR SIG SAV	Optional
14	ADTM1	Optional
15	ADTM7	Optional
16	ADTM13	Optional
17	ADTM19	Optional
18	ADTS1	Optional
19	ADTS7	Optional
20	ADTS13	Optional
21	ADTS19	Optional
22	SPECIFIED KM	Mandatory for Each Countermeasure
23	KM NAME AND TEX	Mandatory for Each Countermeasure
24	MAINT AND OP COSTS	Optional
25	USER COSTS	Optional
26	PERCENT REDUCTION	Optional

a/ Site Type 3 is an intersection.

C. Input Deck Organization

Table 6 presents the input deck organization for the typical situation in which the benefit-cost program has been compiled and is available in object form.

The first cards in the deck are control cards. The format and sequence for these cares depends on programming decisions yet to be made by the Federal Highway Administration Data Systems Division and on the type of computer and operating system used to run the program.

The input cards for each case are headed by Cards 1 through 9. These cards are mandatory input and must be arranged in numerical sequence.

The next cards presented are Cards 10-21. These cards are optional input and should be used as needed. Card 12 may appear more than once, if several variations of the cost weight factors are used, but each of Cards 10, 11 and 13 through 21 should appear no more than once for a given case. There is no required sequence for Cards 10-21.

Cards 22-26 are the final cards presented for each case. These cards provide input data concerning the countermeasures to be evaluated. Cards 22 and 23 are mandatory for each countermeasure to be evaluated. Cards 24-26 contain optional data about the countermeasures and should be used as needed. There is no required sequence for Cards 22-26.

Input cards for subsequent cases should immediately follow the preceding case. The Card Type Code 01 on the first card is sufficient to alert the program that a new case is being read. A blank card should be placed at the end of the deck to terminate the analysis.

D. Error Messages

The program generates several kinds of error messages to inform the user of the reason that a case cannot be processed because of insufficient or invalid input data. These messages are described below.

If a mandatory input card is missing or not in the proper order (as described in Table 6), the following message is printed:

MANDATORY CARD TYPE ____ MISSING

The blank space shown in the message will contain the card type code for the missing card.

TABLE 6

INPUT DECK ORGANIZATION

	Input Cards	Comment
	Control Cards	
First Case	Cards 1-9	Mandatory, must be in proper sequence.
	Cards 10-21	Use as needed, no required sequence.
	Cards 22-26	Cards 22 and 23 are required for each countermeasure. Cards 24-26 are used as needed. Cards 22-26 have no required sequence.
Second Case	Cards 1-9	Mandatory, must be in proper sequence.
	Cards 10-21	Use as needed, no required sequence.
	Cards 22-26	Cards 22 and 23 are required for each countermeasure. Cards 24-26 are used as needed. Cards 22-26 have no required sequence.
	. . .	
Last Case	Cards 1-9	Mandatory, must be in proper sequence.
	Cards 10-21	Use as needed, no required sequence.
	Cards 22-26	Cards 22 and 23 are required for each countermeasure. Cards 24-26 are used as needed. Cards 22-26 have no required sequence.
	Blank Card	Terminates analysis.

If more than one card is included for a card type where only one card is required, the message generated is:

CARD TYPE ____ HAS ALREADY BEEN PROCESSED IN THIS SET

If the user specifies a countermeasure number outside the acceptable range, described in Section VII, the message printed will be:

THE COUNTERMEASURE SUBSCRIPT VALUE IS NOT IN THE LIMITS OF ___ TO ___.

The acceptable range of countermeasure subscripts currently used in the program is 1 to 180.

If the user supplies all mandatory input cards for the site, but does not specify any countermeasures for analysis, the following message is printed:

COUNTERMEASURES FOR ANALYSIS NOT SUPPLIED

If all mandatory card types are included, but some mandatory data on these cards are not supplied, an appropriate message is generated. The missing data messages currently incoporated in the program are:

DATE OF ANALYSIS MISSING OR INVALID
DATE ZEROTH YEAR ENDS MISSING OR INVALID
SEQUENCE NUMBER FOR ANALYSIS IS MISSING
AREA, HIGHWAY OR SITE TYPE MISSING OR INVALID
SITE LENGTH MISSING
FRACTION WET TIME MISSING
IRS MISSING OR INVALID

(This message refers to the code for a prior decision to resurface the facility which must be 0 or 1.)

UN(1) or FCW(1) MISSING

(This message refers to the number of units and final capital worth of surface course planned as the result of a prior decision which must be supplied by the user if IRS = 1.)

LIFF, LIFRS OR LIFRB MISSING

(The variable names in this message refer to the remaining life of the facility, the length of time until scheduled resurfacing and the length of time until scheduled rebuilding, respectively.)

AALL MISSING

(This message refers to the overall number of accidents for the site which must be supplied by the user).

TIM MISSING

(This message refers to the ADT of the major facility in the zeroth year which must be supplied in all cases.)

TIS MISSING

(This message refers to the ADT of the secondary facility in the zeroth year which must be non-zero for intersection sites.)

AS IS OR AS PLANNED SUBSCRIPT NOT SUPPLIED

(This message refers to the variable KWS which identifies the type of pavement surface currently in place or planned to be in place after implementation of a prior decision.)

If any of the errors described in this section are encountered, the case will be aborted and the analysis terminated.

E. Estimates of Computer Running Time

The final programing, system design, and system management for the benefit-cost model are the responsibility of the Data Systems Division, Federal Highway Administration, DOT. There has been insufficient time for this division to program, test, and evaluate the computer running time for the completed model. However, some general comments based on previous experience with computer programs are appropriate.

Although the benefit-cost model computer program is moderately complex and moderately long, the calculations for most cases should not require a large number of repetitive passes through the logic. As a result most computer systems capable of executing the program should process individual cases or sites with relatively short periods in the central processor. The computer use should constitute a minor expense.

VIII. OUTPUT AND OUTPUT INTERPRETATION

This section presents the output format used by the model to print the results of the benefit-cost analysis and discusses the interpretation of these results.

A. Output Format

The computer program provides a printed output for each case that is analyzed. This output presents all of the economic data required by a highway engineer or administrator to make planning and budgeting decisions, and the output will serve as a permanent record of the analysis results. This section of manual presents the output formats used by the model and explains all of the output data.

