Rail-Highway Crossing Resource Allocation Procedure - USER'S GUIDE, SECOND EDITION

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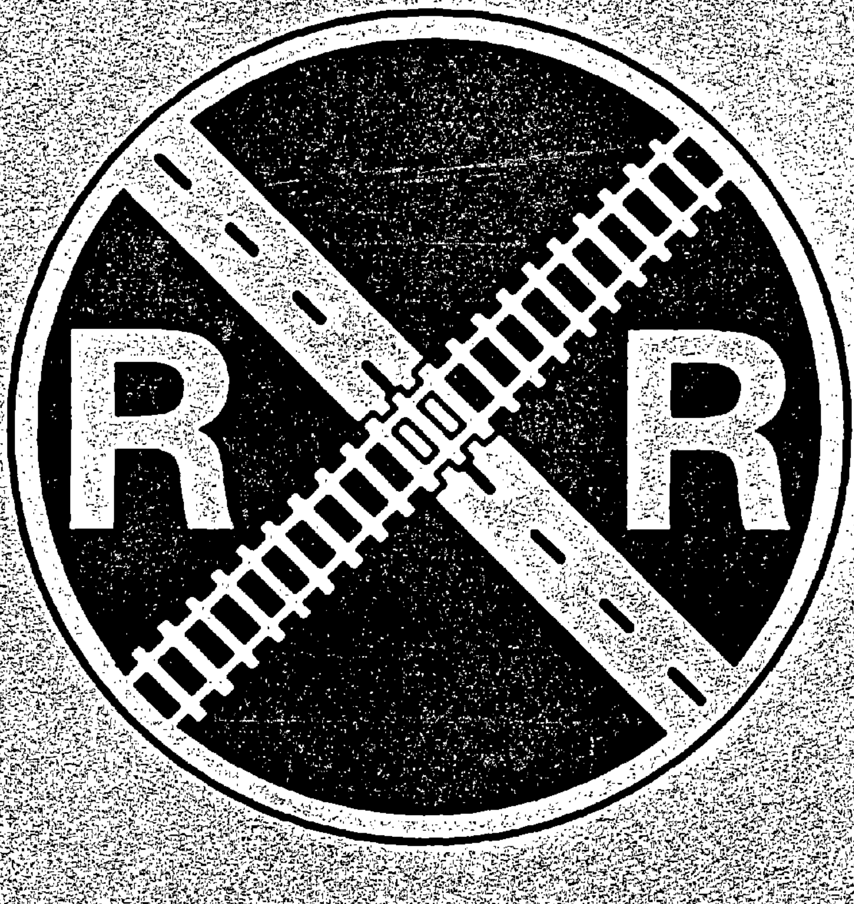

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16. Abstract

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Acts of 1978 and 1982 provide funding authorizations for individual states to improve safety at public rail-highway crossings. Safety improvements frequently consist of the installation of active motorist warning devices such as flashing lights or flashing lights with gates. To assist states and railroads in determining effective allocations of Federal funds for rail-highway crossing improvements, the U.S. Department of Transportation has developed the DOT Rail-Highway Crossing Resource Allocation Procedure. The procedure consists of the DOT accident and casualty prediction formula, which predicts the number of casualties and accidents at crossings, and the resource allocation model, which nominates crossings for improvement on a cost-effective basis and recommends the type of warning device to be installed. This guide provides interested users with complete information for application of the DOT Rail-Highway Crossing Allocation Procedure. This second edition of the guide incorporates results of recent research including a casualty prediction formula, extended data on warning device effectiveness, and consideration of standard highway stop signs as a warning device option under certain conditions.

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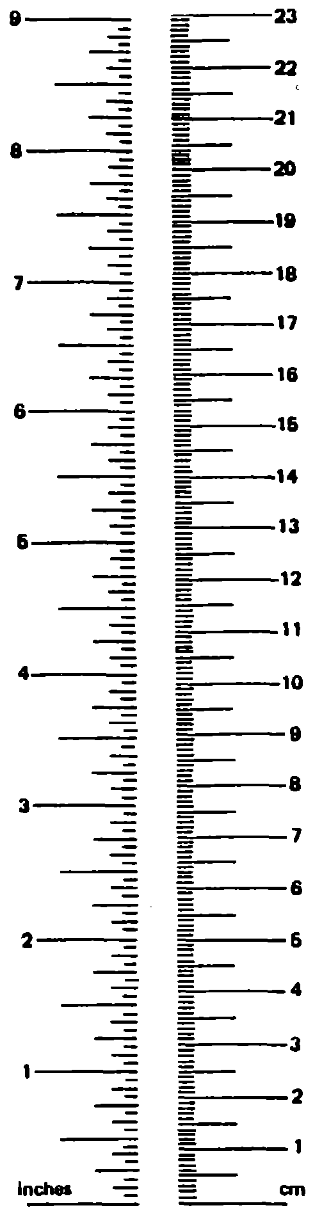
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

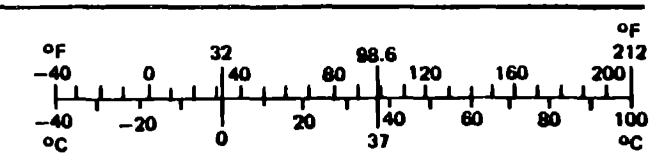
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight 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	36	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



PREFACE

The Department of Transportation's (DOT) rail-highway crossing accident prediction formula and resource allocation model, described in this report, were developed at the Transportation Systems Center (TSC) under the sponsorship of the Federal Railroad Administration's (FRA) Office of Safety and the Federal Highway Administration's (FHWA) Office of Research, Development and Technology. When used together, these procedures provide an automated and systematic means of making preliminary cost-effective allocations of funds for improvement options among individual crossings.

This user's guide provides complete information for application of the DOT Procedures. Preparation of the guide was the overall responsibility of John Hitz of TSC. Mary Cross of TSC and George Reed of Systems Development Corporation were responsible for development and description of computer programs required for application of the procedures.

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1. INTRODUCTION

1.1 PURPOSE

This is the second edition of a guide intended to provide interested users with complete information for application of the DOT Rail-Highway Crossing Resource Allocation Procedure.

1.2 BACKGROUND

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Assistance Acts of 1978 and 1982 provide funding authorizations for individual states to improve safety at public rail-highway crossings. Safety improvements frequently consist of the installation of motorist warning devices such as flashing lights or flashing lights with gates. In support of these safety efforts, several projects have been undertaken by the U.S. Department of Transportation (DOT) to assist states and railroads in determining effective use of Federal funds for rail-highway crossing safety improvement. One of these projects has developed the DOT Rail-Highway Crossing Resource Allocation Procedure to assist state and railroad program managers in identifying candidate crossings for improvement. This procedure, referred to hereafter as the DOT Procedure, recommends crossing safety improvements that yield the greatest accident reduction benefits based on consideration of predicted accidents and casualties at crossings, the cost and effectiveness of warning device options and the budget limit.

Two analytical methods have been developed as part of the DOT Procedure. Their development followed completion of a joint U.S. DOT-AAR (Association of American Railroads) National Rail-Highway Crossing Inventory (hereafter referred to as The Inventory), which numbered and collected inventory information for all public and private crossings in the United States. (Ref. 1) The first analytical method included in the DOT Procedure is the DOT Accident and Casualty Prediction Formula, which computes the expected number of accidents and casualties at crossings based on information available in The Inventory and crossing accident data files. The second analytical method is a resource allocation model designed to rank candidate crossings for improvement on a cost-effective basis and recommend the type of warning device to be installed. This guide provides complete information on how to use these two analytical methods.

1.3 ORGANIZATION OF GUIDE

Chapter 2 provides a technical overview of the DOT Procedure and its two major elements, the DOT accident and casualty prediction formulas and the resource allocation model.

Chapter 3 describes the purpose, development and characteristics of the DOT accident and casualty prediction formulas.

Chapter 4 describes the resource allocation model and its data requirements.

Chapter 5 discusses procedures for use of the DOT Procedure. A sample application is provided as a means of demonstrating its use for different situations.

2. DOT RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE - OVERVIEW

There are currently approximately 200,000 public at-grade rail-highway crossings in the United States. At an average cost of approximately $55,000 per installation, there are insufficient funds available to install automatic warning systems at each of these crossings. The DOT Procedure was designed to assist in determining how limited safety improvement funds should be allocated to specific crossings and warning device improvements to achieve the greatest reduction in accidents and casualties.

Figure 2-1 illustrates the basic functions of the DOT Procedure. Inventory information and the accident histories of the individual crossings being considered are used by the DOT accident prediction formula to provide a list of crossings ranked by the estimated number of accidents or casualties that will occur at each crossing. State crossing programs commonly use such rankings, produced by various formulas, as a basis for determining safety improvements; i.e., crossings are improved in the order of their predicted accident levels, with the crossing having the highest accident rate treated first and so forth. However, if the program objective is to achieve maximum accident reduction for a given total cost, this procedure must be extended to consider the different warning device options which are available for each crossing and their differing costs and effectiveness for reducing accidents. For example, installing a flashing light at the crossing with the tenth highest accident rate might yield a higher accident reduction/cost ratio than installing an automatic gate at the most hazardous crossing. Consequently, the resource allocation model uses the predicted accidents or casualties at each crossing together with information on the safety effectiveness and costs of alternative warning device improvements and the funding level available to determine the most cost-effective set of improvement decisions; i.e., which crossings to improve and the types of warning devices to install at those crossings to result in the greatest accident or casualty reduction given the available funding.

The DOT Procedure does not dictate final decisions for crossing improvements, but does recommend programs to aid in making informed decisions. As an analytical procedure, its recommendations are dependent on accurate input data and assumptions. Errors in The Inventory and assumptions regarding warning device cost and effectiveness may cause inappropriate recommendations. To ensure accuracy of the input data, they

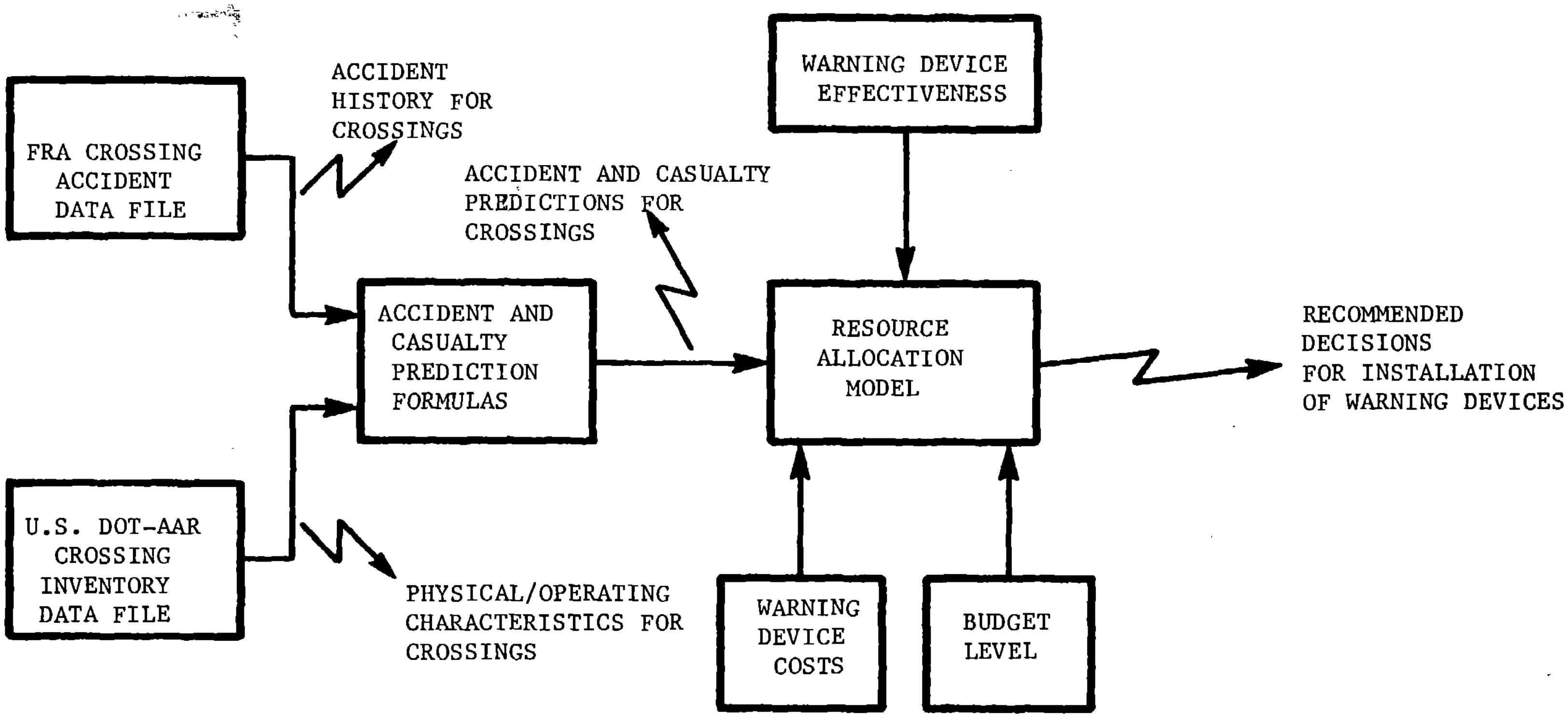

FIGURE 2-1. RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE

should be validated by a diagnostic team as part of their normal duties in making field evaluations of recommended improvements. While in the field, the diagnostic team should also make note of other considerations that may impact final improvement decisions but are not included in the DOT Procedure. These considerations include highway congestion, school bus and hazardous materials traffic, restricted sight distance, and other unusually hazardous, costly or mitigating characteristics of individual crossings. A procedure for performing this evaluation is described in Section 4.2.6. Results of the DOT Procedure, findings of the diagnostic team, inclusion of any state warrants and the judgement of state and local officials should all be considered before final improvement decisions are made.

The primary role of the DOT Procedure is to assist states and railroads in developing crossing safety improvement programs. The first stage in developing these programs is usually to prepare a list of candidate crossings for safety improvements. To assist in preparing this list, the DOT accident prediction formula can be used to rank crossings by predicted accidents or casualties to identify hazardous crossings potentially needing safety improvements. The resource allocation model can then be used to evaluate alternative programs for improving these crossings. For example, the impacts on program benefits of changes in key program parameters such as budget limits, warning device installation strategies (e.g. flashing lights only, gates only) and warning device cost and effectiveness assumptions can be determined. Analysis of these results will help in deciding upon budget levels for crossing improvements and in determining the effectiveness of implementing state warrants specifying installation strategies. Once key program parameters have been decided upon, the DOT Procedure will provide an initial recommended program, based on cost-effectiveness considerations, for review by the state. The DOT Procedure is also useful for railroads in providing recommended uniform improvement programs over their entire rail systems that pass through several states.

Initial results of the DOT Procedure provide useful guidance to diagnostic teams by specifying crossings with recommended improvements that should be field inspected and data that must be checked for accuracy. Using the field verification procedure described in Section 4.2.5, diagnostic teams can determine revised cost-effective improvement decisions for particular crossings where original data were found incorrect. The revised results obtained by the diagnostic team then form a useful basis upon which state and local officials can finalize crossing improvement programs.

3. DOT ACCIDENT AND CASUALTY PREDICTION FORMULA

3.1 INTRODUCTION

Many crossing hazard formulas have been developed in the past and used extensively by those concerned with rail-highway crossing safety. (Ref. 2) Examples are the New Hampshire Formula, the Peabody-Dimmick Formula, the Mississippi Formula, and the Ohio Method. Availability of The Inventory and national accident data by crossing were major considerations which influenced development of the DOT accident and casualty prediction formula. The Inventory contains information on the physical and operating characteristics of all rail-highway crossings in the United States and, thus, affords an improved basis for rail-highway crossing accident and casualty prediction.

The DOT formulas are termed "absolute" formulas since they estimate numbers of accidents and casualties. Other formulas, such as the New Hampshire Formula, are termed "relative" formulas since they provide an index which is associated with expected accidents or casualties only on a relative basis i.e., a larger index means more expected accidents or casualties but the relationship is not linear. The distinction between absolute and relative formulas is important when considering use of a formula to assist in determining cost-effective allocations of improvement funds, as discussed in Section 4. If program effectiveness is to be measured in terms of tangible benefits such as reduced accidents, an absolute formula must be used to ensure that the benefits of alternative actions are consistently evaluated. The use of absolute formulas, such as the DOT formulas, is therefore recommended to support resource allocation decisions.

Both relative and absolute formulas can be used to provide rankings of crossings on the basis of their relative hazards. A comparison of the DOT formulas with several other well-known formulas (Ref. 3) shows the DOT formulas to have significantly improved performance in this regard.

The functions of the DOT accident and casualty prediction formulas are described in Figure 3-1. The formulas provide a means of calculating the expected annual number of accidents and casualties at a crossing on the basis of the crossing's characteristics described in The Inventory and the crossing's historical accident experience described in the FRA Railroad Accident/Incident Reporting Systems (RAIRS). The accident and casualty predictions are produced by the DOT formulas in two steps. Predicted accidents are obtained in the first step using a set of formulas described in Section 3.2. The resulting accident predictions are expressed as expected number of accidents per year at a crossing. If desired, predicted casualties are then obtained in the second step using another set of formulas as described in Section 3.3. The casualty calculations depend on use of predicted accident results from the first step. The casualty predictions for a crossing are expressed in three ways: (1) expected number of fatal accidents per year, (2) expected number of injury accidents per year and (3) total combined casualty index (a weighted combination of fatal and injury accidents per year).