The benefit-cost model produces output in two forms, corresponding to the two stages of the benefit-cost analysis: countermeasure economic feasibility analysis and project formulation. The difference between these stages, as explained in Section IV-A, is that in the economic feasibility analysis each alternate countermeasure is compared with the initial base condition, while in the project formulation stage the countermeasures are compared incrementally, in order of increasing capital costs. When a countermeasure is accepted in project formulation (incremental benefit/cost ratio greater than one), it becomes the base for subsequent calculations. Since the economic data that must be presented are similar, the headings and printout formats used for each stage of the analysis are identical, except for the main heading at the top of each page. The output from the economic feasibility and project formulation analyses are presented on consecutive printout pages.

Figure 4 illustrates the output format that is used for both economic feasibility and project formulation. Lines 1 through 12 of the printout are a heading block containing general information identifying the analysis site and the type of analysis. Beginning with line 18, the printout is organized into groups of three lines labeled BASE, ALTERNATE and ALT-BASE. Each group of lines represents a comparison between one alternative countermeasure and the appropriate base condition. In each stage of the analysis, these groups of three lines are repeated as many times as necessary to compare each alternative with the appropraite base condition. As an example, consider lines 18 to 20, the first group shown in Figure 4. All cash flows for the base and alternate conditions are listed on lines 18 and 19, respectively. Line 20 contains the differences between these cash flows, expressed as the cash flow for the alternate minus the cash flow for the base.

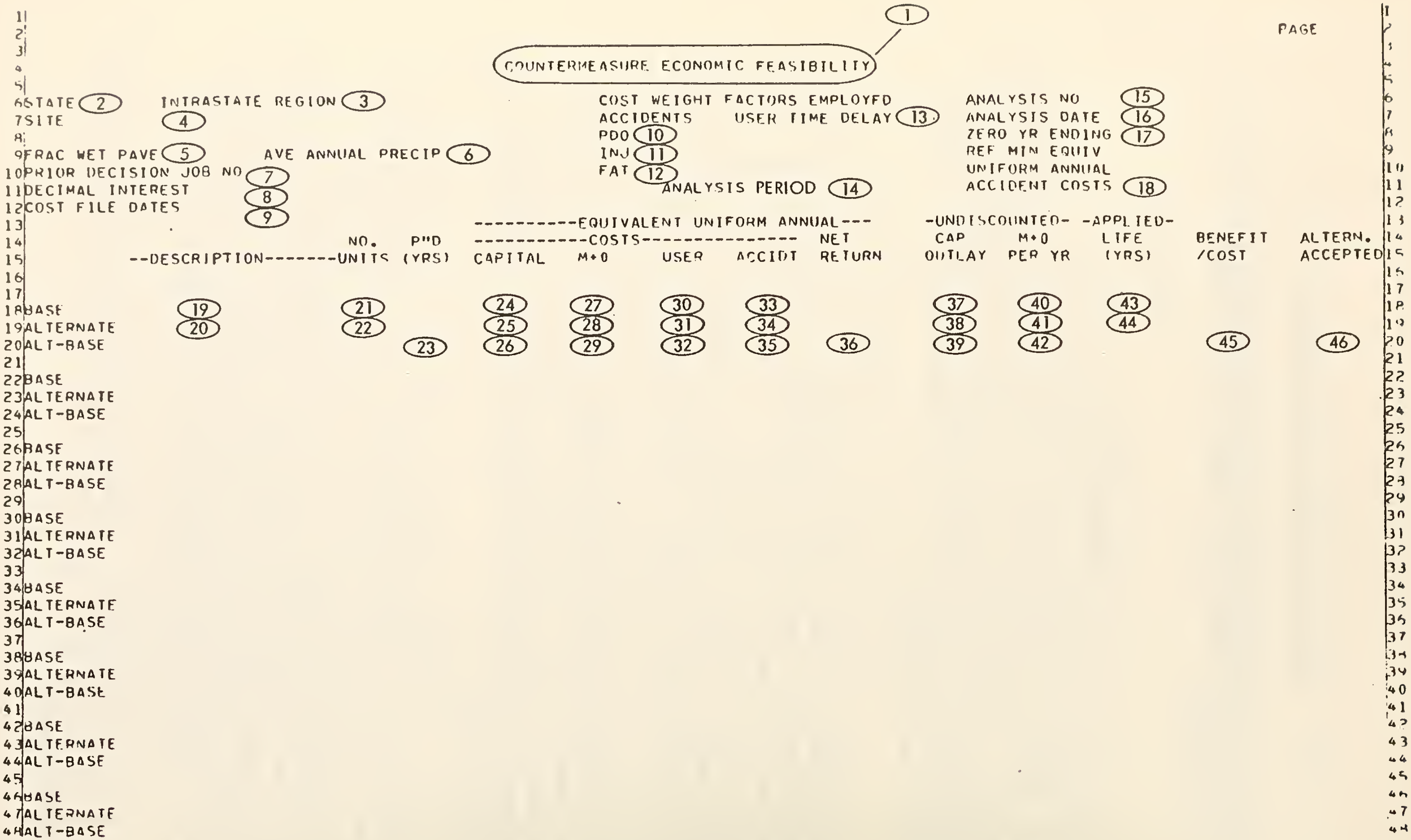

Figure 4 - Format of Printed Output

The data items presented on the output are numbered 1 through 46 in Figure 4. Each of these items is discussed below in detail.

1. Heading block: The following information is presented in the heading at the beginning of each stage of the analysis.

Item 1 - Main Heading. The heading COUNTERMEASURE ECONOMIC FEASIBILITY or PROJECT FORMULATION appears at the top of the page to identify the stage of the analysis for which results are presented.

Item 2 - State. This item is a two-character code identifying the state in which analysis site is located. This code, whose computer symbol is KSTAT, is assigned by the user as input data.

Item 3 - Intrastate Region. This item is a two-character code identifying a region within the state in which the analysis site is located. This code, whose computer symbol is KSTAR, is assigned by the user as input data.

Item 4 - Analysis Site. This space on the printout is reserved for the name or description of the analysis site, as specified by the user. It appears on the printout on two lines, with a maximum of 40 characters on each line.

Item 5 - Fraction of Wet-Pavement Time. This item is the fraction of time with wet pavement at the analysis site and is specified by the user as input. The computer symbol for this fraction is FWET.

Item 6 - Average Annual Precipitation. The average annual precipitation for the region in which the analysis site is located is printed in space 6. This quantity is specified by the user as input and is represented in the computer by the symbol APREC.

Item 7 - Prior-Decision Job Number. If a prior decision has been made to resurface or rebuild the facility, the job number assigned by the user for that decision will appear in space 7. Thus, if a job number appears here, it indicates that the benefit-cost analysis has included the impact of the prior decision. If no prior-decision job number appears, then the facility has been analyzed in its present condition. A complete discussion of the treatment of prior decisions in the model is found in Section V.H of this report.

Item 8 - Decimal Interest Rate. The interest or vestcharge rate used in the analysis is presented here in decimal form. This quantity, represented in the computer by the symbol V, is the minimum rate of return that is acceptable to the user.

Item 9 - Cost File Dates. This space contains the date of the most recent revision(s) of the cost files and other elements of the support system used to obtain date for the analysis. This date is provided so that the user can determine at a later time which version of the Cost files was in use when the analysis was made.

Items 10, 11, 12 and 13 - Cost Weight Factors. The items presented here are the weight factors for costs of property-damage-only accidents, injury accidents, fatal accidents and user time delay, respectively. These variables have a default value of 1.0, which is used unless the user specifies some other value. The cost weight factors are displayed on the output to provide a permanent record of any adjustments made during the analysis to the costs obtained from the cost files. See Section IV.G for a description of these factors.

Item 14 - Length of Analysis Period. This space contains the label LONG or SHORT to identify whether the longer or shorter analysis period has been used when countermeasures with unequal service lives are compared. As stated in Section V.D, the choice of analysis periods is determined by the value of the variable JPER( ). In the default case, the program sets JPER( ) = 2 and uses the longer of the two analysis periods. The user has the option of setting JPER( ) = 1 and using the shorter analysis period, or of performing the analysis twice, using each of the two periods.

Item 15 - Analysis Number. The analysis number is a 14-digit number of the form: XX XX XXXX XXXXXX. The first two digits of the analysis number identify the state in which the analysis site is located. The next two digits identify the appropriate region within that state. The next four digits identify the year in which the analysis was conducted, and the final six digits are a sequence number assigned to the analysis. The analysis number is intended as a unique designation that can be used to identify the particular analysis in a state's file.

Item 16 - Analysis Date. This item is the month, day and year on which the analysis was conducted. It is the form: XX XX XXXX where the first two digits represent the month (01 = January,..., 12 = December), the next two digits represent the day (01,..., 31), and the final four digits represent the year (1977, 1978, 1979, etc.).

Item 17 - Date Zeroth Year Ends. This item is the final date of the zeroth year of the analysis. The zeroth year is the year during which the countermeasure is implemented. This date is specified by the user as input and is presented in the same format as Item 16.

Item 18 - Minimum Equivalent Uniform Annual Accident Cost. The minimum equivalent uniform annual accident cost is not incorporated in the current version of the model, but a space is reserved for it on the output should it be added in a subsequent revision. This quantity represents the lowest total accident cost that would be possible if the most effective available countermeasure were implemented. This quantity will be used in Subroutine SIG to determine whether any significant accident savings are possible at the analysis site.

2. Comparisons of base and alternate conditions: Cash flows and other relevant data for the each pair of base and alternate conditions analyzed are presented on the printout lines labeled BASE and ALTERNATE. The differences between these cash flows are used in the calculation of the benefit/cost ratio and are presented on the line, ALT-BASE. The following discussion describes each item found on these three lines.

Items 19 and 20 - Countermeasure Description. These spaces contain 20 character titles identifying the countermeasures compared on the lines. The user specifies a name for each countermeasure selected as input to the model. In the economic feasibility stage, the base case will always be the present condition of the facility (or its projected condition based on prior decisions), and will be identified in item 19 by the designation EXISTING. The alternate will be a user-selected countermeasure with a user-selected name. In the project formulation stage, the base will be the least expensive countermeasure, but the initial base may be replaced by a more cost-beneficial countermeasure as the incremental analysis proceeds.

Items 21 and 22 - Number of Countermeasure Units. Items 21 and 22 identify the number of units of each countermeasure required for the base and alternate cases. These values are specified by the user and their units must be compatible with the unit costs available in the cost files. The numbers of units are used to determine the capital cost of each countermeasure from the cost files. When the existing condition is used as the base, item 21 will be zero, but in all other situations items 21 and 22 are non-zero. The computer symbols for items 21 and 22 are UN(KB) and UN(KC), respectively.

Item 23 - Period of Analysis. This data item is the period of analysis (in years) that is used to compare the base and alternate conditions. It is printed on the third (ALT-BASE) line and its computer symbol is IA. The period of analysis is determined by the program for each base and alternate countermeasure, and depends on their normal service lives and on the user's selection of the long or short option for length of analysis period.

Items 24, 25 and 26 - Equivalent Uniform Annual Capital Costs. Items 24 and 25 are the equivalent uniform annual capital costs for the base and alternate conditions, respectively. These are determined by annualizing all capital expenditures for each countermeasure. The equivalent uniform annual capital cost for the existing condition is zero except in two cases. First, if a prior decision has been made to resurface (or to resurface as part of rebuilding), the capital cost for the resurfacing appears in the base case when an alternative resurfacing countermeasure is evaluated in economic feasibility. If the alternative surface is accepted its capital costs in subsequent calculations for project formulation are reduced in accord with the capital commitment from the prior decision.

In the second situation, base case capital costs will appear in economic feasibility calculations when a resurfacing countermeasure would last longer than the existing surface course. In this situation the future capital cost for the base case resurfacing is discounted and distributed over the entire period until its end of life. There is no influence in project formulation calculations.

Item 26 is the difference between the equivalent uniform annual capital costs for the alternate and base conditions and is used as the denominator of the benefit/cost ratio. The computer symbols for these three capital costs are UCC(1), UCC(2), and UCC(3), respectively.

Items 27, 28 and 29 - Equivalent Uniform Annual Maintenance and Operating Costs. The meanings of these costs are directly analogous to the capital costs discussed above, except that they represent the maintenance and operating costs. The maintenance and operating costs are always non-zero, even for the existing condition. The computer symbols for items 27, 28 and 29 are EUAMØ(1), EUAMØ(2), and EUAMØ(3), respectively.