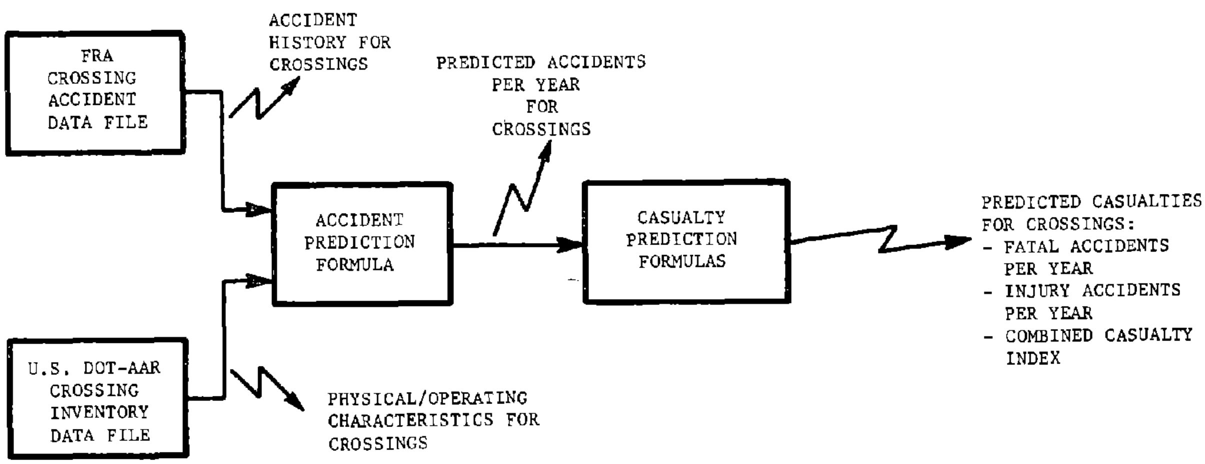

FIGURE 3-1. DOT RAIL-HIGHWAY CROSSING ACCIDENT PREDICTION FORMULA

3.2 DESCRIPTION OF FORMULAS FOR ACCIDENT PREDICTION

3.2.1 Overview

Accident predictions are produced by combining two independent predictions of a crossing's accidents to produce a more accurate resultant prediction. The two independent predictions are obtained from the following sources:

1. A formula described in Section 3.2.2 provides an initial prediction of accidents on the basis of a crossing's characteristics as described in The Inventory. This formula, termed the "basic formula", is used to predict crossing accidents in a manner similar to other common formulas such as the Peabody-Dimmick formula.

2. A second prediction is provided by the actual observed accident history at a crossing as described in Section 3.2.3. This prediction assumes that future accidents per year are approximated by the average historical accident rate. It is referred to as a crossing's "accident history".

The above two independent predictions are combined as a weighted average using the general accident prediction formula described in Section 3.2.4.

3.2.2 Basic Formula

The initial prediction of a crossing's accidents (a) is determined from the basic accident prediction formula described in Equation 3-1 below. The basic formula produces a prediction on the basis of a crossing's characteristics as described in The Inventory. The technique used for developing the basic formula involved applying nonlinear multiple regression techniques to crossing characteristics stored in The Inventory and to accident data contained in the FRA Railroad Accident/Incident Reporting System (RAIRS). The 1976 accident file and the August 1976 Inventory were used to develop the formula. Half of the file was used to determine the formula coefficients by regression and iteration (data set A) and the other half was used for testing of the formula (data set B). Data sets A and B were disjoint, of equal size and comprised of a random sample of records from The Inventory, including all records for which accident data existed in the RAIRS file. Each data set was categorized into two groups of accident and nonaccident crossings.

The resulting basic formula can be expressed as a series of factors which, when multiplied together, yield the initial predicted accidents per year (a) at a crossing. Each factor in the formula represents a characteristic of the crossing described in The Inventory. The general expression of the basic formula is shown below:

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL \qquad (3\text{-}1)$$

where

a = initial accident prediction, accidents per year at the crossing

K = constant for initialization of factor values at 1.00*

EI = factor for exposure index based on product of highway and train traffic

MT = factor for number of main tracks

DT = factor for number of thru trains per day during daylight

HP = factor for highway paved (yes or no)

MS = factor for maximum timetable speed*

HT = factor for highway type*

HL = factor for number of highway lanes

Three sets of equations are used to determine the value of each factor, one for each of the following three categories of warning devices:

1. Passive, including the following warning device classes:

   Class 1 - No signs or signals
   Class 2 - Other signs
   Class 3 - Stop signs
   Class 4 - Crossbucks

2. Flashing lights, including the following warning device classes:

   Class 5 - Special e.g., flagman
   Class 6 - Highway signals, wig-wags or bells
   Class 7 - Flashing lights

*New formula factors not included in the previous version of the basic formula described in References 3 and 4.

3. Gates, including the following warning device class:

Class 8 - Automatic gates with flashing lights

The crossing characteristic factor equations for the three warning device categories are shown in Table 3-1. Each set of factor equations should be used only for crossings with the warning device classes for which it was designed. For example, if it is desired to predict the number of accidents at a crossing with crossbucks, then the passive set of equations should be used.

The numerical value of each factor is related to the degree of correlation that a specific crossing characteristic was found to have with crossing accident rates. For those cases in Table 3-1 where the value of the factor is indicated as a constant 1.0, it was found that the characteristic did not have a significant relationship to crossing accidents.

The structure of the basic accident prediction formula makes it possible to construct look-up tables of numerical values for the crossing characteristic factors. To predict the accidents at a particular crossing whose Inventory characteristics are known, the values of the factors are found in the table and multiplied together. The factor values for the three warning device categories (passive, flashing lights and gates) are found in Tables 3-2, 3-3 and 3-4, respectively. Detailed procedures for use of the tables and computer automation of the accident prediction formula are presented in Section 5.1.

An inspection of the factor value tables shows that exposure index (EI), based on the product of annual average daily highway traffic (c) and average daily train traffic (t), has the strongest relationship to predicted accidents. All other factors can be seen as having a secondary relationship to predicted accidents. It is useful in understanding the nature of the basic accident prediction formula to plot the relationship of accidents to the primary crossing characteristics of highway and train traffic, while holding the secondary factors constant at nominal values. When this is done, predicted accidents (a), can be viewed as a surface defined over the c, t plane. The plots are shown in Figures 3-2, 3-3 and 3-4 for the three warning device categories. The predicted accident surface is

TABLE 3-1. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

		CROSSING CHARACTERISTIC FACTORS						
CROSSING CATEGORY	FORMULA CONSTANT K	EXPOSURE INDEX FACTOR EI	MAIN TRACKS FACTOR MT	DAY THRU TRAINS FACTOR DT	HIGHWAY PAVED FACTOR HP	MAXIMUM SPEED FACTOR MS	HIGHWAY TYPE FACTOR HT	HIGHWAY LANES FACTOR HL
PASSIVE	0.002268	$((c \times t + 0.2)/0.2)^{0.3334}$	$e^{0.2094mt}$	$((d + 0.2)/0.2)^{0.1336}$	$e^{-0.6160(hp-1)}$	$e^{0.0077ms}$	$e^{-0.1000(ht-1)}$	1.0
FLASHING LIGHTS	0.003646	$((c \times t + 0.2)/0.2)^{0.2953}$	$e^{0.1088mt}$	$((d + 0.2)/0.2)^{0.0470}$	1.0	1.0	1.0	$e^{0.1380(hl-1)}$
GATES	0.001088	$((c \times t + 0.2)/0.2)^{0.3116}$	$e^{0.2912mt}$	1.0	1.0	1.0	1.0	$e^{0.1036(hl-1)}$

c = annual average number of highway vehicles per day (total both directions)

t = average total train movements per day

mt = number of main tracks

d = average number of thru trains per day during daylight

hp = highway paved, yes = 1.0, no = 2.0

ms = maximum timetable speed, mph

ht = highway type factor value

hl = number of highway lanes

HIGHWAY TYPE	INVENTORY CODE	ht VALUE
RURAL		
Interstate	01	1
Other principal arterial	02	2
Minor arterial	06	3
Major collector	07	4
Minor collector	08	5
Local	09	6
URBAN		
Interstate	11	1
Other freeway and expressway	12	2
Other principal arterial	14	3
Minor arterial	16	4
Collector	17	5
Local	19	6

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TABLE 3-2. FACTOR VALUES FOR CROSSINGS WITH PASSIVE WARNING DEVICES

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.002268	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.22	1	1.23	1	1.27			5	1.04			2	1.00
	6- 10	3.30	2	1.52	2	1.38	2 (no)	0.54	10	1.08	02&12	0.90	3	1.00
	11- 20	4.24	3	1.87	3	1.45			15	1.12			4	1.00
	21- 30	5.01	4	2.31	4	1.50			20	1.17	06&14	0.82	5	1.00
	31- 50	5.86	5	2.85	5	1.55			25	1.21			6	1.00
	51- 80	6.89	6	3.51	6	1.58			30	1.26	07&16	0.74	7	1.00
	81- 120	7.95			7	1.61			35	1.31			8	1.00
	121- 200	9.29			8	1.64			40	1.36	08&17	0.67	9	1.00
	201- 300	10.78			9	1.67			45	1.41				
	301- 400	12.06			10	1.69			50	1.47	09&19	0.61		
	401- 500	13.11			11-20	1.78			55	1.53				
	501- 600	14.02			21-30	1.91			60	1.59				
	601- 700	14.82			31-40	2.00			65	1.65				
	701- 1000	16.21			41-60	2.09			70	1.71				
	1001- 1300	17.93							75	1.78				
	1301- 1600	19.37							80	1.85				
	1601- 2000	20.81							85	1.92				
	2001- 2500	22.42							90	2.00				
	2501- 3000	23.97												
	3001- 4000	25.98												
	4001- 6000	29.26												
	6001- 8000	32.73												
	8001- 10000	35.59												
	10001- 15000	39.71												
	15001- 20000	44.43												
	20001- 25000	48.31												
	25001- 30000	51.65												
	30001- 40000	55.98												
	40001- 50000	60.87												
	50001- 60000	65.08												
	60001- 70000	68.81												
	70001- 90000	73.74												
	90001- 110000	79.44												
	110001- 130000	84.42												
	130001- 180000	91.94												
	180001- 230000	100.92												
	230001- 300000	109.94												
	300001- 370000	118.87												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.

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**For definition of highway type codes, see Table 3-1.

TABLE 3-3. FACTOR VALUES FOR CROSSINGS WITH FLASHING LIGHT WARNING DEVICES

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.003646	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.27	1	1.11	1	1.09			5	1.00			2	1.15
	6- 10	2.99	2	1.24	2	1.12	2 (no)	1.00	10	1.00	02&12	1.00	3	1.32
	11- 20	3.59	3	1.39	3	1.14			15	1.00			4	1.51
	21- 30	4.17	4	1.55	4	1.15			20	1.00	06&14	1.00	5	1.74
	31- 50	4.79	5	1.72	5	1.17			25	1.00			6	1.99
	51- 80	5.52	6	1.92	6	1.18			30	1.00	07&16	1.00	7	2.29
	81- 120	6.27			7	1.18			35	1.00			8	2.63
	121- 200	7.20			8	1.19			40	1.00	08&17	1.00	9	3.02
	201- 300	8.22			9	1.20			45	1.00				
	301- 400	9.07			10	1.20			50	1.00	09&19	1.00		
	401- 500	9.77			11-20	1.23			55	1.00				
	501- 600	10.37			21-30	1.26			60	1.00				
	601- 700	10.89			31-40	1.28			65	1.00				
	701- 1000	11.79			41-60	1.30			70	1.00				
	1001- 1300	12.89							75	1.00				
	1301- 1600	13.80							80	1.00				
	1601- 2000	14.71							85	1.00				
	2001- 2500	15.72							90	1.00				
	2501- 3000	16.67												
	3001- 4000	17.91												
	4001- 6000	19.89												
	6001- 8000	21.97												
	8001- 10000	23.66												
	10001- 15000	26.08												
	15001- 20000	28.80												
	20001- 25000	31.02												
	25001- 30000	32.91												
	30001- 40000	35.34												
	40001- 50000	38.06												
	50001- 60000	40.39												
	60001- 70000	42.43												
	70001- 90000	45.11												
	90001- 110000	48.18												
	110001- 130000	50.85												
	130001- 180000	54.84												
	180001- 230000	59.56												
	230001- 300000	64.25												
	300001- 370000	68.86												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.

**For definition of highway type codes, see Table 3-1.

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TABLE 3-4. FACTOR VALUES FOR CROSSINGS WITH GATE WARNING DEVICES

GENERAL FORM OF BASIC ACCIDENT PREDICTION FORMULA: a = K x EI x MT x DT x HP x MS x HT x HL

K	"c" x "t"	EI	Main Tracks	MT	Day Thru Trains	DT	Highway Paved	HP	Maximum Timetable Speed	MS	Highway Type Code**	HT	Highway Lanes	HL
0.001088	0*	1.00	0	1.00	0	1.00	1 (yes)	1.00	0	1.00	01&11	1.00	1	1.00
	1- 5	2.37	1	1.34	1	1.00			5	1.00			2	1.11
	6- 10	3.18	2	1.79	2	1.00	2 (no)	1.00	10	1.00	02&12	1.00	3	1.23
	11- 20	3.86	3	2.40	3	1.00			15	1.00			4	1.36
	21- 30	4.51	4	3.21	4	1.00			20	1.00	06&14	1.00	5	1.51
	31- 50	5.22	5	4.29	5	1.00			25	1.00			6	1.68
	51- 80	6.07	6	5.74	6	1.00			30	1.00	07&16	1.00	7	1.86
	81- 120	6.94			7	1.00			35	1.00			8	2.07
	121- 200	8.03			8	1.00			40	1.00	08&17	1.00	9	2.29
	201- 300	9.23			9	1.00			45	1.00				
	301- 400	10.25			10	1.00			50	1.00	09&19	1.00		
	401- 500	11.08			11-20	1.00			55	1.00				
	501- 600	11.80			21-30	1.00			60	1.00				
	601- 700	12.43			31-40	1.00			65	1.00				
	701- 1000	13.51			41-60	1.00			70	1.00				
	1001- 1300	14.84							75	1.00				
	1301- 1600	15.96							80	1.00				
	1601- 2000	17.07							85	1.00				
	2001- 2500	18.30							90	1.00				
	2501- 3000	19.48												
	3001- 4000	21.00												
	4001- 6000	23.46												
	6001- 8000	26.06												
	8001- 10000	28.18												
	10001- 15000	31.22												
	15001- 20000	34.67												
	20001- 25000	37.49												
	25001- 30000	39.91												
	30001- 40000	43.03												
	40001- 50000	46.53												
	50001- 60000	49.53												
	60001- 70000	52.18												
	70001- 90000	55.67												
	90001- 110000	59.68												
	110001- 130000	63.16												
	130001- 180000	68.41												
	180001- 230000	74.63												
	230001- 300000	80.85												
	300001- 370000	86.98												

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway lanes factor

* Less than one train per day.
**For definition of highway type codes, see Table 3-1.