Items 30, 31 and 32 - Equivalent Uniform Annual User Costs. The meanings of these costs are directly analogous to the maintenance and operating costs discussed above, except that they represent user costs associated with construction or other implementation. The computer symbols for items 30, 31 and 32 are EUAUC(1), EUAUC(4) and EUAUC(3), respectively.

Items 33, 34 and 35 - Equivalent Uniform Annual Accident Costs. The meanings of these costs are directly analogous to the maintenance and operating costs discussed above except that they represent the cost of traffic accidents at the analysis site. The computer symbols for items 33, 34 and 35 are EUAAC(1), EUAAC(2) and EUAAC(3), respectively.

Item 36 - Net Return. This quantity is the sum of the equivalent uniform annual costs shown on the ALT-BASE line for capital outlays, maintenance and operating costs, user costs and accident costs. The net return is represented in the computer program by the symbol RN.

Items 37, 38 and 39 - Undiscounted Capital Outlays. Items 37 and 38 are the undiscounted capital costs for the base and alternate conditions. Each of these quantities is the sum of the values of all capital outlays at the time they occur. When the only capital outlay occurs during the zeroth year, these quantities are simply the present value of the equivalent uniform annual capital costs given in items 24 and 25. Item 39 is the difference between the undiscounted capital outlays for the alternate and base conditions. The computer symbols for items 37, 38 and 39 are CØLD (1), CØLD (2) and CØLD (3), respectively.

Attention is directed to the output in the situation when a resurfacing countermeasure is evaluated in project formulation, and, a prior decision has been made to resurface. The capital commitment associated with the prior decision will have been used to reduce the capital outlay and the uniform annual capital cost for the resurfacing countermeasure in project formulation output. The separate costs associated with the prior decision and the alternative surface course are shown in the output for economic feasibility.

Items 40, 41 and 42 - Undiscounted Average Maintenance and Operating Expenses. Items 40 and 41 are the average undiscounted maintenance and operating expenses per year for the entire analysis period for the base and alternate conditions. These items are the sums of all maintenance and operating expenditures during the analysis period divided by the number of years in the analysis period. Item 42 is the difference between items 41 and 40. The computer symbols for items 40, 41 and 42 are AMØ(1), AMØ(2) and AMØ(3), respectively.

Items 43 and 44 - Applied Lives of Countermeasures. These spaces contain the applied lives for the base and alternate conditions. The applied life of a countermeasure can differ from the normal service life, as explained in Section IV.C. The computer symbols for Items 43 and 44 are LAF(KB) and LAF(KC), respectively.

Items 45 - Benefit/Cost Ratio. The benefit/cost ratio, represented by the computer symbol BCR(KC), is formed from the equivalent uniform annual cash flows shown on the printout, using the definition presented in Section V.B.

Item 46 - Acceptance of Alternatives. If the benefit/cost ratio is larger than 1.0, the alternate is accepted and YES is printed on the output. If the benefit/cost ratio is smaller than 1.0, the alternate is rejected and NO is printed. In the economic feasibility stage, acceptance of an alternate countermeasure means that the alternate is preferable to the existing condition and should be included in the project formulation state. If a countermeasure is rejected in the economic feasibility stage, it is not considered further. If an alternate is accepted in the project formulation stage, it becomes the new base to which subsequent alternates are compared. The last alternate for which a YES is found in the acceptance of alternatives column on the project formulation printout is the best investment of capital.

B. Output Interpretation

This section describes the interpretation of the analysis results printed on the program output and explains how these results should be used by the highway engineer or administrator in decision-making. The benefit-cost model is a tool that can be used by the decision-maker, but its results should be only one consideration out of many that influence the final decision.

The program output contains a recommendation of the most cost-beneficial countermeasure, which can be easily determined from the acceptance-of-alternatives column on the printouts. The last alternate marked YES on the project formulation printout is the most cost-beneficial countermeasure. If all of the alternates in the project formulation stage are marked NO, then the initial base for that stage (the least expensive of the feasible countermeasures) is the most cost-beneficial.

The user should not decide to implement the most cost-beneficial countermeasure solely on the basis of the recommendation indicated by the acceptance of alternatives column for three reasons. First, the output presents a great deal of additional economic data about each countermeasure that should be considered by the user. Second, although the model considers the economic effects of countermeasures that will be important in the majority of situations, particular decisions may be influenced by economic considerations not incorporated in the model. And, third, many non-economic and non-quantitative factors that cannot be incorporated into any economic model must be considered by the decision-maker.

The printed output provides a great deal of valuable economic data for the decision-maker in a highly condensed form. For instance, the benefit/cost ratios of all countermeasures are available. Several countermeasures may be nearly as cost-beneficial as the recommended alternative and, given the uncertainity involved in any economic analysis, might actually be preferable. Such countermeasures should certainly receive active consideration. The annual net return for each countermeasure is an alternative to the benefit/cost ratio for evaluating the countermeasures. (The negative net returns with the largest magnitude are most preferable.) Funds available to implement highway safety countermeasures are always limited. The output contains the undiscounted capital outlay for each countermeasure, which can be compared with the available budget for the year in which the countermeasure will be installed.* Finally, the output presents the effects of each countermeasure on maintenance and operating costs, and on user costs due to construction activity, which the decision-maker should consider in the light of available budgets and state policies.

In some situations, the user may choose to add some additional costs which are not incorporated in the present model. For example, vehicle operating costs and other user costs are not included in the model except as they are affected by construction activity. If such costs are substantial for a given analysis, as might occur in an urban area, the user can easily recompute the benefit/cost ratios to include such costs and be guided by the revised values.

Most decisions will be influenced by factors which are non-economic and/or non-quantitative. Such factors include noise, air and water pollution, visual quality, land use impacts, legal and political considerations, and community values and preferences. The consideration of these factors in relation to the economic consequences evaluated by the model depends on the subjective evaluations and judgements of the decision-maker.

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* The user's attention is directed to the detailed description of undiscounted capital outlays in the preceding section.

IX. UPDATING THE SYSTEM FILES

The system files (usually on magnetic tape) are the major component of the support system for the computerized benefit-cost model. The files contain data of several types that may need to be updated periodically. The general procedure for updating the files is shown in Figure 5 where the file contents are, for brevity, indicated as costs.

The details of the file formats and updating procedures have been the responsibility of the Data Systems Division, Federal Highway Administration, Department of Transportation.

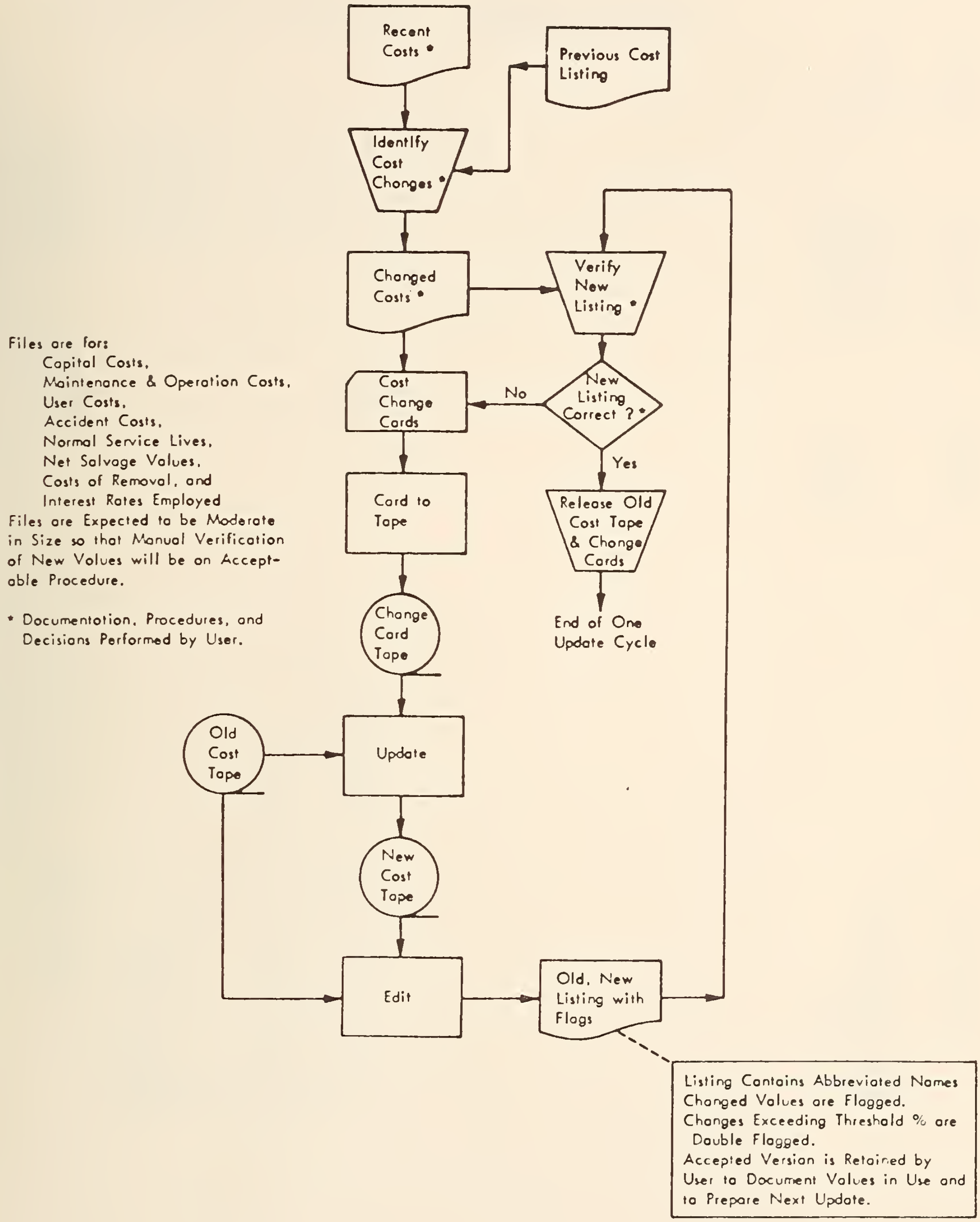

Figure 5 - Files Maintenance System

APPENDIX

INPUT CARD FORMATS

CARD NO. 1 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 01		Mandatory	I2
3-20	STATE AND REGION		Mandatory	4A4,A2
21-22	State Code	KSTAT	Mandatory	I2
23-24	Region Code	KSTAR	Mandatory	I2

CARD NO. 2 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 02		Mandatory	I2
3-20	GENERAL INPUT		Mandatory	4A4,A2
21-30	Date of Analysis		Mandatory	2(I2,X),I4
31-40	Date Zeroth Year Ends		Mandatory	2(I2,X),14
41-44	Blank			
45-50	Sequence Number for Analysis		Mandatory	I6
51-60	Decimal Interest Rate	V	Optional	F10.2
61-70	Upper Limit on Number of Years to be Used in Any Period of Analysis	MXYR	Optional	I10

CARD NO. 3 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 03		Mandatory	I2
3-20	SITE DESCRIP ONE		Mandatory	4A4,A2
21-60	First Line of Site Description		Mandatory	10A4

CARD NO. 4 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 04		Mandatory	I2
3-20	SITE DESCRIP TWO		Mandatory	4A4,A2
21-60	Second Line of Site Description		Mandatory	10A4

CARD NO. 5 MANDATORY

Columns	Date Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 05		Mandatory	I2
3-20	SITE CHAR		Mandatory	4A4, A2
21-23	Area Type	IATYP	Mandatory	I3
24-26	Highway Type	IHTYP	Mandatory	I3
27-29	Site Type	ISITE	Mandatory	I3
30	Blank			
31-40	Site Length	TLGH	Mandatory	F10.0
41-50	Percent of Wet-Exposure Time	FWET	Mandatory	F10.0
51-60	Annual Precipitation (in.)	APREC	Optional	F10.0
61-70	Mean depth of current macrotexture (milli-in.)	AMDYØ	Optional	F10.0
71-80	Current British Portable Number	ABPNYØ	Optional	F10.0