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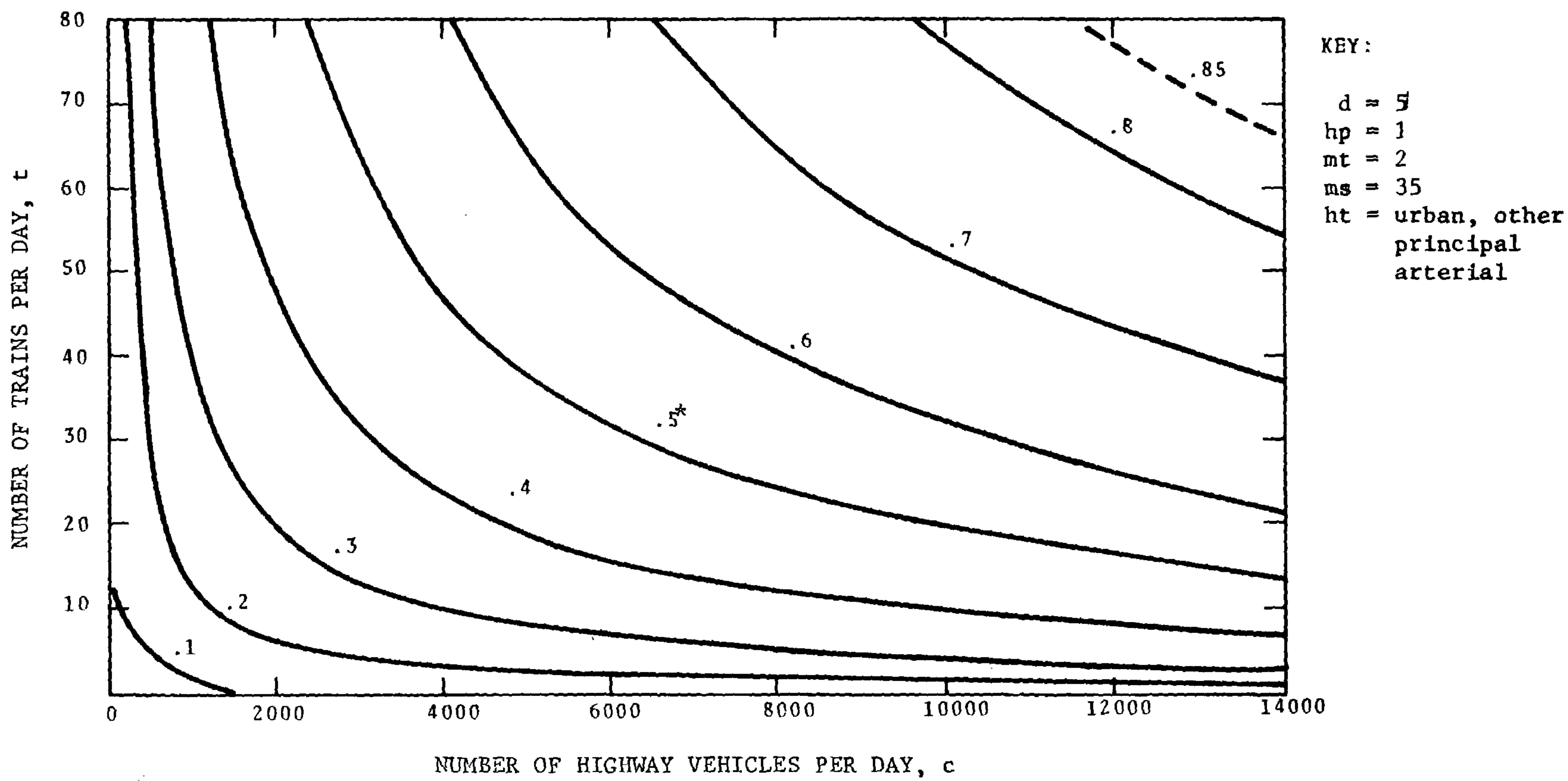
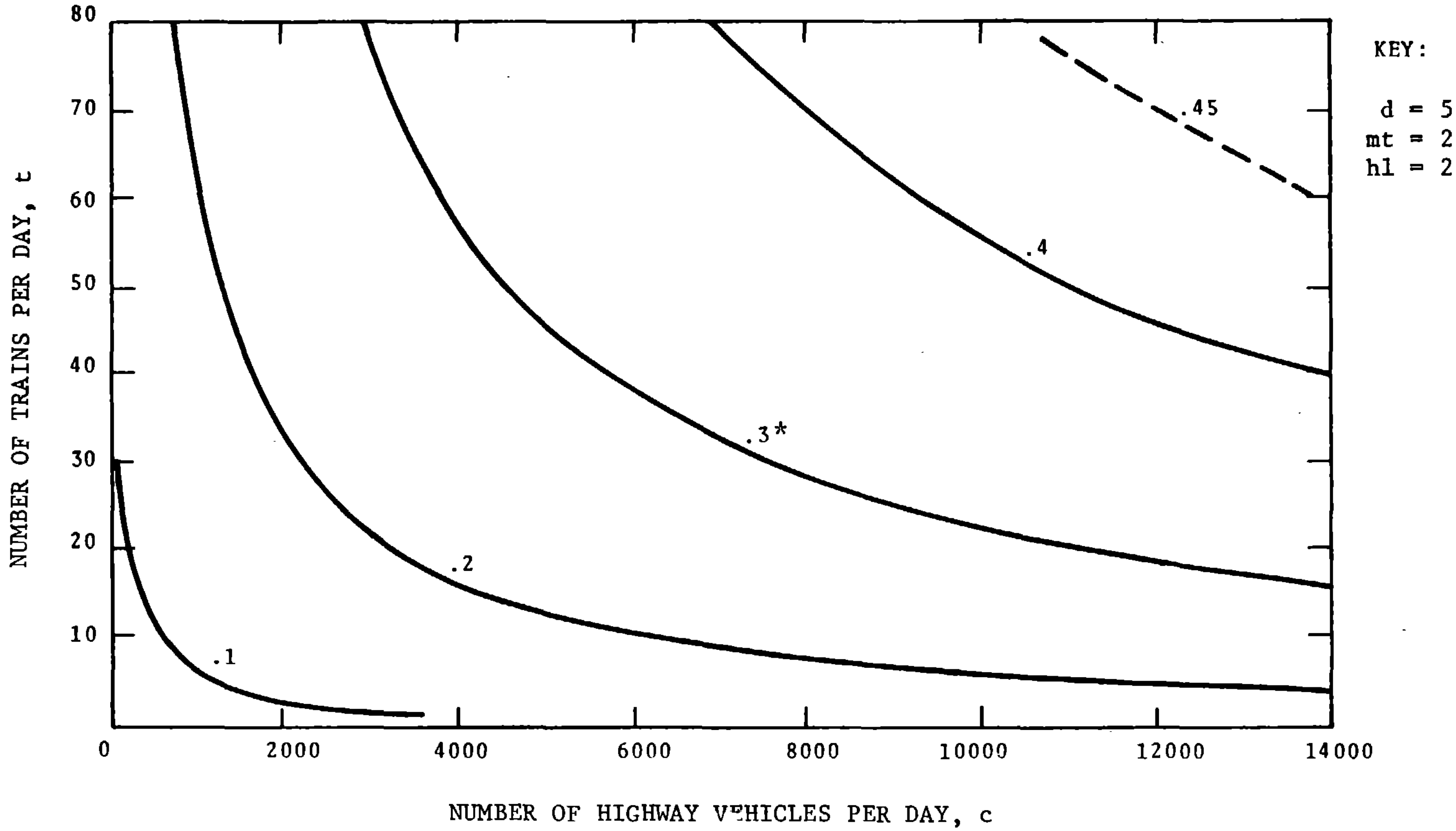


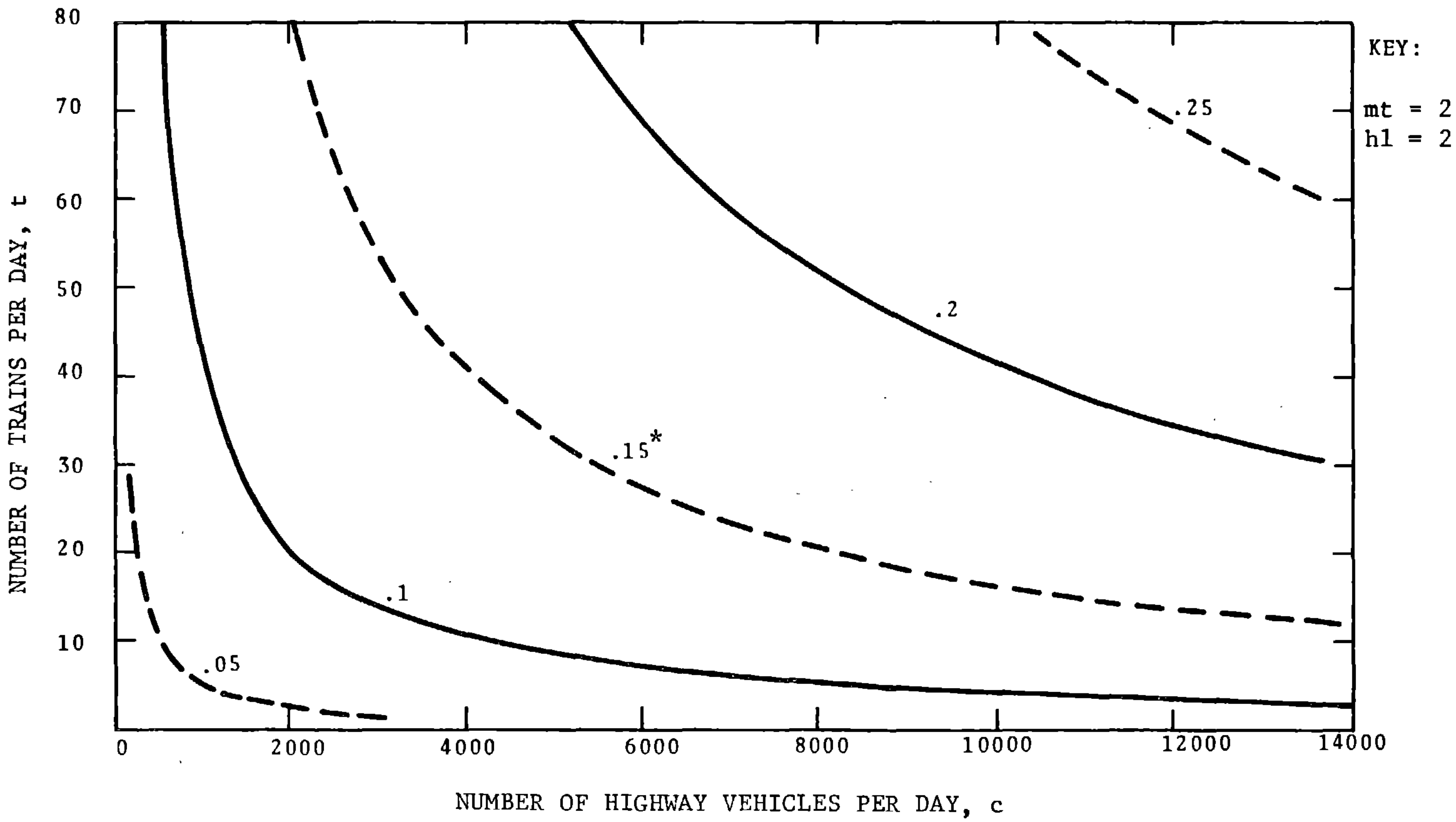
*Numbers on lines denote predicted accidents per year.

FIGURE 3-2. LINES OF EQUAL ACCIDENT PREDICTION LEVEL FOR WARNING DEVICE CLASSES 1,2,3,4



*Numbers on lines denote predicted accidents per year.

FIGURE 3-3. LINES EQUAL ACCIDENT PREDICTION LEVEL FOR WARNING DEVICE CLASSES 5,6,7



*Numbers on lines denote predicted accidents per year.

FIGURE 3-4. LINES OF EQUAL ACCIDENT PREDICTION LEVEL FOR WARNING DEVICE CLASS 8 portrayed by a set of equal-accident-level lines, which are analagous to contour lines on a topographical map. The larger the accident value, the higher above the c, t plane is the accident surface.

The plots show that the relationship of accidents to highway and train traffic is strongest at low values of traffic. An increase in highway and/or train traffic from low levels, say from 1000 to 2000 cars per day or 5 to 10 trains per day, increases the accident level to a greater extent than a similar change at high traffic volumes. This nonlinear relationship is important when considering the relative impacts on accident levels of future changes in traffic patterns between crossings that currently have different traffic volumes.

For different values of the secondary factors, the surfaces would have the same essential character. This is based on the observation from sensitivity results that any change in the secondary factors, other than d (number of thru trains per day during daylight), will cause the surface to be changed only by a constant. For different values of d, the multiplier of the surface is a function of d, and hence the effect is more complex, but it is expected that the character of the surface would not change significantly.

3.2.3 Accident History

The second independent prediction of a crossing's accident rate is derived from the crossing's accident history. This information is obtained from the FRA RAIRS file which contains records of all accidents that occurred at crossings. The required measure of accident history is the ratio N/T where N is the number of accidents which occurred at a crossing over a period of T years. At this time (July, 1984), the FRA RAIRS has 9 years of accident data correlated with The Inventory.

Use of accident history, along with the prediction obtained from the basic formula, improves the overall prediction. This improvement results because accident history serves as a surrogate for other characteristics which affect crossing hazards but are not included in the Inventory; e.g., sight distance. The most accurate predictions, in theory, will result from use of all the available accident history, assuming crossing characteristics remained constant. However, the extent of improvement is minimal if data for more than 5 years are used. It is therefore recommended that only data for the most recent 5 years of accident history be used. This ensures both good performance from the accident prediction formula and use of the most relevant data. Accident history information older than 5 years may be misleading because of changes that occur to crossing characteristics over time. If it is known that a significant change has occurred to a crossing during the most recent 5 years, such as a warning device upgrade, only the accident data since the change should be used.

3.2.4 General Accident Prediction Formula

The general DOT accident prediction formula can be expressed as follows:

$$A = \frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right) \qquad (3\text{-}2)$$

where

A = final accident prediction, accidents per year at the crossing

a = initial accident prediction from basic formula (equation 3-1), accidents per year at the crossing

$\frac{N}{T}$ - = accident history prediction, accidents per year, where N is the number of observed accidents in T years at the crossing

T_O = formula weighting factor = 1.0 / (0.05 + a)

The general DOT accident prediction formula (Equation 3-2) calculates a weighted average of a crossing's predicted accidents from the basic formula (a, Equation 3-1) and accident history (N/T). Values for the final accident prediction (A), obtained from Equation 3-2, for different values of the initial prediction (a), from Equation 3-1, and different accident histories (N/T) are tabularized in Tables 3-5 to 3-9. Each table represents results for a specific number of years for which accident history data are available. If, the number of years of accident data, T, is a fraction, the final accident prediction, A, can be interpolated from the tables or determined directly from the formula.

TABLE 3-5. FINAL ACCIDENT PREDICTION FROM INITIAL PREDICTION AND ACCIDENT HISTORY ,1 YEAR OF ACCIDENT DATA (T=1).

INITIAL PREDICTION FROM BASIC MODEL, a	NUMBER OF ACCIDENTS, N, IN T YEARS					
	0	1	2	3	4	5
0.00	0.000	0.048	0.095	0.143	0.190	0.238
0.01	0.009	0.066	0.123	0.179	0.236	0.292
0.02	0.019	0.084	0.150	0.215	0.280	0.346
0.03	0.028	0.102	0.176	0.250	0.324	0.398
0.04	0.037	0.119	0.202	0.284	0.367	0.450
0.05	0.045	0.136	0.227	0.318	0.409	0.500
0.06	0.054	0.153	0.252	0.351	0.450	0.550
0.07	0.063	0.170	0.277	0.384	0.491	0.598
0.08	0.071	0.186	0.301	0.416	0.531	0.646
0.09	0.079	0.202	0.325	0.447	0.570	0.693
0.10	0.087	0.217	0.348	0.478	0.609	0.739
0.20	0.160	0.360	0.560	0.760	0.960	1.160
0.30	0.222	0.481	0.741	1.000	1.259	1.519
0.40	0.276	0.586	0.897	1.207	1.517	1.828
0.50	0.323	0.677	1.032	1.387	1.742	2.097
0.60	0.364	0.758	1.152	1.545	1.939	2.333
0.70	0.400	0.829	1.257	1.686	2.114	2.543
0.80	0.432	0.892	1.351	1.811	2.270	2.730
0.90	0.462	0.949	1.436	1.923	2.410	2.897
1.00	0.488	1.000	1.512	2.024	2.537	3.049
1.10	0.512	1.047	1.581	2.116	2.651	3.186
1.20	0.533	1.089	1.644	2.200	2.756	3.311
1.30	0.553	1.128	1.702	2.277	2.851	3.426
1.40	0.571	1.163	1.755	2.347	2.939	3.531
1.50	0.588	1.196	1.804	2.412	3.020	3.627
1.60	0.604	1.226	1.849	2.472	3.094	3.717
1.70	0.618	1.255	1.891	2.527	3.164	3.800
1.80	0.632	1.281	1.930	2.579	3.228	3.877
1.90	0.644	1.305	1.966	2.627	3.288	3.949
2.00	0.656	1.328	2.000	2.672	3.344	4.016
2.10	0.667	1.349	2.032	2.714	3.397	4.079
2.20	0.677	1.369	2.062	2.754	3.446	4.138
2.30	0.687	1.388	2.090	2.791	3.493	4.194
2.40	0.696	1.406	2.116	2.826	3.536	4.246
2.50	0.704	1.423	2.141	2.859	3.577	4.296

TABLE 3-6. FINAL ACCIDENT PREDICTION FROM INITIAL PREDICTION AND ACCIDENT HISTORY ,2 YEARS OF ACCIDENT DATA (T=2).

INITIAL PREDICTION FROM BASIC MODEL, a	NUMBER OF ACCIDENTS, N, IN T YEARS								
	0	1	2	3	4	5	6	7	8
0.00	0.000	0.045	0.091	0.136	0.182	0.227	0.273	0.318	0.364
0.01	0.009	0.063	0.116	0.170	0.223	0.277	0.330	0.384	0.438
0.02	0.018	0.079	0.140	0.202	0.263	0.325	0.386	0.447	0.509
0.03	0.026	0.095	0.164	0.233	0.302	0.371	0.440	0.509	0.578
0.04	0.034	0.110	0.186	0.263	0.339	0.415	0.492	0.568	0.644
0.05	0.042	0.125	0.208	0.292	0.375	0.458	0.542	0.625	0.708
0.06	0.049	0.139	0.230	0.320	0.410	0.500	0.590	0.680	0.770
0.07	0.056	0.153	0.250	0.347	0.444	0.540	0.637	0.734	0.831
0.08	0.063	0.167	0.270	0.373	0.476	0.579	0.683	0.786	0.889
0.09	0.070	0.180	0.289	0.398	0.508	0.617	0.727	0.836	0.945
0.10	0.077	0.192	0.308	0.423	0.538	0.654	0.769	0.885	1.000
0.20	0.133	0.300	0.467	0.633	0.800	0.967	1.133	1.300	1.467
0.30	0.176	0.382	0.588	0.794	1.000	1.206	1.412	1.618	1.824
0.40	0.211	0.447	0.684	0.921	1.158	1.395	1.632	1.868	2.105
0.50	0.238	0.500	0.762	1.024	1.286	1.548	1.810	2.071	2.333
0.60	0.261	0.543	0.826	1.109	1.391	1.674	1.957	2.239	2.522
0.70	0.280	0.580	0.880	1.180	1.480	1.780	2.080	2.380	2.680
0.80	0.296	0.611	0.926	1.241	1.556	1.870	2.185	2.500	2.815
0.90	0.310	0.638	0.966	1.293	1.621	1.948	2.276	2.603	2.931
1.00	0.323	0.661	1.000	1.339	1.677	2.016	2.355	2.694	3.032
1.10	0.333	0.682	1.030	1.379	1.727	2.076	2.424	2.773	3.121
1.20	0.343	0.700	1.057	1.414	1.771	2.129	2.486	2.843	3.200
1.30	0.351	0.716	1.081	1.446	1.811	2.176	2.541	2.905	3.270
1.40	0.359	0.731	1.103	1.474	1.846	2.218	2.590	2.962	3.333
1.50	0.366	0.744	1.122	1.500	1.878	2.256	2.634	3.012	3.390
1.60	0.372	0.756	1.140	1.523	1.907	2.291	2.674	3.058	3.442
1.70	0.378	0.767	1.156	1.544	1.933	2.322	2.711	3.100	3.489
1.80	0.383	0.777	1.170	1.564	1.957	2.351	2.745	3.138	3.532
1.90	0.388	0.786	1.184	1.582	1.980	2.378	2.776	3.173	3.571
2.00	0.392	0.794	1.196	1.598	2.000	2.402	2.804	3.206	3.608
2.10	0.396	0.802	1.208	1.613	2.019	2.425	2.830	3.236	3.642
2.20	0.400	0.809	1.218	1.627	2.036	2.445	2.855	3.264	3.673
2.30	0.404	0.816	1.228	1.640	2.053	2.465	2.877	3.289	3.702
2.40	0.407	0.822	1.237	1.653	2.068	2.483	2.898	3.314	3.729
2.50	0.410	0.828	1.246	1.664	2.082	2.500	2.918	3.336	3.754

TABLE 3-7. FINAL ACCIDENT PREDICTION FROM INITIAL PREDICTION AND ACCIDENT HISTORY ,3 YEARS OF ACCIDENT DATA (T=3).