CARD NO. 6 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 06		Mandatory	I2
3-20	PRIOR DECISION		Mandatory	4A4,A2
21-30	Code for Prior Decision to Resurface	IRS	Mandatory	I10
31-40	Number of Units of Surface Course Planned As Result of Prior Decision	UN(1)	Mandatory if IRS = 1	F10.0
41-50	Final Capital Worth of Surface Course Planned as Result of Prior Decision	FCW(1)	Mandatory if IRS = 1	F10.0
51-60	Current or Planned Type of Surface Course	KWS	Optional	I10
61-70	Current Skid Number	SNYØ	Optional	F10.0

CARD NO. 7 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 07		Mandatory	I2
3-20	FACILITY LIFE		Mandatory	4A4,A2
21-30	Normal Remaining Life of Facility (Years)	LIFF	Mandatory	I10
31-40	Scheduled or Estimated Years Until Resurfacing	LIFRS	Mandatory	I10
41-50	Scheduled or Estimated Years Until Rebuilding	LIFRB	Mandatory	I10

CARD NO. 8 MANDATORY

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 08		Mandatory	I2
3-20	ACCIDENT DATA		Mandatory	4A4,A2
21-23	Total Number of Accidents Prior to Countermeasure Implementation	AALL	Mandatory	F3.0
24-26	Number of Fatal and Injury Accidents Prior to Countermeasure Implementation	AFI	Optional	F3.0
27-29	Number of Property-Damage-Only Accidents Prior to Countermeasure Implementation	APDØ	Optional	F3.0
30-32	Number of Head-on Accidents Prior to Countermeasure Implementation	AHØ	Optional	F3.0
33-35	Number of Rear-End Accidents Prior to Countermeasure Implementation	ARE	Optional	F3.0
36-38	Number of Side-Swipe Accidents Prior to Countermeasure Implementation	ASS	Optional	F3.0
39-41	Number of Right-Angle Accidents Prior to Countermeasure Implementation	ARA	Optional	F3.0
42-44	Number of Left-Turn Accidents Prior to Countermeasure Implementation	ALT	Optional	F3.0
45-47	Number of Parking-Related Accidents Prior to Countermeasure Implementation	APR	Optional	F3.0
48-50	Number of Fixed-Object Accidents Prior to Countermeasure Implementation	AFØ	Optional	F3.0
51-53	Number of Pedestrian Accidents Prior to Countermeasure Implementation	APED	Optional	F3.0
54-56	Number of Other Accidents Prior to Countermeasure Implementation	AØTH	Optional	F3.0
57-59	Number of Wet-Pavement Accidents Prior to Countermeasure Implementation	AWET	Optional	F3.0
60-62	Number of Dry-Pavement Accidents Prior to Countermeasure Implementation	ADRY	Optional	F3.0
63-65	Number of Nighttime Accidents Prior to Countermeasure Implementation	ANIT	Optional	F3.0
66-68	Number of Daytime Accidents Prior to Countermeasure Implementation	ADAY	Optional	F3.0

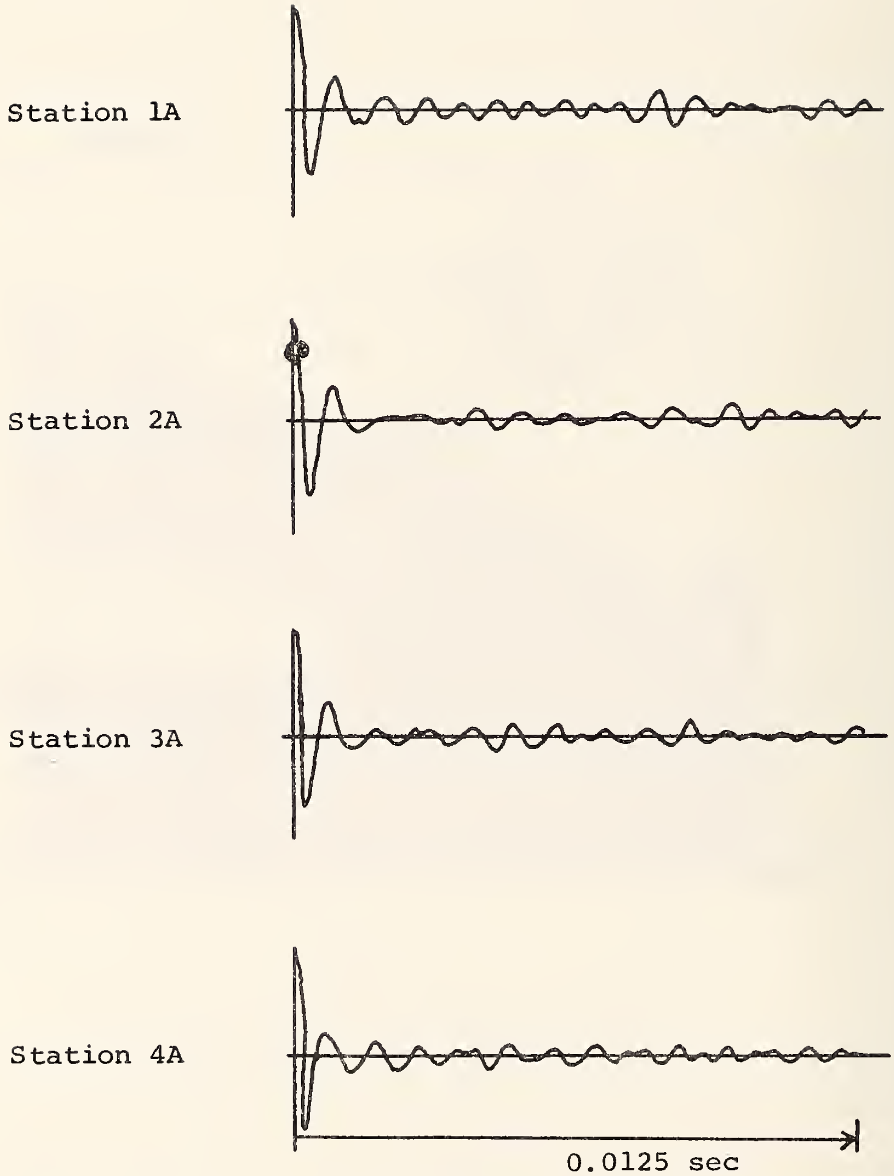

FIGURE 13.- SIGNATURES OF 85-101 BRIDGE, GIRDER A;
FILTER: 1,000 - 6,400 Hz.