INITIAL PREDICTION FROM BASIC MODEL, a	NUMBER OF ACCIDENTS, N, IN T YEARS												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0.00	0.000	0.043	0.087	0.130	0.174	0.217	0.261	0.304	0.348	0.391	0.435	0.478	0.522
0.01	0.008	0.059	0.110	0.161	0.212	0.263	0.314	0.364	0.415	0.466	0.517	0.568	0.619
0.02	0.017	0.074	0.132	0.190	0.248	0.306	0.364	0.421	0.479	0.537	0.595	0.653	0.711
0.03	0.024	0.089	0.153	0.218	0.282	0.347	0.411	0.476	0.540	0.605	0.669	0.734	0.798
0.04	0.031	0.102	0.173	0.244	0.315	0.386	0.457	0.528	0.598	0.669	0.740	0.811	0.882
0.05	0.038	0.115	0.192	0.269	0.346	0.423	0.500	0.577	0.654	0.731	0.808	0.885	0.962
0.06	0.045	0.128	0.211	0.293	0.376	0.459	0.541	0.624	0.707	0.789	0.872	0.955	1.038
0.07	0.051	0.140	0.228	0.316	0.404	0.493	0.581	0.669	0.757	0.846	0.934	1.022	1.110
0.08	0.058	0.151	0.245	0.338	0.432	0.525	0.619	0.712	0.806	0.899	0.993	1.086	1.180
0.09	0.063	0.162	0.261	0.359	0.458	0.556	0.655	0.754	0.852	0.951	1.049	1.148	1.246
0.10	0.069	0.172	0.276	0.379	0.483	0.586	0.690	0.793	0.897	1.000	1.103	1.207	1.310
0.20	0.114	0.257	0.400	0.543	0.686	0.829	0.971	1.114	1.257	1.400	1.543	1.686	1.829
0.30	0.146	0.317	0.488	0.659	0.829	1.000	1.171	1.341	1.512	1.683	1.854	2.024	2.195
0.40	0.170	0.362	0.553	0.745	0.936	1.128	1.319	1.511	1.702	1.894	2.085	2.277	2.468
0.50	0.189	0.396	0.604	0.811	1.019	1.226	1.434	1.642	1.849	2.057	2.264	2.472	2.679
0.60	0.203	0.424	0.644	0.864	1.085	1.305	1.525	1.746	1.966	2.186	2.407	2.627	2.847
0.70	0.215	0.446	0.677	0.908	1.138	1.369	1.600	1.831	2.062	2.292	2.523	2.754	2.985
0.80	0.225	0.465	0.704	0.944	1.183	1.423	1.662	1.901	2.141	2.380	2.620	2.859	3.099
0.90	0.234	0.481	0.727	0.974	1.221	1.468	1.714	1.961	2.208	2.455	2.701	2.948	3.195
1.00	0.241	0.494	0.747	1.000	1.253	1.506	1.759	2.012	2.265	2.518	2.771	3.024	3.277
1.10	0.247	0.506	0.764	1.022	1.281	1.539	1.798	2.056	2.315	2.573	2.831	3.090	3.348
1.20	0.253	0.516	0.779	1.042	1.305	1.568	1.832	2.095	2.358	2.621	2.884	3.147	3.411
1.30	0.257	0.525	0.792	1.059	1.327	1.594	1.861	2.129	2.396	2.663	2.931	3.198	3.465
1.40	0.262	0.533	0.804	1.075	1.346	1.617	1.888	2.159	2.430	2.701	2.972	3.243	3.514
1.50	0.265	0.540	0.814	1.088	1.363	1.637	1.912	2.186	2.460	2.735	3.009	3.283	3.558
1.60	0.269	0.546	0.824	1.101	1.378	1.655	1.933	2.210	2.487	2.765	3.042	3.319	3.597
1.70	0.272	0.552	0.832	1.112	1.392	1.672	1.952	2.232	2.512	2.792	3.072	3.352	3.632
1.80	0.275	0.557	0.840	1.122	1.405	1.687	1.969	2.252	2.534	2.817	3.099	3.382	3.664
1.90	0.277	0.562	0.847	1.131	1.416	1.701	1.985	2.270	2.555	2.839	3.124	3.409	3.693
2.00	0.280	0.566	0.853	1.140	1.427	1.713	2.000	2.287	2.573	2.860	3.147	3.434	3.720
2.10	0.282	0.570	0.859	1.148	1.436	1.725	2.013	2.302	2.591	2.879	3.168	3.456	3.745
2.20	0.284	0.574	0.865	1.155	1.445	1.735	2.026	2.316	2.606	2.897	3.187	3.477	3.768
2.30	0.286	0.578	0.870	1.161	1.453	1.745	2.037	2.329	2.621	2.913	3.205	3.497	3.789
2.40	0.287	0.581	0.874	1.168	1.461	1.754	2.048	2.341	2.635	2.928	3.222	3.515	3.808
2.50	0.289	0.584	0.879	1.173	1.468	1.763	2.058	2.353	2.647	2.942	3.237	3.532	3.827

TABLE 3-8. FINAL ACCIDENT PREDICTION FROM INITIAL PREDICTION AND ACCIDENT HISTORY ,4 YEARS OF ACCIDENT DATA (T=4).

INITIAL PREDICTION FROM BASIC MODEL, a	NUMBER OF ACCIDENTS, N, IN T YEARS														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.00	0.000	0.042	0.083	0.125	0.167	0.208	0.250	0.292	0.333	0.375	0.417	0.458	0.500	0.542	0.583
0.01	0.008	0.056	0.105	0.153	0.202	0.250	0.298	0.347	0.395	0.444	0.492	0.540	0.589	0.637	0.685
0.02	0.016	0.070	0.125	0.180	0.234	0.289	0.344	0.398	0.453	0.508	0.563	0.617	0.672	0.727	0.781
0.03	0.023	0.083	0.144	0.205	0.265	0.326	0.386	0.447	0.508	0.568	0.629	0.689	0.750	0.811	0.871
0.04	0.029	0.096	0.162	0.228	0.294	0.360	0.426	0.493	0.559	0.625	0.691	0.757	0.824	0.890	0.956
0.05	0.036	0.107	0.179	0.250	0.321	0.393	0.464	0.536	0.607	0.679	0.750	0.821	0.893	0.964	1.036
0.06	0.042	0.118	0.194	0.271	0.347	0.424	0.500	0.576	0.653	0.729	0.806	0.882	0.958	1.035	1.111
0.07	0.047	0.128	0.209	0.291	0.372	0.453	0.534	0.615	0.696	0.777	0.858	0.939	1.020	1.101	1.182
0.08	0.053	0.138	0.224	0.309	0.395	0.480	0.566	0.651	0.737	0.822	0.908	0.993	1.079	1.164	1.250
0.09	0.058	0.147	0.237	0.327	0.417	0.506	0.596	0.686	0.776	0.865	0.955	1.045	1.135	1.224	1.314
0.10	0.062	0.156	0.250	0.344	0.438	0.531	0.625	0.719	0.812	0.906	1.000	1.094	1.188	1.281	1.375
0.20	0.100	0.225	0.350	0.475	0.600	0.725	0.850	0.975	1.100	1.225	1.350	1.475	1.600	1.725	1.850
0.30	0.125	0.271	0.417	0.563	0.708	0.854	1.000	1.146	1.292	1.437	1.583	1.729	1.875	2.021	2.167
0.40	0.143	0.304	0.464	0.625	0.786	0.946	1.107	1.268	1.429	1.589	1.750	1.911	2.071	2.232	2.393
0.50	0.156	0.328	0.500	0.672	0.844	1.016	1.188	1.359	1.531	1.703	1.875	2.047	2.219	2.391	2.563
0.60	0.167	0.347	0.528	0.708	0.889	1.069	1.250	1.431	1.611	1.792	1.972	2.153	2.333	2.514	2.694
0.70	0.175	0.363	0.550	0.738	0.925	1.113	1.300	1.488	1.675	1.863	2.050	2.238	2.425	2.613	2.800
0.80	0.182	0.375	0.568	0.761	0.955	1.148	1.341	1.534	1.727	1.920	2.114	2.307	2.500	2.693	2.886
0.90	0.188	0.385	0.583	0.781	0.979	1.177	1.375	1.573	1.771	1.969	2.167	2.365	2.563	2.760	2.958
1.00	0.192	0.394	0.596	0.798	1.000	1.202	1.404	1.606	1.808	2.010	2.212	2.413	2.615	2.817	3.019
1.10	0.196	0.402	0.607	0.813	1.018	1.223	1.429	1.634	1.839	2.045	2.250	2.455	2.661	2.866	3.071
1.20	0.200	0.408	0.617	0.825	1.033	1.242	1.450	1.658	1.867	2.075	2.283	2.492	2.700	2.908	3.117
1.30	0.203	0.414	0.625	0.836	1.047	1.258	1.469	1.680	1.891	2.102	2.313	2.523	2.734	2.945	3.156
1.40	0.206	0.419	0.632	0.846	1.059	1.272	1.485	1.699	1.912	2.125	2.338	2.551	2.765	2.978	3.191
1.50	0.208	0.424	0.639	0.854	1.069	1.285	1.500	1.715	1.931	2.146	2.361	2.576	2.792	3.007	3.222
1.60	0.211	0.428	0.645	0.862	1.079	1.296	1.513	1.730	1.947	2.164	2.382	2.599	2.816	3.033	3.250
1.70	0.213	0.431	0.650	0.869	1.088	1.306	1.525	1.744	1.962	2.181	2.400	2.619	2.837	3.056	3.275
1.80	0.214	0.435	0.655	0.875	1.095	1.315	1.536	1.756	1.976	2.196	2.417	2.637	2.857	3.077	3.298
1.90	0.216	0.437	0.659	0.881	1.102	1.324	1.545	1.767	1.989	2.210	2.432	2.653	2.875	3.097	3.318
2.00	0.217	0.440	0.663	0.886	1.109	1.332	1.554	1.777	2.000	2.223	2.446	2.668	2.891	3.114	3.337
2.10	0.219	0.443	0.667	0.891	1.115	1.339	1.562	1.786	2.010	2.234	2.458	2.682	2.906	3.130	3.354
2.20	0.220	0.445	0.670	0.895	1.120	1.345	1.570	1.795	2.020	2.245	2.470	2.695	2.920	3.145	3.370
2.30	0.221	0.447	0.673	0.899	1.125	1.351	1.577	1.803	2.029	2.255	2.481	2.707	2.933	3.159	3.385
2.40	0.222	0.449	0.676	0.903	1.130	1.356	1.583	1.810	2.037	2.264	2.491	2.718	2.944	3.171	3.398
2.50	0.223	0.451	0.679	0.906	1.134	1.362	1.589	1.817	2.045	2.272	2.500	2.728	2.955	3.183	3.411

TABLE 3-9. FINAL ACCIDENT PREDICTION FROM INITIAL PREDICTION AND ACCIDENT HISTORY ,5 YEARS OF ACCIDENT DATA (T=5).

INITIAL PREDICTION FROM BASIC MODEL, a	NUMBER OF ACCIDENTS, N, IN T YEARS														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0.00	0.000	0.040	0.080	0.120	0.160	0.200	0.240	0.280	0.320	0.360	0.400	0.440	0.480	0.520	0.560
0.01	0.008	0.054	0.100	0.146	0.192	0.238	0.285	0.331	0.377	0.423	0.469	0.515	0.562	0.608	0.654
0.02	0.015	0.067	0.119	0.170	0.222	0.274	0.326	0.378	0.430	0.481	0.533	0.585	0.637	0.689	0.741
0.03	0.021	0.079	0.136	0.193	0.250	0.307	0.364	0.421	0.479	0.536	0.593	0.650	0.707	0.764	0.821
0.04	0.028	0.090	0.152	0.214	0.276	0.338	0.400	0.462	0.524	0.586	0.648	0.710	0.772	0.834	0.897
0.05	0.033	0.100	0.167	0.233	0.300	0.367	0.433	0.500	0.567	0.633	0.700	0.767	0.833	0.900	0.967
0.06	0.039	0.110	0.181	0.252	0.323	0.394	0.465	0.535	0.606	0.677	0.748	0.819	0.890	0.961	1.032
0.07	0.044	0.119	0.194	0.269	0.344	0.419	0.494	0.569	0.644	0.719	0.794	0.869	0.944	1.019	1.094
0.08	0.048	0.127	0.206	0.285	0.364	0.442	0.521	0.600	0.679	0.758	0.836	0.915	0.994	1.073	1.152
0.09	0.053	0.135	0.218	0.300	0.382	0.465	0.547	0.629	0.712	0.794	0.876	0.959	1.041	1.124	1.206
0.10	0.057	0.143	0.229	0.314	0.400	0.486	0.571	0.657	0.743	0.829	0.914	1.000	1.086	1.171	1.257
0.20	0.089	0.200	0.311	0.422	0.533	0.644	0.756	0.867	0.978	1.089	1.200	1.311	1.422	1.533	1.644
0.30	0.109	0.236	0.364	0.491	0.618	0.745	0.873	1.000	1.127	1.255	1.382	1.509	1.636	1.764	1.891
0.40	0.123	0.262	0.400	0.538	0.677	0.815	0.954	1.092	1.231	1.369	1.508	1.646	1.785	1.923	2.062
0.50	0.133	0.280	0.427	0.573	0.720	0.867	1.013	1.160	1.307	1.453	1.600	1.747	1.893	2.040	2.187
0.60	0.141	0.294	0.447	0.600	0.753	0.906	1.059	1.212	1.365	1.518	1.671	1.824	1.976	2.129	2.282
0.70	0.147	0.305	0.463	0.621	0.779	0.937	1.095	1.253	1.411	1.568	1.726	1.884	2.042	2.200	2.358
0.80	0.152	0.314	0.476	0.638	0.800	0.962	1.124	1.286	1.448	1.610	1.771	1.933	2.095	2.257	2.419
0.90	0.157	0.322	0.487	0.652	0.817	0.983	1.148	1.313	1.478	1.643	1.809	1.974	2.139	2.304	2.470
1.00	0.160	0.328	0.496	0.664	0.832	1.000	1.168	1.336	1.504	1.672	1.840	2.008	2.176	2.344	2.512
1.10	0.163	0.333	0.504	0.674	0.844	1.015	1.185	1.356	1.526	1.696	1.867	2.037	2.207	2.378	2.548
1.20	0.166	0.338	0.510	0.683	0.855	1.028	1.200	1.372	1.545	1.717	1.890	2.062	2.234	2.407	2.579
1.30	0.168	0.342	0.516	0.690	0.865	1.039	1.213	1.387	1.561	1.735	1.910	2.084	2.258	2.432	2.606
1.40	0.170	0.345	0.521	0.697	0.873	1.048	1.224	1.400	1.576	1.752	1.927	2.103	2.279	2.455	2.630
1.50	0.171	0.349	0.526	0.703	0.880	1.057	1.234	1.411	1.589	1.766	1.943	2.120	2.297	2.474	2.651
1.60	0.173	0.351	0.530	0.708	0.886	1.065	1.243	1.422	1.600	1.778	1.957	2.135	2.314	2.492	2.670
1.70	0.174	0.354	0.533	0.713	0.892	1.072	1.251	1.431	1.610	1.790	1.969	2.149	2.328	2.508	2.687
1.80	0.176	0.356	0.537	0.717	0.898	1.078	1.259	1.439	1.620	1.800	1.980	2.161	2.341	2.522	2.702
1.90	0.177	0.358	0.540	0.721	0.902	1.084	1.265	1.447	1.628	1.809	1.991	2.172	2.353	2.535	2.716
2.00	0.178	0.360	0.542	0.724	0.907	1.089	1.271	1.453	1.636	1.818	2.000	2.182	2.364	2.547	2.729
2.10	0.179	0.362	0.545	0.728	0.911	1.094	1.277	1.460	1.643	1.826	2.009	2.191	2.374	2.557	2.740
2.20	0.180	0.363	0.547	0.731	0.914	1.098	1.282	1.465	1.649	1.833	2.016	2.200	2.384	2.567	2.751
2.30	0.180	0.365	0.549	0.733	0.918	1.102	1.286	1.471	1.655	1.839	2.024	2.208	2.392	2.576	2.761
2.40	0.181	0.366	0.551	0.736	0.921	1.106	1.291	1.475	1.660	1.845	2.030	2.215	2.400	2.585	2.770
2.50	0.182	0.367	0.553	0.738	0.924	1.109	1.295	1.480	1.665	1.851	2.036	2.222	2.407	2.593	2.778

Referring to Tables 3-5 to 3-9, the value of the final accident prediction (A) is determined from the intersection of the appropriate column and row for the values of the initial prediction (a) and the observed number of accidents (N). Thus, if a = 0.05 and N = 4, for T = 5 (Table 3-9), the number of predicted accidents (A) is 0.300.

An investigation of the general DOT accident prediction formula and the tables will show the following interrelationship of A, a, and N/T:

1. The final prediction (A) will be a weighted average of a and N/T, i.e., it will lie between the values of a and N/T.

2. If a = N/T, then the final prediction (A) will equal a and N/T.

3. If no accident history is available, T = 0, then the final prediction (A) will equal the initial prediction (a) from the basic formula.

3.3 DESCRIPTION OF FORMULAS FOR CASUALTY PREDICTION

3.3.1 Overview

The effort to develop casualty prediction formulas was motivated by the recognition that rail-highway crossing accidents are not equally severe. In recent years about 67 percent of crossing accidents resulted in no casualties while all fatalities resulted from only 6.6 percent of all accidents. Clearly, crossings that exhibit a tendency toward more severe accidents, should be given priority for safety improvements. A formula which can help in identifying these crossings will improve the safety benefits obtained from crossing improvements. The casualty prediction formulas described here represent the results of a successful effort to achieve that objective. (Ref. 4)

Two casualty prediction formulas have been developed, a fatality prediction formula and an injury prediction formula. When used with the accident prediction formulas, described in Section 3.2, these two formulas provide two measures of accident severity, predicted fatal accidents and predicted injury accidents. A fatal accident is defined as an accident which results in at least one fatality independent of injuries or property damage. An injury accident is an accident which results in no fatalities and at least one injury independent of property damage.

The casualty prediction formulas are designed to be used with the general accident prediction formula (Equation 3-2) to produce the estimates of fatal and injury accidents per year at crossings. The casualty prediction formulas used without the accident prediction formula produce estimates of the probability of a casualty accident given that an accident occurred. For example, the fatality prediction formula estimates the probability of a fatal accident given that an accident occurred at a crossing; i.e., fatal accidents per accident. When this estimate is multiplied by the crossing's estimated accidents from the accident prediction formula (Equation 3-2) the result is predicted fatal accidents per year at the crossing. As a further illustration, if a crossing has a predicted accident rate of 0.5 accidents per year and a predicted fatal accident probability of 0.2 fatal accidents per accident, the result will be a predicted fatal accidents per year of 0.1.

In addition to predicted fatal and injury accidents per year, a third measure of accident severity can be obtained from use of the casualty prediction formulas. This measure, referred to as the combined casualty index (CCI), is a weighted sum of the fatal and injury accident predictions. It provides a more comprehensive index of accident severity; however, its use involves making judgements as to the relative severity of fatal and injury accidents.

Development of the casualty prediction formulas involved performing regression analyses of data on crossings which experienced accidents. The dependent variables for the fatality and injury regression formulas were allowed one of two values indicating whether the accident did or did not result in a fatal or injury accident. The independent variables represented various characteristics of the accident crossings as desribed in the inventory. Accident and inventory data for 1978, 1979, and 1980 were used for formula development. The resulting formulas were evaluated using 1981 data. The regression procedure used is referred to as the logistic descriminant approach which employs an iterative weighted regression technique. This approach is the same as that used in development of the accident prediction formulas. (Ref. 3)

3.3.2 Fatality and Injury Prediction Formulas

The formulas for predicting the probabilities of fatal accidents and injury accidents can be expressed in terms of several factors which are combined by simple mathematical operations in a manner similar to the basic accident prediction formula (Section 3.2.2). Each factor in the formulas respresents a characteristic of the crossing as described in The Inventory. The probability of a fatal accident given an accident is expressed as:

$$P(FA|A) = 1/(1 + CF \times MS \times TT \times TS \times UR) \qquad (3\text{-}3)$$

where: P(FA|A) = probability if a fatal accident, given an accident
CF = formula constant (695)
MS = factor for maximum timetable train speed
TT = factor for thru trains per day
TS = factor for switch trains per day
UR = factor for urban or rural crossing

The probability of an injury accident given an accident is expressed as:

$$P(IA|A) = (1 - P(FA|A))/(1 + CI \times MS \times TK \times UR) \quad (3\text{-}4)$$

where: P(IA|A) = probability of an injury accident, given an accident

P(FA|A) = probability of a fatal accident, given an accident, obtained from Equation 3-3.

CI = formula constant (4.280)

MS = factor for maximum timetable train speed

TK = factor for number of tracks

UR = factor for urban or rural crossing

The equations for calculating values of the crossing characteristic factors are listed in Table 3-10 for the fatal accident probability formula and Table 3-11 for the injury accident probability formula. To simplify use of the formulas, the values of the crossing characteristic factors have been tabulated for typical values of crossing characteristics. These values are to be found in Tables 3-12 and 3-13 for the fatal accident and injury accident probability formulas, respectively. An inspection of the factor value tables shows the relative influence of the various factors on accident severity. In the case of fatal accident severity (Table 3-12) maximum timetable train speed has factor values which range over two orders of magnitude while the other factor values range over less than one order of magnitude. Maximum timetable train speed, therefore, has a much stronger influence on fatal accident severity than the number of trains or the urban-rural location of the crossing. For injury accident severity (Table 3-13) the number of tracks has a slightly greater influence on severity than maximum timetable train speed. The urban-rural location of the crossing has the least influence on injury accident severity.

TABLE 3-10. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS FOR FATAL ACCIDENT PROBABILITY FORMULA

Fatal Accident Probability Formula: $P(FA|A) = 1/(1 + CF \times MS \times TT \times TS \times UR)$

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Formula constant	$CF = 695$
Maximum Timetable Train Speed Factor	$MS = ms^{-1.074}$
Thru Trains Per Day Factor	$TT = (tt + 1)^{-0.1025}$
Switch Trains Per Day Factor	$TS = (ts + 1)^{0.1025}$
Urban - Rural Crossing Factor	$UR = e^{0.1880ur}$

where:

ms = maximum timetable train speed, mph

tt = number of thru trains per day

ts = number of switch trains per day

ur: urban crossing = 1, rural crossing = 0

TABLE 3-11. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS FOR INJURY ACCIDENT PROBABILITY FORMULA

Injury Accident Probability Formula: P(IA!A) = (1 - P(FA!A))/(1 + CI x MS x TK x UR)

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Fatal Accident Probability	P(FA!A), see Equation 3-3 and Table 3-10
Formula Constant	CI = 4.280
Maximum Timetable Train Speed Factor	$MS = ms^{-0.2334}$
Number of Tracks Factor	$TK = e^{0.1176tk}$
Urban - Rural Crossing Factor	$UR = e^{0.1844ur}$

where:

ms = maximum timetable train speed, mph

tk = total number of tracks at crossing

ur: urban crossing = 1, rural crossing = 0

TABLE 3-12. FACTOR VALUES FOR FATAL ACCIDENT PROBABILITY FORMULA

Fatal Accident Probability Formula: P(FA|A) = 1/(1 + CF x MS x TT x TS x UR)

FORMULA CONSTANT CF	MAXIMUM TIMETABLE TRAIN SPEED	MS	THRU TRAINS PER DAY	TT	SWITCH TRAINS PER DAY	TS	URBAN-RURAL CROSSING	UR
695.0	1	1.000	0	1.000	0	1.000	0 (rural)	1.000
	5	0.178	1	0.931	1	1.074	1 (urban)	1.207
	10	0.084	2	0.894	2	1.119		
	15	0.055	3	0.868	3	1.152		
	20	0.040	4	0.848	4	1.179		
	25	0.032	5	0.832	5	1.202		
	30	0.026	6	0.819	6	1.221		
	40	0.019	7	0.808	7	1.238		
	50	0.015	9	0.790	9	1.266		
	60	0.012	10	0.782	10	1.279		
	70	0.010	20	0.732	20	1.366		
	80	0.009	30	0.703	30	1.422		
	90	0.008	40	0.683	40	1.464		
	100	0.007	50	0.668	50	1.497		

TABLE 3-13. FACTOR VALUES FOR INJURY ACCIDENT PROBABILITY FORMULA

Injury Accident Probability Formula: $P(IA|A) = (1 - P(FA|A))/(1 + CI \times MS \times TK \times UR)$

FATAL ACCIDENT PROBABILITY, P(FA|A)	FORMULA CONSTANT CI	MAXIMUM TIMETABLE TRAIN SPEED	MS	TOTAL NUMBER OF TRACKS	TK	URBAN-RURAL CROSSING	UR
See Equation 3-3 and Tables 3-10 & 3-12	4.280	1	1.000	0	1.000	0 (rural)	1.000
		5	0.687	1	1.125	1 (urban)	1.202
		10	0.584	2	1.265		
		15	0.531	3	1.423		
		20	0.497	5	1.800		
		25	0.472	6	2.025		
		30	0.452	7	2.278		
		40	0.423	8	2.562		
		50	0.401	9	2.882		
		60	0.385	10	3.241		
		70	0.371	15	5.836		
		80	0.360	20	10.507		
		90	0.350				
		100	0.341				

To obtain predicted numbers of fatal and injury accidents the fatal and injury accident probabilities, from Equations 3-3 and 3-4, are multiplied by predicted accidents from Equation 3-2. Hence, the formula for predicted fatal accidents at a crossing is:

$$FA = P(FA|A) \times A \qquad (3\text{-}5)$$

where: FA = predicted fatal accidents per year

P(FA|A) = predicted fatal accident probability from Equation 3-3

A = predicted accidents per year from Equation 3-2

The formula for predicted injury accidents at a crossing is:

$$IA = P(IA|A) \times A \qquad (3\text{-}6)$$

where: IA = predicted injury accidents per year

P(IA|A) = predicted injury accident probability from Equation 3-4

A = predicted accidents per year from Equation 3-2

To illustrate characteristics of the fatal and injury accident probability formulas, the two functions P(FA|A) and P(IA|A) are plotted as a function of maximum timetable train speed in Figure 3-5. The figure contains five individual plots which show how the functions change when one of the other four factors which influence accident severity (thru trains, switch trains, tracks and urban-rural location) is varied. The values of the factors are shown on the individual plots.

Several observations can be made regarding the characteristics of the functions. The probability of a fatal accident given an accident P(FA|A) increases as a nearly linear function of timetable train speed. Changes in the number of thru and switch trains or the urban-rural location of the crossings does not have a major influence on fatal accident probability.

The probability of an injury accident given an accident P(IA|A) increases as a nonlinear function of timetable train speed. Injury accident probability generally increases rapidly with timetable train speed and then remains relatively constant beyond 40 mph. The function actually decreases at high speeds under certain conditions.

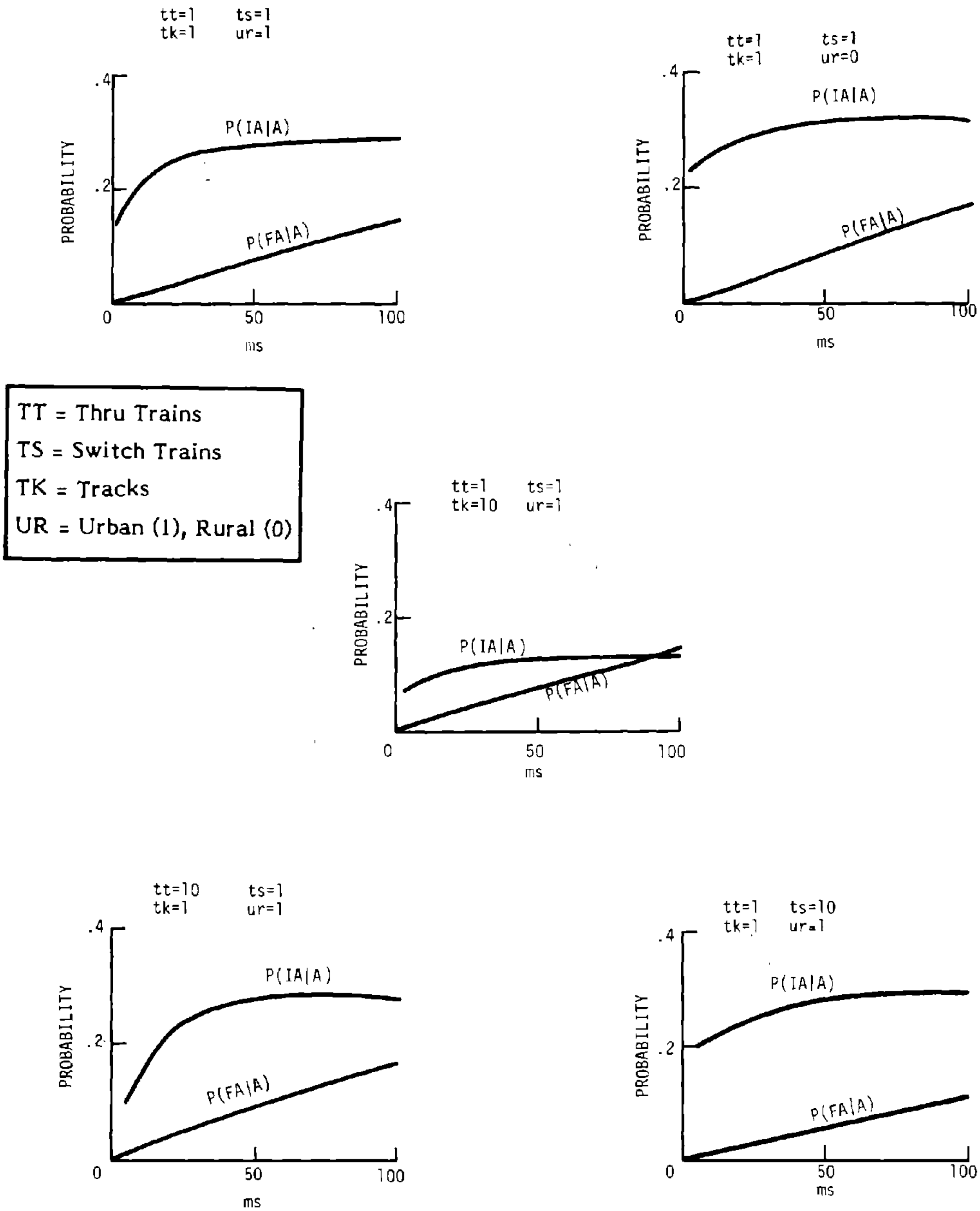


FIGURE 3-5. TYPICAL PLOTS OF PROBABILITY OF FATAL ACCIDENTS P(FA|A) AND PROBABILITY OF INJURY ACCIDENTS P(IA|A) AS A FUNCTION OF TIMETABLE TRAIN SPEED ms.

This is expected since, as accident severity increases, casualties will increasingly be fatalities rather than injuries. The number of tracks at the crossing has a significant influence on the function (injury accident probability decreases with the number of tracks); however, the urban-rural location has only a minor influence.

The extreme nonlinear nature of the injury accident probability formula presents problems with its use for resource allocation purpose. Since it does not consistently increase with actual accident severity, crossings with high actual severity could be ranked lower than crossings with lesser actual severity. Resource allocation priorities based on predicted injury accidents can therefore produce less than optimal results. For this reason, the preferred measure for resource allocation purposes is fatal accident probability by itself or combined with injury accident probability as described below to produce a combined casualty index.

3.3.3 Combined Casualty Index Formula

The severity of crossing accidents, measured by casualties, has two dimensions, injuries and fatalities. On a casualty severity scale those accidents of lower severity will tend to have more injuries while those of higher severity will tend to have more fatalities. The frequency distribution of accident severity tends to be the opposite; i.e., injury accidents tend to be more frequent than fatal accidents. Thus, a comprehensive indicator of total accident casualty impacts should take into account both the number and nature (i.e., injuries versus fatalities) of accident casualties. Using this approach, a crossing that has, for example, many injury accidents can be considered on the same scale as one with few fatal accidents. The combined casualty index (CCI) formula was developed to achieve this objective.

The CCI formula is a weighted sum of the predicted fatal and injury accident probabilities obtained from Equation 3-3 and 3-4, respectively. It is expressed as follows:

$$P(CCI) = K \times P(FA|A) + P(IA|A) \qquad (3\text{-}7)$$

where: P(CCI) = combined casualty index probability

K = formula weight selected by user

P(F|A) = probability of a fatal accident, given an accident, obtained from Equation 3-3

P(I|A) = probability of an injury accident, given an accident, obtained from Equation 3-4

The CCI formula can be considered an "equivalent injury" accident probability function. It converts fatal accident to equivalent injury accident probability using the constant K and adds this value to the injury accident probability value. The user of the P(CCI) formula must specify a value for the constant K. This value indicates the relative impact of fatal versus injury accidents. The user is best qualified to determine the basis upon which an appropriate value of K is to be selected. A number of studies have been performed that are relevant to this topic. (Ref. 13 and 14) Based on results of accident costs in Reference 14 a default value of 50 for K was chosen for the DOT Procedure.

The probability value, P(CCI), obtained from Equation 3-7, must be multiplied by the accident prediction, from Equation 3-2, in a manner similar to the fatal and injury accident probability values, to yield the predicted CCI value for the crossing:

$$CCI = P(CCI) \times A \qquad (3\text{-}8)$$

where: CCI = combined casualty index

P(CCI) = combined casualty index probability from Equation 3-7

A = predicted accidents per year from Equation 3-2.

4. RESOURCE ALLOCATION MODEL

4.1 INTRODUCTION

The resource allocation model was developed to assist state and railroad officials in the crossing safety improvement decision process. (Ref. 5) The procedure provides initial recommended lists of crossing improvements for consideration. These initial recommendations may be used by states to guide the on-site inspection of crossings by diagnostic teams. Revised results based on information obtained by the diagnostic teams provides a useful set of recommendations upon which state and railroad officials can finalize crossing safety improvement plans.