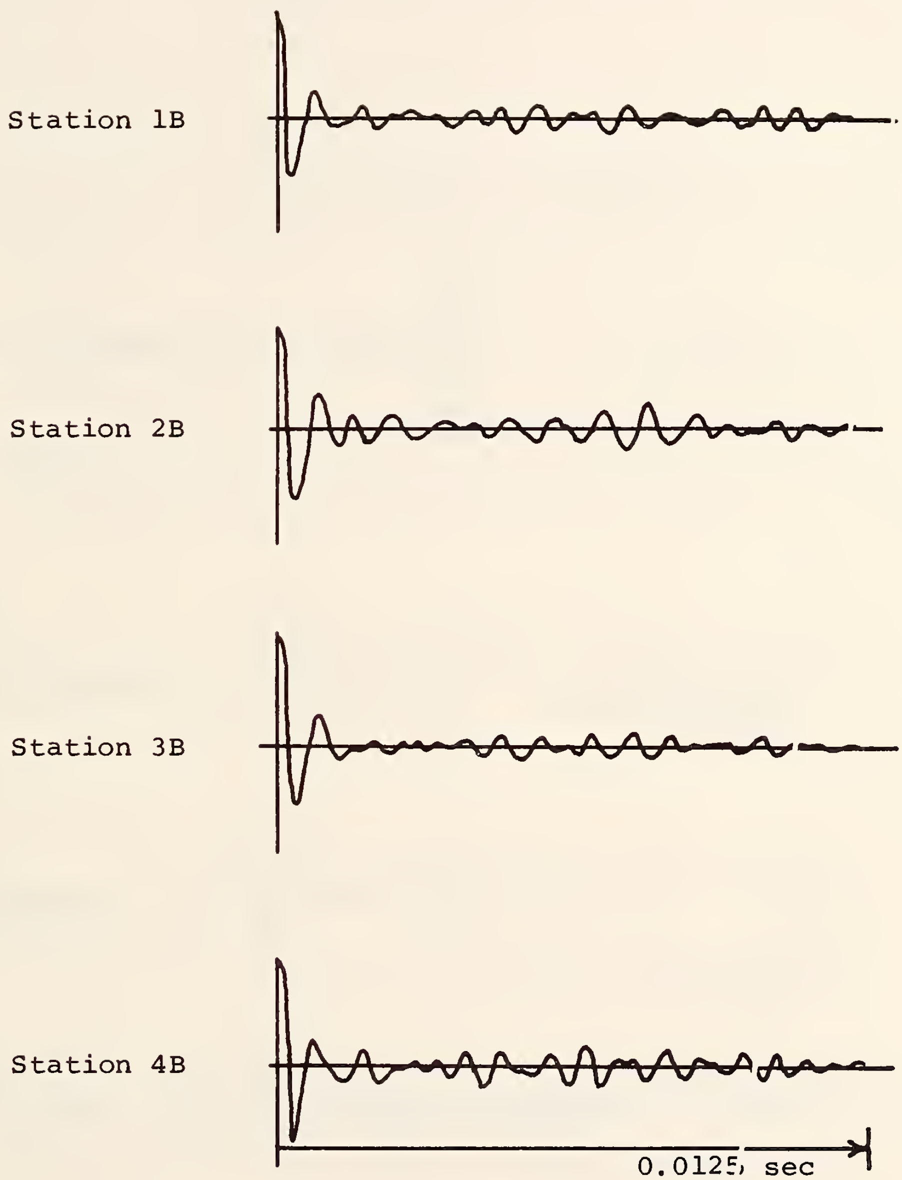

FIGURE 14.- SIGNATURES OF 85-101 BRIDGE, GIRDER B;
FILTER: 1,000 - 6,400 Hz.

CARD NO. 11 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Code Type = 11		Mandatory	I2
3-20	JOB NUMBER PRIOR DEC		Mandatory	4A4,A2
21-30	Job Number (No Alphabetic Characters)		Optional	I10
31-40	Same as Columns 21-30		Optional	I10
41-50	Same as Columns 21-30		Optional	I10
51-60	Same as Columns 31-40		Optional	I10

CARD NO. 12

OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory if Card is Used	Format
1-2	Card Type Code = 12		Mandatory	I2
3-20	WEIGHT FACTORS		Mandatory	4A4,A2
21-30	Subscript for Five Items that Follow (integer; maximum value of 6)	NVAR	Mandatory	I10
31-40	Weight Factor for Property-Damage-Only Accident Costs	FPD(NVAR)	Optional	F10.0
41-50	Weight Factor for Injury Accident Costs	FIA(NVAR)	Optional	F10.0
51-60	Weight Factor for Fatal Accident Costs	FFA(NVAR)	Optional	F10.0
61-70	Weight Factor for User Time Delay	FUTC(NVAR)	Optional	F10.0
71-80	Code for Period of Analysis	JPER(NVAR)	Optional	I10

CARD NO. 13 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 13		Mandatory	I2
3-20	COEFF FOR SIG SAV		Mandatory	4A4,I2

(This card is not presently used. It may be used to input values for CFAS and CCAS in a future revision of the model.)

CARD NO. 14 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 14		Mandatory	I2
3-20	ADTM1		Mandatory	4A4,I2
21-30	ADT of Major Facility in Year 1	ADTM(1)	Mandatory	F10.0
31-40	Same for Year 2	ADTM(2)	Optional	F10.0
41-50	Same for Year 3	ADTM(3)	Optional	F10.0
51-60	Same for Year 4	ADTM(4)	Optional	F10.0
61-70	Same for Year 5	ADTM(5)	Optional	F10.0
71-80	Same for Year 6	ADTM(6)	Optional	F10.0

CARD NO. 15 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 15		Mandatory	I2
3-20	ADTM7		Mandatory	4A4,A2
21-30	ADT of Major Facility in Year 7	ADTM(7)	Mandatory	F10.0
31-40	Same for Year 8	ADTM(8)	Optional	F10.0
41-50	Same for Year 9	ADTM(9)	Optional	F10.0
51-60	Same for Year 10	ADTM(10)	Optional	F10.0
61-70	Same for Year 11	ADTM(11)	Optional	F10.0
71-80	Same for Year 12	ADTM(12)	Optional	F10.0