The resource allocation model can provide safety improvement recommendations for two general categories of motorist warning devices upgrades: (1) active warning devices (i.e., flashing lights and gates) and (2) standard highway stop signs. The user of the resource allocation model has the option of selecting either or both sets of recommendations. Descriptions of the resource allocation model for active warning devices and stop signs are provided below in Sections 4.2 and 4.3, respectively.

4.2 RESOURCE ALLOCATION MODEL FOR ACTIVE WARNING DEVICES

4.2.1 Overview

The resource allocation model for active warning devices provides a list of crossings with recommended warning device improvements. The recommendations are based on achieving the greatest accident or casualty reduction for the available budget, given the cost and safety effectiveness of the active warning device options.

Input to the resource allocation model includes predicted accidents or casualties for the crossings being considered, costs and effectiveness of the different safety improvement options (e.g., flashing lights and gates), and the budget level available for safety improvement. Accident or casualty predictions for crossings can come from any prediction formula which computes number of accidents or casualties per year. The DOT accident and casualty prediction formula described in the previous section were developed for this purpose.

Cost data for the warning device options may include total life cycle costs (the sum of procurement, installation, and maintenance), or the costs associated with only a particular phase of a project. These costs are needed for the following categories of active warning device improvements currently considered by the model: flashing lights for a previously passive crossing, gates for a previously passive crossing, and gates at a crossing previously equipped with flashing lights. Cost data on warning device improvements which can be used for the resource allocation model are presented in Section 4.2.4.

Warning device effectiveness required by the resource allocation model is defined as the decimal fraction by which accidents are expected to be reduced by installation of a warning device. Effectiveness is a relative measure involving both existing and proposed warning systems at a crossing to be upgraded. If automatic gates have an effectiveness of 0.83, when installed at a crossing with a passive warning device, the accident rate at the crossing will be reduced by 83 percent. Automatic gates installed at a crossing with flashing lights would have a lower effectiveness. An improvement which completely eliminates accidents, such as grade separations or closures, would have an effectiveness of 1.0; i.e., it is 100 percent effective. Values of effectiveness for different active warning device improvement combinations are presented in Section 4.2.5.

The budget level for crossing improvements, used as input to the resource allocation model, should include the total multi-year funding available, even though it may exceed a single year's budget. The reason for this is that the resource allocation model will produce a different and possibly conflicting set of decisions depending upon the budget level used. If, for example, the first-year budget of a 2-year program is used, a specific set of decisions will result from the model. Use of the model again for the next year's budget, incorporating the crossing improvements made the previous year, will result in a new set of decisions. Some of the new decisions may involve further improvements to crossings just upgraded the previous year, resulting in an inefficient program. The best approach would have been to use the total 2-year budget for the first application of the model, and then fund the improvement decisions over a 2-year period.

The resource allocation model is intended to assist state and railroad planners in formulating decisions on crossing improvements. There are a number of applications where the model can be useful in this role. In its primary application, the model could use the state listing of crossings, ranked by predicted accidents or casualties, to produce a list of suggested improvement projects. The project list indicates which crossings are to be upgraded and the type of upgrade to be performed. The state can then use this suggested program as a basis to select crossings for on-site inspections by diagnostic teams. The diagnostic teams can validate original data used by the model, revise the suggested program if data has changed and obtain additional information on potential crossing hazards for consideration prior to finalizing program plans. A procedure for accomplishing this evaluation process is described in Section 4.2.6.

The resource allocation model can also be used to assess the sensitivity of improvement decisions to variations in the input parameters of warning device cost and effectiveness and predicted crossing accidents. If, for a given crossing or set of crossings, these parameters are known to be different than originally assumed, the new values can be substituted into the model and new results obtained. The effect of the new parameters can be assessed by a comparison of new improvement decisions with those resulting from the previous assumptions. This type of application is useful in evaluating the impacts of known or proposed changes in crossing characteristics, such as increases in train or highway traffic on certain routes, or closures of specific crossings.

The resource allocation model is also useful for evaluating the impacts of alternative program strategies. The model can be easily modified to incorporate constraints imposed on certain improvement actions by state warrants or guidelines. An example of such a constraint would be a gates-only policy at crossings with train speeds exceeding certain values. Variations in program budgeting such as inclusion versus exclusion of warning device maintenance costs and single-year versus multi-year funding limits, can also be evaluated with the resource allocation model.

4.2.2 Description of Model Algorithm

Three categories of warning device classes are considered by the resource allocation algorithm, and are the same categories evaluated by the accident prediction formulas. Warning device classes 1 through 4 are grouped together and called "passive" warning systems, meaning that they are not train-activated devices. Classes 5, 6, and 7 are grouped together and called "flashing lights," since public crossings which are equipped with flashing lights predominate in this category. Class 8 remains as a separate warning device category called "gates".

Table 4-1 is a matrix showing the effectiveness and cost symbols for the three warning device groupings used in describing the resource allocation algorithm. The matrix reflects the possible combinations of active warning device improvements currently considered by the model. For passive crossings, single track, two upgrade options exist, flashing lights or gates. For passive, multiple-track crossings, the model allows only the gate option to be considered in accordance with Federal regulations.* For flashing light crossings, the only improvement option is gates. The model can be modified by extending the basic logic to include other options, however, it would also be necessary to determine the costs and effectiveness of any additional options that are considered.

For each combination of existing and proposed warning device, a pair of parameters (E_j,C_j), as shown in Table 4-1, must be provided for the resource allocation algorithm, where $j = 1$ for flashing lights installed at a passive crossing, $j = 2$ for gates installed at

*23 CFR 646.214(b)(3)(i)

TABLE 4-1. EFFECTIVENESS/COST SYMBOL MATRIX

	PROPOSED WARNING DEVICE			
	FLASHING LIGHTS		AUTOMATIC GATES	
EXISTING WARNING DEVICE	EQUIPMENT EFFECTIVENESS	EQUIPMENT COST	EQUIPMENT EFFECTIVENESS	EQUIPMENT COST
Passive	E_1	C_1	E_2	C_2
Flashing Lights	—	—	E_3	C_3

a passive crossing, and $j = 3$ for gates installed at a crossing with flashing lights. The first parameter (E_j) is the effectiveness of installing the proposed warning device at the crossing. The second parameter (C_j) is the corresponding cost of the proposed warning device.

The resource allocation model considers all crossings with either passive or flashing light warning devices as candidates for improvements. If, for example, a single-track passive crossing, i, is considered, it could be upgraded with either flashing lights, with an effectiveness E_1, or gates, with an effectiveness of E_2. The number of predicted accidents or casualties at crossing i is AC_i; hence, the reduced accidents or casualties per year is AC_iE_1 for the flashing light option and AC_iE_2 for the gate option. The corresponding costs for these two improvements are C_1 and C_2. The accident or casualty reduction/cost ratios for these improvements are AC_iE_1/C_1 for flashing lights and AC_iE_2/C_2 for gates. The rate of increase in accident or casualty reduction versus costs that results from changing an initial decision to install flashing lights with a decision to install gates, at crossing i, is referred to as the incremental accident or casualty reduction/cost ratio and is equal to $AC_i(E_2-E_1)/(C_2-C_1)$. The incremental accident or casualty reduction/cost ratio is used by the algorithm to compare the cost-effectiveness of a decision to further upgrade a passive crossing from flashing lights to gates with an alternative decision to upgrade another crossing instead. If a passive multiple-track crossing, i, is considered, the only improvement option allowable would be installation of gates, with an effectiveness of E_2, a cost of C_2 and an accident or casualty reduction/cost ratio of $AC_i E_2/C_2$. If crossing i was originally a flashing light crossing, the only improvement option available would be installation of gates, with an effectiveness of E_3, a cost of C_3 and an accident or casualty reduction/cost ratio of AC_iE_3/C_3.

The resource allocation algorithm systematically computes the accident or casualty reduction/cost ratios, including incrementals, of all allowable improvement options for all crossings under consideration. The individual accident or casualty reduction/cost ratios are then sorted and selected by the algorithm so that the associated improvements result in the maximum accident or casualty reduction obtainable for the available budget. The total cost of the improvements is the sum of the individual project costs (C_1, C_2 and C_3). The total accident or casualty reduction is the sum of the individual accident or casualty reductions of the form AC_iE_j.

A flow diagram describing the logic of the resource allocation algorithm is shown in Figure 4-1. The input to this program consists of the set of crossings for which the model is to apply, the accidents or casualties predicted per year for these crossings, the warning device parameters (E_1, E_2, E_3, C_1, C_2, C_3) and the available budget (CMAX). It should be noted that more than one value for each of the six effectiveness and cost parameters can be provided to the algorithm. Thus, for example, several values of E, can be used to account for different crossing situations. Multiple effectiveness values for each type of upgrade, currently available for the algorithm, are discussed in more detail in Section 4.2.5.

The algorithm, described in Figure 4-1, proceeds according to the following steps in computing optimal resource allocations.

Step 1: The reasonable assumption is made for the algorithm that $E_2 > E_1$ and $C_2 > C_1$. This assumes that gates are more effective at passive crossings than flashing lights and that gates cost more. However, the effectiveness/cost ratio for flashing lights (E_1/C_1) could be greater or less than that for gates (E_2/C_2). If $E_1/C_1 > E_2/C_1$, the algorithm computes incremental accident or casualty reduction/cost ratios for all allowable improvements at each crossing according to the procedure outlined in step 2A below. Step 2A is based on the assumption that flashing lights have a greater effectiveness/cost ratio than gates. If the opposite is true -- that gates have an

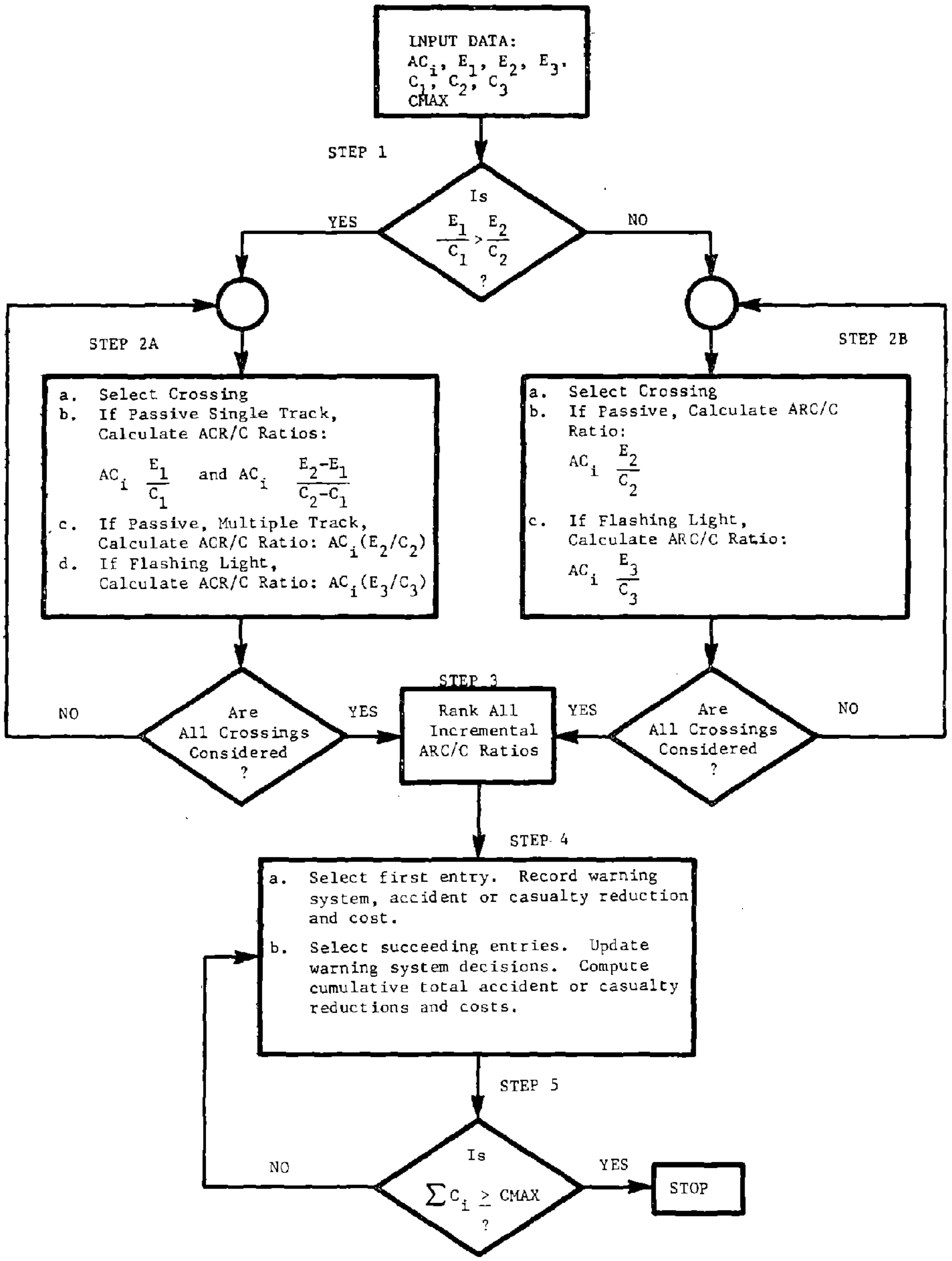


FIGURE 4-1. RESOURCE ALLOCATION ALGORITHM

effectiveness/cost ratio equal to or greater than flashing lights ($E_1/C_1 \leq E_2/C_2$) -- then step 2B is followed for computing the improvement accident or casualty reduction/cost ratios. Step 2B assumes that gates will always be installed at passive crossings.

Step 2A: In step 2A, two accident or casualty reduction/cost ratios are calculated for each single-track passive crossing, AC_iE_1/C_1 and the incremental ratio $AC_i(E_2-E_1)/(C_2-C_1)$, where AC_i is the number of accidents or casualties predicted per year for the crossing. These two ratios correspond to the two actions available for single-track passive crossings, either to install flashing lights or a revised decision to install gates. For multiple-track passive crossings, only the accident or casualty reduction/cost ratio for installation of gates is calculated (AC_iE_2/C_2), to conform with Federal regulations. For each crossing equipped with flashing lights, the algorithm computes AC_iE_3/C_3, corresponding to an upgrading from flashing lights to gates. The accident or casualty reduction/cost ratio is represented in units of accidents or casualties prevented per year per dollar.

Step 2B: The algorithm computes the accident or casualty reduction/cost ratio AC_iE_2/C_2 for passive crossings and the ratio AC_iE_3/C_3 for crossings with flashing lights. These accident or casualty reduction/cost ratios are associated with installing only gates at crossings. For the step 2B case, these actions are always optimal to the alternative of installing flashing lights, since the accident or casualty reduction/cost ratio and the absolute cost of gates are greater than for flashing lights.

Step 3: Regardless of whether step 2A or 2B is followed, all of the accident or casualty reduction/cost ratios calculated by the algorithm are ranked with the largest first. The list of accident or casualty reduction/cost ratios represents a sequence of optimal decisions starting with the top of the list.

Step 4: This step consists of a series of iterations, where the algorithm progresses down the list of ranked accident or casualty reduction/cost ratios. This process is equivalent to making the optimum decision of achieving the maximum accident or casualty reduction for each additional increment in cost incurred. If the accident or casualty reduction/cost ratio at any given step on the list is calculated as AC_iE_1/C_1, a decision is made to install flashing lights at a passive crossing, with an accident or casualty reduction of AC_iE_1 and cost of C_1. If the accident or casualty reduction/cost ratio is $AC_i (E_2-E_1)/(C_2-C_1)$, a previous decision to install flashing lights is changed to installation of gates at a passive crossing. The incremental accident or casualty reduction of changing the previous decision is $AC_i(E_2-E_1)$, and the incremental cost is $C_2 -C_1$. If the accident or casualty reduction/cost ratio is AC_iE_2/C_2, then a decision is made to install gates at a passive crossing without prior consideration of flashing lights. The accident or casualty reduction is AC_iE_2 at a cost of C_2. If the accident or casualty reduction is AC_iE_3/C_3, then a decision is made to install gates at a crossing which had flashing lights. The accident or casualty reduction is AC_iE_3 at a cost of C_3. The total accident or casualty reduction at each step is the sum of the previous accident or casualty reductions, and the total cost is the sum of the previous costs.

In addition to determining the total accident or casualty reduction and cost at each step, the algorithm also determines the particular warning systems which are to be installed at particular crossings. Since the crossings which were affected are known, the actual accidents or casualties, location, and all other information in The Inventory for those crossings, are also known. Thus, the output of the program could include any of this information and any computations based on this information. Several types of output are shown in Section 5.2.

Step 5: The cumulative total cost at each step, proceeding down the list of accident or casualty reduction/costs ratios, is compared with the available budget specified as input to the algorithm. When the total cost equals or exceeds the budget, the program ends. Otherwise, the sequential procedure described in step 4 continues.

4.2.3 Demonstration of Model Algorithm

To demonstrate operation of the algorithm, an example which considers the three crossings described in Table 4-2 follows. For this example predicted accidents, A_i, rather than predicted casualties will be used as the measure of crossing hazard. The predicted accidents per year and current warning device information for the crossings together with assumed warning device cost and effectiveness parameters, presented in Table 4-3, constitute the input data for the algorithm.

TABLE 4-2. SAMPLE CROSSINGS FOR ALGORITHM DEMONSTRATION

CROSSING	CURRENT WARNING DEVICE	PREDICTED ACCIDENTS PER YEAR A_i
X_1 (single track)	Passive	$A_1 = 0.3$
X_2	Flashing Lights	$A_2 = 0.2$
X_3	Flashing Lights	$A_3 = 0.1$

TABLE 4-3. EFFECTIVENESS/COST INPUT DATA

	- - - - - - - PROPOSED WARNING DEVICE - - - - - - -			
	FLASHING LIGHTS		AUTOMATIC GATES	
EXISTING WARNING DEVICE	EQUIPMENT EFFECTIVENESS	EQUIPMENT COST	EQUIPMENT EFFECTIVENESS	EQUIPMENT COST
Passive	$E_1 = 0.7$	$C_1 = \$25,000$	$E_2 = 0.9$	$C_2 = \$45,000$
Flashing Lights	--	--	$E_3 = 0.667$	$C_3 = \$35,000$

The algorithm proceeds through the following steps which were described in the previous section and in Figure 4-1.