CARD NO. 16 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 16		Mandatory	I2
3-20	ADTM13		Mandatory	4A4,A2
21-30	ADT for Major Facility in Year 13	ADTM(13)	Mandatory	F10.0
31-40	Same for Year 14	ADTM(14)	Optional	F10.0
41-50	Same for Year 15	ADTM(15)	Optional	F10.0
51-60	Same for Year 16	ADTM(16)	Optional	F10.0
61-70	Same for Year 17	ADTM(17)	Optional	F10.0
71-80	Same for Year 18	ADTM(18)	Optional	F10.0

CARD NO. 17 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 17		Mandatory	I2
3-20	ADTM19		Mandatory	4A4, A2
21-30	ADT For Major Facility in Year 19	ADTM(19)	Mandatory	F10.0
31-40	Same for Year 20	ADTM(20)	Optional	F10.0

CARD NO. 18

Columns	Data Item	Symbol	OPTIONAL Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 18		Mandatory	I2
3-20	ADTS1		Mandatory	ADTS1
21-30	Same as Card No. 14 for Secondary Facility			
31-40				
41-50				
51-60				
61-70				
71-80				

CARD NO. 19 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 19		Mandatory	I2
3-20	ADTS7		Mandatory	4A4, A2
21-30				
31-40				
41-50	Same as Card No. 15 for Secondary Facility			
51-60				
61-70				
71-80				

CARD NO. 20

OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 20		Mandatory	I2
3-20	ADTS13		Mandatory	4A4, A2
21-30 31-40 41-50 51-60 61-70 71-80	Same as Card No. 16 for Secondary Facility			

CARD NO. 21 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 21		Mandatory	I2
3-20	ADTS19		Mandatory	4A4, A2
21-30 31-40	Same as Card No. 21 for Secondary Facility			

CARD NO. 22 — MANDATORY FOR EACH COUNTERMEASURE

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 22		Mandatory	I2
3-20	SPECIFIED KM		Mandatory	4A4, A2
21-30	Countermeasure Number	KM	Mandatory	I10
31-40	Number of Units of Countermeasure	UN(KM)	Mandatory	F10.0
41-50	Specified Capital Cost Per Unit	SPAPC(KM)	Mandatory for Right-of-Way Countermeasures	F10.0
51-60	Applied Life (Years) for Countermeasure KM at Analysis Site	LAF(KM)	Mandatory for Right-of-Way Countermeasures	F10.0
61-70	Final Capital Worth Per Unit of Countermeasure KM After LAF(KM) Years at Analysis Site	FCW(KM)	Mandatory for Right-of-Way Countermeasures and When LAF(KM) Is Read In	F10.0

CARD NO. 23

MANDATORY FOR EACH COUNTERMEASURE

Columns	Data Item	Symbol	Optional or Mandatory	Format
1-2	Card Type Code = 23		Mandatory	I2
3-20	KM NAME AND TEX		Mandatory	4A4, A2
21-30	Countermeasure Number	KM	Mandatory	I10
31-50	Countermeasure Name		Mandatory	5A4
51-60	Initial mean texture depth (milli-in.)	AMDR(KM)	Optional	F10.0
61-70	Initial British Portable Tester number	BPNR(KM)	Optional	F10.0

CARD NO. 24 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 24		Mandatory	I2
3-20	MAINTENANCE AND OPERATING COSTS		Mandatory	4A4, A2
21-30	Countermeasure Number	KM	Mandatory	I10
31-40	Average Annual Maintenance and Operating Costs Per Unit of Countermeasure	SCMAØ(KM)	Optional	F10.0
41-50	Annual Rate of Change of Maintenance and Operating Costs Per Unit of Countermeasure	SSMAØ(KM)	Optional	F10.0
51-60	Upper Bound on Annual Maintenance and Operating Expenses	SMAØM(KM)	Optional	F10.0

CARD NO. 25 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 25		Mandatory	I2
3-20	USER COSTS		Mandatory	4A4, A2
21-30	Countermeasure Number	KM	Mandatory	I10
31-40	Time that Traffic Service is Reduced Due to Construction of Countermeasure for length ZLGH(KM)	TDUR(KM)	Mandatory	F10.0
41-50	Type of Construction Zone Configuration	KZOW(KM)	Mandatory	I10
51-60	Length of Construction Zone	ZLGH(KM)	Mandatory	F10.0
61-70	Code for Construction Schedule	KCSCD(KM)	Mandatory	I10

CARD NO. 26 OPTIONAL

Columns	Data Item	Symbol	Optional or Mandatory (if card is used)	Format
1-2	Card Type Code = 26		Mandatory	I2
3-20	PERCENT REDUCTION		Mandatory	4A4, A2
21-30	Countermeasure Number	KM	Mandatory	I10
31-33	Percent Reduction of All Accidents	PRALL(KM)	Optional	F3.0
34-36	Percent of Fatal and Injury Accidents	PRFI(KM)	Optional	F3.0
37-39	Percent Reduction of Property-Damage-Only Accidents	PRPDØ(KM)	Optional	F3.0
40-42	Percent Reduction of Head-On Accidents	PRHØ(KM)	Optional	F3.0
43-45	Percent Reduction of Rear-End Accidents	PRRE(KM)	Optional	F3.0
46-48	Percent Reduction of Side-Swipe Accidents	PRSS(KM)	Optional	F3.0
49-51	Percent Reduction of Right-Angle Accidents	PRRA(KM)	Optional	F3.0
52-54	Percent Reduction of Left-Turn Accidents	PRLT(KM)	Optional	F3.0
55-57	Percent Reduction of Parking-Related Accidents	PRPR(KM)	Optional	F3.0
58-60	Percent Reduction of Fixed-Object Accidents	PRFØ(KM)	Optional	F3.0
61-63	Percent Reduction of Pedestrian Accidents	PRPED(KM)	Optional	F3.0
64-66	Percent Reduction of Other Accidents	PRØTH(KM)	Optional	F3.0
67-69	Percent Reduction of Wet-Pavement Accidents	PRWET(KM)	Optional	F3.0
70-72	Percent Reduction of Dry-Pavement Accidents	PRDRY(KM)	Optional	F3.0
73-75	Percent Reduction of Nighttime Accidents	PRNIT(KM)	Optional	F3.0
76-78	Percent Reduction of Daytime Accidents	PRDAY(KM)	Optional	F3.0

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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD–2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.