Step 1: The effectiveness/cost ratio for flashing lights (E_1/C_1) is greater than that for gates (E_2/C_2); hence, the algorithm follows step 2A. (See Figure 4-1) This implies that the most effective first action which can be taken at a passive crossing is the installation of flashing lights.

Step 2A: The crossings are selected for analysis by the algorithm in the order they appear in Table 4-2. For each crossing selected, the appropriate accident reduction/cost ratios are calculated, corresponding to all the allowable warning device improvements which may be made. The results of these calculations are shown in Table 4-4.

Step 3: The accident reduction/cost ratios, as calculated in step 2A, are ranked in descending order, beginning with the largest. The warning device improvement action at each crossing, represented by the ratios and corresponding cumulative accident reduction and cost, are tabulated in Table 4-5.

Step 4: From the ranked list in Table 4-5, the first action selected by the algorithm corresponds to the first ranked accident reduction/cost ratio: installation of flashing lights at crossing X_1 with a cost of \$25,000. The next action selected by the algorithm corresponds to the next ranked accident reduction/cost ratio: installation of gates at crossing X_2, resulting in a cumulative cost of \$60,000 for the first two projects. The algorithm proceeds in this manner until the cumulative total cost of all improvement actions equals the available budget (CMAX). It should be noted that the third action selected by the algorithm does not involve an additional crossing, but revises an earlier decision to install gates rather than flashing lights at crossing X_1. This type of revision is typical of the algorithm for normal applications, as additional funding is made available. For the above example, if a total of \$115,000 were available for improvements (CMAX = \$115,000), the algorithm would proceed through the fourth item on the list involving crossing X_3. The overall improvement actions for \$115,000 would result in the installation of gates at all three crossings.

TABLE 4-4. STEP 2: CALCULATION OF ACCIDENT REDUCTION/COST RATIOS

CROSSING	CURRENT WARNING DEVICE	INSTALL FLASHING LIGHTS AT PASSIVE CROSSING:	REVISE DECISION FROM INSTALLING FLASHING LIGHTS TO GATES AT PASSIVE CROSSING:	INSTALL GATES AT FLASHING LIGHT CROSSING
		- - - IMPROVEMENT OPTIONS - - -		
		$AR/C = A_i\left(\frac{E_1}{C_1}\right)$	$AR/C = A_i\left(\frac{E_2 - E_1}{C_2 - C_1}\right)$	$AR/C = A_i\left(\frac{E_3}{C_3}\right)$
X_1	Passive, Single Track	$AR/C = 0.3\left(\frac{0.7}{25,000}\right) = 8.4 \times 10^{-6}$	$AR/C = 0.3\left(\frac{0.9 - 0.7}{45,000 - 25,000}\right) = 3.0 \times 10^{-6}$	-----
X_2	Flashing Lights	-----	-----	$AR/C = 0.2\left(\frac{0.667}{35,000}\right) = 3.8 \times 10^{-6}$
X_3	Flashing Lights	-----	-----	$AR/C = 0.1\left(\frac{0.667}{35,000}\right) = 1.9 \times 10^{-6}$

TABLE 4-5. STEP 3: RANKING OF ACCIDENT REDUCTION/COST RATIOS

RANK	ACCIDENT REDUCTION/COST RATIO	WARNING DEVICE IMPROVEMENT ACTION	E_jA_i ACCIDENTS REDUCED PER YEAR	ΣE_jA_i CUMULATIVE ACCIDENTS REDUCED PER YEAR	ΣC_j CUMULATIVE COSTS
1	8.4×10^{-6}	Install Flashing Lights at Crossing X_1	0.21	0.21	$25,000
2	3.8×10^{-6}	Install Gates at Crossing X_2	0.13	0.34	$60,000
3	3.0×10^{-6}	Install Gates at Crossing X_1	0.06	0.40	$80,000
4	1.9×10^{-6}	Install Gates at Crossing X_3	0.07	0.47	$115,000

4.2.4 Active Warning Device Cost Data

As described above, the resource allocation model requires data on the costs of the warning device improvement options. A study has been performed to determine average national values for these costs. (Ref. 6) The costs determined include the initial installation costs (including procurement) and the net present value (NPV) maintenance costs over the life of the equipment which are added together to yield the total life cycle cost. These costs were originally determined in 1977 dollars. An additional study was performed by the Association of American Railroads (AAR) in 1982 to determine the annual maintenance costs of warning devices.(Ref. 7) The AAR study results for maintenance costs were combined with the earlier study results for installation costs and updated to 1983 dollars using the procedure outlined below. These 1983 warning device costs are presented in Table 4-6.

TABLE 4-6. WARNING DEVICE IMPROVEMENT COSTS, 1983

IMPROVEMENT OPTION	INSTALLATION COST	NPV MAINTENANCE COST	NPV LIFE CYCLE COST
Passive to Flashing Lights, C_1	$43,800	$10,700	$54,500
Passive to Gates, C_2	$65,300	$18,700	$84,000
Flashing Lights to Gates, C_3	$58,700	$18,700	$77,400

The category of costs that are used as input to the resource allocation model (installation, maintenance, life cycle or some combination of these) can be determined at the discretion of the user. Installation costs reflect the immediate costs to the state and Federal Government of completing the project. Maintenance costs are the long term recurring costs of the project, usually to the railroads; however, some states share in these costs. Total life cycle costs reflect the project's total cost over its useful life.

Since the costs shown in Table 4-6 have been inflating, a procedure has been developed to produce multipliers for the installation and maintenance costs that will increase their amounts to current dollars. The procedure uses the annual index of charge-out prices and wage rates from the AAR. (Ref. 8)

The inflation multiplier for installation costs (MI) is determined from the average increase in the "Materials and Supplies" index, (MS) and the "Wage Rate" index (WR) from the year for which the latest cost information is available. The 1983 values for the MS and WR indexes are 140 and 179 respectively. The multiplier for installation costs, MI, for some future year beyond 1983 is therefore:

$$MI = \frac{(MS/140 + WR/179)}{2} \qquad (4\text{-}1)$$

where

MI = inflation multiplier for installation costs
MS = materials and supplies index for the current year
WR = wage rate index for the current year

The inflation multiplier for maintenance costs (MM) is a weighted average of 95 percent of the installation cost multiplier MI, (determined from equation 4-1 above) and 5 percent of the increase in the "Fuel" index (F) from the year for which the latest cost information is available. The 1983 value of the F index is 232. The multiplier for maintenance costs, MM, for some future year beyond 1983 is therefore:

$$MM = MI \times 0.95 + (F/232) \times 0.05 \qquad (4\text{-}2)$$

where

MM = inflation multiplier for maintenance costs
F = fuel index for the current year

The cost values shown in Table 4-6 are national averages, and their use will produce decisions by the resource allocation model useful in formulating improvement programs. The study to determine these costs (Ref. 6) did not reveal any significant shifts in costs by region of the country, although some variation by railroad was observed. If other values for the average costs of improvements are available and are thought to more accurately reflect the application in question, these values may be substituted for those suggested here.

Use of average costs introduces the simplification of not accounting for the actual variation in costs that can occur from one project to another. Average values assume, for example, that all passive crossings upgraded to gates will cost the same. If the user can determine more accurately the actual variation in costs for improvement options on all crossings being considered, these costs could be used. To do so, however, will require modification of the model program to permit cost data to be input on an individual crossing basis. The model program currently accepts only the three cost values (C_1,C_2,C_3,) as input.

Caution should be exercised in adjusting the costs of a few selected projects while assigning average costs to all other projects. If this is done, decisions regarding the adjusted crossings may be unreasonably biased by the algorithm. The effect on individual crossing decisions of changes in a crossing's cost characteristics from the average values can be determined manually, using a procedure described in Section 4.2.6. With this procedure, all other decisions by the algorithm will remain constant, while it can be determined if the decision regarding the crossing in question will change with the new cost values.

4.2.5 Active Warning Device Effectiveness Data

Three investigations have been performed to determine the effectiveness of warning devices in reducing accidents at rail-highway crossings. The most recent study performed by the U.S. Department of Transportation, used information in The Inventory and the FRA accident reporting system. (Ref. 9) This study compared the accident rates at crossings both before and after warning device improvements had been made to determine their effectiveness during the period from 1975 to 1980. A similar study, also performed for the U.S. Department of Transportation used the same information sources for the years 1975 to 1978. (Ref. 10) A third study was performed in 1974 by the California Public Utilities Commission. (Ref. 11) This study examined accident rates before and after upgrades at 1552 California crossings over the period from 1960 to 1970. The results of these three studies are shown in Table 4-7 in terms of single "standard" effectiveness values (E_1, E_2 and E_3) for the three improvement options considered by the resource allocation model.

4-7. STANDARD SET OF EFFECTIVENESS VALUES FOR WARNING DEVICE IMPROVEMENTS

WARNING DEVICE IMPROVEMENT OPTION	2nd DOT STUDY, 1975 to 1980 DATA	1st DOT STUDY, 1975 to 1978 DATA	CALIFORNIA STUDY, 1960 to 1970 DATA
Passive to Flashing Lights, E_1	0.70	0.65	0.64
Passive to Gates, E_2	0.83	0.84	0.88
Flashing Lights to Gates, E_3	0.69	0.64	0.66

The effectiveness values resulting from the three studies are similar but differences exist. These differences are probably a reflection of variations in crossing characteristics over time and regions of the country. The question arises as to which set of values to use for the resource allocation model. As with the cost data, any set of values which the user feels accurately reflect the situation being evaluated may be used. Without other information to the contrary, the effectiveness values from the latest DOT study are recommended, since they were most recently developed, and used the largest data base of national scope.

The latest DOT study on warning device effectiveness determined that several crossing characteristics, out of many investigated, had a significant influence on warning device effectiveness. Specifically, it was found that the effectiveness of warning device upgrades was less for crossings with multiple tracks and crossings with greater than 10 trains per day. These results were used to develop an "extended" set of effectiveness values shown in Table 4-8. At the option of the user, the resource allocation model has the capability to use either the extended set of values or the reduced set of standard values shown in Table 4-7. Unless otherwise specified by the user, the resource allocation model uses the extended set of values since their use results in improved performance of the model.

TABLE 4-8. EXTENDED SET OF EFFECTIVENESS VALUES FOR WARNING DEVICE IMPROVEMENTS

WARNING IMPROVEMENT OPTION	NUMBER OF TRACKS: / NUMBER OF TRAINS/DAY:	SINGLE ≤ 10	SINGLE >10	MULTIPLE ≤ 10	MULTIPLE >10
Passive to Flashing Lights, E_1		0.75	0.61	0.65	0.57
Passive to Gates, E_2		0.90	0.80	0.86	0.78
Flashing Lights to Gates, E_3		0.89	0.69	0.65	0.63

4.2.6 Field Verification and Revision of Resource Allocation Results

Crossings selected for improvements by the resource allocation model should be inspected by a diagnostic team to determine the accuracy of input data and the reasonableness of the recommended improvement. The inspection may show that data from The Inventory are not correct, resulting in an inaccurate predicted accident or casualty rate. Also, the assumed warning device effectiveness and cost may be found inappropriate for the particular crossing. In addition, the diagnostic team should make note of hazardous conditions at crossings, such as limited sight distance or hazardous materials traffic, that are not included in the resource allocation model but should be considered before making a final decision. A manual procedure has been developed to evaluate the impact of changes in crossing data on the improvement decision made by the resource allocation model. This procedure can be performed without rerunning the model and is incorporated in a worksheet, shown in Figure 4-2. The worksheet, guides the diagnostic team through the on-site evaluation procedure using a five-step set of instructions.

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE VERIFICATION WORKSHEET

This worksheet provides a format and instructions for use in field evaluation of crossings to determine if initial recommendations for warning device installations from the Resource Allocation Procedure should be revised. Steps 1 through 5, described below, should be followed in making the determination. In Steps 1 and 3, the intial information (left column) is obtained from office inventory data prior to the field inspection. In Step 4, the decision criteria values are obtained from the Resource Allocation Model printout.

STEP 1: VALIDATE DATA USED IN CALCULATING PREDICTED ACCIDENTS.

CROSSING CHARACTERISTICS	INITIAL INFORMATION	REVISED INFORMATION
Crossing Number	________	________
Location	________	________
Existing Warning Device	________	________
Total Trains Per Day (t)	________	________
Annual Average Daily Highway Traffic (c)	________	________
Total Switch Trains Per Day (ts)	________	________
Day Thru Trains (d)	________	________
Total Thru Trains Per Day (tt)	________	________
Number Of Main Tracks (mt)	________	________
Total Number Of Tracks (tk)	________	________
Is Highway Paved? (hp)	________	________
Maximum Timetable Speed, mph (ms)	________	________
Highway Type (ht)	________	________
Number Of Highway Lanes (hl)	________	________
Urban-Rural Location (ur)	________	________
Number Of Years Of Accident History (T)	________	________
Number Of Accidents In T Years (N)	________	________
Predicted Accident Or Casulaty Rate (AC)	________	________

STEP 2: CALCULATE REVISED ACCIDENT OR CASUALTY PREDICTION FROM DOT FORMULA IF ANY DATA IN STEP 1 HAS BEEN REVISED.

Revised Predicted Accidents or Casulaties (AC) = ______________

STEP 3: VALIDATE COST AND EFFECTIVENESS DATA FOR RECOMMENDED WARNING DEVICE.

	INITIAL INFORMATION	REVISED INFORMATION
Assumed Effectivness Of Recommended Warning Device (E)	________	________
Assumed Cost Of Recommended Warning Device (C)	________	________
Recommended Warning Device Installation	________	

FIGURE 4-2. "FIELD VERIFICATION WORKSHEET"

STEP 4: DETERMINE IF RECOMMENDED WARNING DEVICE IS REVISED IF AC, E OR C HAS CHANGED.

Instructions for Determining If Recommended Warning Device Should Be Revised

1. Obtain Decision Criteria Values From Resource Allocation Model Output:

DC_1 = ________ DC_2 = ________ DC_3 = ________ DC_4 = ________

2. Calculate: $R = \frac{\text{Revised AC}}{\text{Previous AC}} \times \frac{\text{Revised E}}{\text{Previous E}} \times \frac{\text{Previous C}}{\text{Revised C}}$

3. Compare R with Appropriate Decision Criteria as Shown Below:

3a. Existing Passive Crossing (Classes 1, 2, 3, 4) Single Track

Comparison	Decision
$DC_2 \leq R$	Gates
$DC_1 \leq R < DC_2$	Flashing Lights
$R < DC_1$	No Installation

3b. Existing Passive Crossing (Classes 1, 2, 3, 4) Multiple Tracks

Comparison	Decision
$DC_3 \leq R$	Gates
$R < DC_3$	No Installation

3c. Existing Flashing Light Crossing (Classes 5, 6, 7)

Comparison	Decision
$DC_4 \leq R$	Gates
$R < DC_4$	No Installation

4. Revised Recommended Warning Device Installation:* ________________________________

STEP 5: DETERMINE OTHER CROSSING CHARACTERISTICS THAT MAY INFLUENCE WARNING DEVICE INSTALLATION DECISIONS.

Multiple tracks where one train/locomotive may obscure vision of another train? ________________

Percent trucks ________________

Passenger train operations over crossing? ________________

High speed trains with limited sight distance?** ________________

Combination of High Speeds and moderately high volumes of highway and rail traffic?** ________________

Either, or any combination of, high vehicular traffic volumes, high numbers of train movements, substantial numbers of school buses or trucks carrying hazardous materials, unusually restricted sight distance or continuing accident occurrences?** ________________

---

*The cost and effectiveness values for the revised warning device are assumed to change by an amount proportional to the change in these values for the initial recommended warning device as determined in Step 3.

**Gates with flashing lights are the only recommended warning device per 23CFR 646.214(b)(3)(i).

FIGURE 4-2. "FIELD VERIFICATION WORKSHEET" (Cont.)

Steps 1, and 2 of the worksheet involve validating crossing characteristics data, and recalculating the predicted accidents or casualties if any of the data is revised. Step 3 validates the cost and effectiveness assumptions for the recommended warning device. As a result of completing steps 1, 2 and 3, three basic inputs to the resource allocation model may have changed: (1) number of predicted accidents or casualties (AC); (2) warning device effectiveness (E); and (3) warning device cost (C). Step 4 of the worksheet describes the procedure for determining if any input changes will affect the improvement decision. This procedure requires the computation of the parameter (R) using the formula below and described in part 2 of step 4:

$$R = \frac{\text{Revised AC}}{\text{Previous AC}} \times \frac{\text{Revised E}}{\text{Previous E}} \times \frac{\text{Previous C}}{\text{Revised C}} \qquad (4\text{-}3)$$

The value of R is the ratio of the revised to previous accident or casualty reduction/cost ratio, for the original recommended improvement action. The R value is then compared with the appropriate decision criteria values (DC_1, DC_2, DC_3, and DC_4) as described within part 3 of step 4 on the worksheet. The decision criteria values are obtained from the standard output report (see Figure 5-4) of the resource allocation model. The result of this comparison will determine if the original recommended improvement should be revised.

The decision criteria values are computed by the standard program of the resource allocation model for each crossing considered (see Section 5.2 for description of programs). The formula for computing the four decision criteria are shown below:

$$DC_1 = (ACR/C_m)/(A_i(E_1/C_1)) \qquad (4\text{-}4)$$

$$DC_2 = (ACR/C_m)/(A_i(E_2-E_1)/(C_2-C_1)) \qquad (4\text{-}5)$$

$$DC_3 = (ACR/C_m)/(A_i(E_2/C_2)) \qquad (4\text{-}6)$$

$$DC_4 = (ACR/C_m)/(A_i(E_3/C_3)) \qquad (4\text{-}7)$$

where

ACR/C_m = the minimum accident or casualty reduction/cost ratio corresponding to the last (lowest) improvement action selected by the resource allocation model.

The decision criteria represent the amount by which the accident or casualty reduction/cost ratio for a particular improvement action can be changed and still be selected by the model. The improvement actions corresponding to the decision criteria (DC_1, DC_2, DC_3 and DC_4) are, respectively, single-track passive to flashing lights, single-track passive to gates, multiple-track passive to gates, and flashing lights to gates. Comparing the R value to the decision criteria is equivalent to determining if the actual change in accident or casualty reduction/cost ratio due to revised data is still within the limits permitting selection of the same improvement action.

To demonstrate use of the revision procedure, the following example is provided. A single-track passive crossing was selected by the resource allocation model for upgrading to gates. This crossing is listed as the 9th crossing (ID# 000120R) on the sample standard output report of the resource allocation model shown in Figure 5-4. The crossing was inspected by a diagnostic team, and it was found that some of the data from The Inventory used in calculating the predicted accidents were incorrect. In addition, the assumed values for the installation costs and effectiveness of gates at the crossing were deemed inappropriate. Using the new data, a revised prediction of accidents was calculated according to the tabularized procedure described in Section 5.1.1. The previous and revised accident prediction, cost, and effectiveness parameters for the crossing are listed below:

	Previous	Revised
Predicted Accidents, A	0.40	0.50
Warning Device Effectiveness, E	0.80	0.90
Warning Device Cost, C	$65,300	$115,000

Using the above data, the R value is calculated using equation 4-3 (also shown on the worksheet, step 4, part 2):

$$R = (.50/.40)\,(.90/.80)(65{,}300/115{,}000)$$

$$= 0.799$$

The decision criteria for this crossing, obtained from the standard output report of the resource allocation model, Figure 5-4, are:

DC_1 = 0.352
DC_2 = 0.864
DC_3 = not computed since the crossing is single track
DC_4 = not computed since the crossing is passive

Comparing R with the decision criteria values, as described in step 4, part 3a of the worksheet, shows that R is greater than DC_1, but less than DC_2. This means that the original decision to install gates at this crossing should be revised to install flashing lights as the most cost-effective decision if the new data for the crossing are assumed correct.

4.3 RESOURCE ALLOCATION MODEL FOR STANDARD HIGHWAY STOP SIGNS

The most recent DOT study on warning device effectiveness (Ref. 9) determined that standard highway stop signs may be effective in reducing crossing accidents. The average level of effectiveness for upgrades to standard highway stop signs from other passive devices was found to be 0.35 (95 percent confidence interval, 0.16, to 0.54). This level of effectiveness coupled with their low cost ($400 installation or $800 total 30-year life cycle cost, including "stop ahead" signs, for a two-stop sign installation) make standard highway stop signs worthy of consideration for certain crossing situations needing improvement where funding is not available for active warning devices (Ref. 9). The FHWA has established the following guidelines for the selection of candidate crossings for stop signs (Ref. 2, 12):

The use of the stop signs at railroad-highway grade crossings shall be limited to those grade crossings selected after need is established by a detailed traffic engineering study. Such crossings should have the following characteristics:

1. Highway should be secondary in character with low traffic counts.
2. Train traffic should be substantial.
3. Line of sight to an approaching train is restricted by physical features such that approaching traffic is required to reduce speed to 10 miles per hour or less in order to stop safely.
4. At the stop bar, there must be sufficient sight distance down the track to afford ample time for a vehicle to cross the track before the arrival of the train.

The engineering study may determine other compelling reasons for the need to install a stop sign, however, this should only be an interim measure until active traffic control devices can be installed. Stop signs shall not be used on primary through highways or at grade crossings with active traffic control devices.

Whenever a stop sign is installed at a grade crossing, a stop ahead shall be installed in advance of the stop sign.

The resource allocation model provides, at the option of the user, a list of crossings that are possible candidates for standard highway stop signs. This list is produced by selecting from the passive crossings under consideration those with less than 400 average daily traffic (ADT) counts for rural roads and less than 1500 ADT counts for urban roads, greater than 10 trains per day and single tracks. The crossings on the list are ranked by the accident or casualty prediction measure selected by the user. Unlike the resource allocation model results for active warning devices the stop sign list is not ranked by accident or casualty reduction/cost ratios. The reason for this is twofold: (1) based on presently available information it is assumed that all stop sign upgrades have the same cost and effectiveness; hence, a ranking by accident or casualty reduction/cost ratio would be the same as that by accident or casualty prediction and (2) since the number of crossings that are realistic candidates for stop signs are so few and their costs are so low, stop sign installation decisions will be made primarily on factors other than their accidents or casualty reduction/cost ratios relative to active warning device projects.

The stop sign candidate report can be produced either with or without the report of active warning device recommendations. If the resource allocation procedure is used to produce both reports, it is possible that the same crossing could appear on both lists; i.e., a crossing that is a possible candidate for stop signs may also be a candidate for an active warning device. To provide a means of integrating this information, the report on active warning device recommendations will indicate, at the option of the user, if a crossing is also a possible candidate for stop signs.

5. APPLICATION OF DOT RESOURCE ALLOCATION PROCEDURE

5.1 DOT ACCIDENT AND CASUALTY PREDICTION FORMULAS

5.1.1 Manual Calculation of Predicted Accidents and Casualties

If the number of predicted accidents or casualties is required for a few crossings, a convenient manual procedure can be used, employing the formula tables presented in Sections 3.2 and 3.3. Manual use of the DOT accident and casualty prediction formulas is illustrated in the following example. Characteristics of the sample crossing for which the number of predicted accidents and casualties is to be determined are shown in Table 5-1.

TABLE 5-1. CHARACTERISTICS OF SAMPLE CROSSING

CHARACTERISTIC	VALUE
Present warning device	Crossbucks
Annual average daily highway traffic	350
Total number of trains movements per day	15
Total number of thru trains per day	10
Total number of switch trains per day	5
Number of main tracks	2
Total number of tracks (main and other)	2
Number of thru trains per day during daylight	5
Highway paved?	yes
Maximum timetable speed, mph	40
Highway type	Rural minor arterial (06)
Number of highway lanes	2
Urban - rural location	Rural
Number of years accident data, T	4
Number of accidents, N, in T years	2

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First, the basic formula (Equation 3-1) is used to determine the initial accident prediction (a):

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$$

where

a = initial accident prediction
K = constant
EI = factor for exposure (product of highway and train traffic)
MT = factor for number of main tracks
DT = factor for number of thru trains per day during daylight
HP = factor for highway paved (yes or no)
MS = factor for maximum timetable speed
HT = factor for highway type
HL = factor for number of highway lanes

The basic formula factor values (K, EI, MT, DT, HP, MS, HT and HL) can be determined from Table 3-2 for passive crossings, using the crossing's characteristics listed in Table 5-1:

K = 0.002268

EI = exposure index factor value for the product of 350 average daily highway vehicles times 15 total train movements per day (c x t = 5250)
= 29.26

MT = 1.52

DT = 1.55

HP = 1.00

MS = 1.36

HT = 0.82

HL = 1.00

Substituting the factor values into the basic formula yields:

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$$
$$= 0.002268 \times 29.26 \times 1.52 \times 1.55 \times 1.00 \times 1.36 \times 0.82 \times 1.00$$
$$= 0.17 \text{ accidents per year}$$

The final accident prediction (A) is determined by combining the initial prediction (a) with the crossing's accident history using Tables 3-5 thru 3-9, which are developed from the general DOT accident prediction formula (Equation 3-2). For the sample crossing, 2 accidents (N) occurred over the past 4 years (T); therefore, Table 3-8 is used. With an initial accident prediction (a = 0.17) between 0.10 and 0.20, it can be seen from Table 3-8 that the final accident prediction (A) will be between 0.25 and 0.35. A reasonable estimate of A can be determined from linear interpolation:

$$A = 0.25 + ((0.17-0.10)/(0.20-0.10))\ (0.35-0.25)$$

$$= 0.32 \text{ accidents per year}$$

To determine the number of fatal accidents at the sample crossing, the fatal accident probability is first obtained using Equation 3-3:

$$P(FA!A) = 1/(1 + CF \times MS \times TT \times TS \times UR)$$

where: CF = formula constant

MS = factor for maximum timetable train speed

TT = factor for thru trains per day

TS = factor for switch trains per day

UR = factor for urban or rural crossing

The factor values for the fatal accident probability formula can be determined from Table 3-12 using the sample crossing characteristics from Table 5-1:

CF = 695.0
MS = 0.019
TT = 0.782
TS = 1.202
UR = 1.000

Substituting the factor values into the fatal accident probability formula yields:

P(FA!A) = 1/(1 + CF X MS X TT X TS X UR)
= 1/(1 + 695.0 x 0.019 x 0.782 x 1.202 x 1.000)
= .075 probability of a fatal accident given an accident

The fatal accident probability is then multiplied by the predicted accidents, computed above using Equation 3-2, to obtain the predicted number of fatal accidents for the sample crossing per Equation 3-5:

FA = P(FA!A) x A
= 0.075 x 0.32
= 0.024 fatal accidents per year

To determine the number of injury accidents at the sample crossing, the injury accident probability is first obtained using Equation 3-4:

P(IA!A) = (1 - P(FA!A))/(1 + CI x MS x TK x UR)

where: P(FA!A) = probability of a fatal accident, given an accident, obtained from equation 3-3:
CI = formula constant
MS = factor for maximum timetable train speed
TK = factor for number of tracks
UR = factor for urban or rural crossing

The factor values for the injury accident probability formula can be determined from Table 3-13 using the sample crossing characteristics from Table 5-1:

P(FA|A) = .075 (computed above from fatal accident probability severity formula)

CI = 4.280

MS = 0.423

TK = 1.265

UR = 1.000

Substituting the factor values into the injury accident probability formula yields:

P(IA|A) = (1 - P(FA|A))/(1 + CI x MS x TK x UR)

= (1 - .075)/(1 + 4.280 x 0.423 x 1.265 x 1.000)

= 0.281 probability of an injury accident given an accident

The injury accident probability is then multiplied by the predicted accidents, computed above using Equation 3-2, to obtain the predicted number of injury accidents for the sample crossing per Equation 3-6:

IA = P (IA|A) x A

= 0.281 x 0.32

= 0.090 injury accidents per year

To determine the combined casualty index for the sample crossing, the combined casualty index probability is first obtained using Equation 3-7:

P(CCI) = K x P(FA|A) + P(IA|A)

where: K = formula weight selected by user

P(FA|A) = fatal accident probability obtained from Equation 3-3

P(IA|A) = injury accident probability obtained from Equation 3-4

Substituting a value of 50 for K and the fatal and injury accident probability values computed above for the sample crossings into the combined casualty index probability formula yields:

$$P(CCI) = K \times P(FA|A) + P(IA|A)$$
$$= 50 \times 0.075 + 0.281$$
$$= 4.031$$

The combined casualty index probability is then multiplied by the predicted accidents, computed above using Equation 3-2, to obtain the combined casualty index for the sample crossing per Equation 3-8:

$$CCI = P(CCI) \times A$$
$$= 4.031 \times 0.32$$
$$= 1.290 \text{ combined casualty index}$$

5.1.2. Computer Programs for Calculation of Predicted Accidents and Casualties

This section describes procedures for using the DOT accident and casualty prediction formula computer programs to obtain the number of predicted accidents or casualties per year for large numbers of crossings, and to list the crossings ranked by number of predicted accidents or casualties. Complete information for making the computer runs is supplied, provided the required input data are available and are in the format specified here. Modifications can be made to the programs to accept a different format. Data in the format specified here can be obtained from the Federal Railroad Administration, Office of Safety.

Two separate FORTRAN programs are used to generate accident and casualty prediction listings. The first program calculates predicted basic, final, fatal and injury accidents as well as the combined casualty index for each crossing. The second program generates the output in a report format ranking crossings by either predicted accidents, fatal accidents or combined casualty index. The two programs run sequentially according to the following steps:

1. Execute the Accident and Casualty Prediction Formula Program.
2. Sort the output file from step 1 in descending order of either predicted accidents, fatal accidents or combined casualty index. The field this file is sorted on will be the one that the crossings are ranked by in the output report.
3. Execute the Accident and Casualty Prediction Formula Report program to produce the accident/casualty prediction output report.

The Accident and Casualty Prediction Formula Program is shown in Exhibit A-1. A variable dictionary for this program is provided in Exhibit A-2. This program sequentially processes crossing input files (see Exhibit A-3 for input format) in the following manner:

While processing the crossing input file:

1. Select next crossing record.
2. Calculate basic predicted accident rate.
3. Calculate final predicted accident rate.
4. Calculate fatal, injury and combined casualty index rates.
5. Accumulate totals for basic, final, fatal, injury and combined casualty index rates, and also the number of crossings.
6. Append basic, final, fatal, injury and combined casualty index rates to current crossing record and write current record to output file.

When the crossing input file is processed:

1. Print out totals for basic, final, fatal, injury and combined casualty index rates, and also total number of crossings.

The Accident and Casualty Prediction Formula Program is divided into three sections. The first section, Calculate Basic Predicted Accidents, calculates the basic number of predicted accidents (H) for a crossing. The program uses one of three different equations to make this calculation. The equation used is dependent on the warning device classification of the current crossing. For warning device classes 1-4 the Crossbucks (passive device) equation is used , classes 5-7 the Flashing Lights equation is used and class the 8 The Gates equation is used.

The factors used in the Crossbucks, Flashing Lights and Gates equations are described in detail in Section 3. For warning device classes 1-4 the program determines the appropriate highway type (HT) weighting factor value by examining the functional classification variables (FC1, FC10) of the road at the crossing. A cross reference table for these functional codes and corresponding (HT) weighting factor values can be seen in Table 3-1.

The basic accident prediction formula computes the initial predicted accident rate for each crossing on the basis of the crossing's current warning device class. If, during the last five years, a change in warning device took place, the formula computes the basic predicted accidents on the basis of the previous warning device class and then executes the Modify For Upgrades/Downgrades By Effectiveness section of the program. This portion of the program makes an adjustment to the predicted accidents using the appropriate effectiveness factor (see Tables 4-7 & 4-8) to account for the influence of the warning device change. For individual crossings, this procedure more accurately determines the short term (less than five years) change in the crossing's accident rate than use of the basic formula for the new warning device. For example, if a passive crossing was upgraded to gates in the last five years, the passive (Crossbucks) formula would be used, the results of which would be multiplied by the effectiveness factor for gates (1.0 - the effectiveness of the upgrade to gates) to obtain the initial predicted accidents for the crossing with gates. Similarly, the predicted accidents would be divided by the effectiveness factor of the new warning device if a downgrade took place.

The next section of the Accident and Casualty Prediction Formula Program, Calculate Final Predicted Accidents, (Exhibit A-1) uses an algebraic equivalent of Equation 3-2 from Section 3.2.4 to calculate the final predicted accident rate. This calculation is achieved in three basic steps. First the number of years of accident history (T) for the crossing must be determined. A maximum value of five is used even though seven years of accident history are available. The most recent years of accident history data are always used. If a crossing has been upgraded or opened during the last five years the value of T is reduced from five to the number of years since the crossing has been upgraded or opened. This same method is used for crossings which have been downgraded and private crossings which have changed to public crossings in the five year period. The second step of this calculation involves the accumulation of accident history data to obtain the total number of accidents in the most recent T years (N). After values for T and N have been determined the final predicted accidents (A) calculation is executed.

Subroutine Caslty calculates predicted fatal and injury accidents, and a combined casualty index for the current crossing. Information is passed between this subroutine and the main program via common blocks FATCOM and FATC2. This subroutine simply receives crossing information, performs fatal, injury and combined casualty index calculations, and then return values for these three calculations to the main program. For a detailed explanation of the fatal, injury and combined casualty index formulas see Section 3.3.

Sample input to the Accident and Casualty Prediction Formula Program is shown in Exhibit A-3. Each record represents one crossing, and is formatted according to the data field descriptions given in Exhibit A-4. The source of fields 1 through 22 are from the U.S. DOT-AAR National Rail-Highway Crossing Inventory; fields 23 through 29 are from the FRA Railroad Accident/Incident Reporting System. Both data bases are maintained by the Federal Railroad Administration, Office of Safety.

Sample output from the Accident and Casualty Prediction Formula Program is shown in Exhibit A-5. The field description and the data contained in them are identical to the input (Exhibits A-3 & A-4) except that another five fields, each 10 characters in length, have been added to the beginning of each record. These fields contain fatal, injury, combined casualty index, final and basic accident figures. All five of these fields are real numbers in F10.7 format. This program also writes a second output file to the terminal monitor. This file contains totals for all five of these accident prediction figures along with the total number of crossings processed.

The output from the Accident and Casualty Prediction Formula Program shown in Exhibit A-5, is used as input to the Accident and Casualty Prediction Formula Report Program, Standard Highway Stop Sign Program and also the Resource Allocation Program (see Section 5-2). The Accident and Casualty Prediction Formula Report Program, shown in Exhibit A-6, generates one of three different possible reports. The first report is a ranking by fatal predicted accidents, the second by final predicted accidents and the third by combined casualty index. The data must first be sorted in descending order on the field the crossings will be ranked by, and then used as input to the Accident and Casualty Prediction Formula Report Program. Sample output from the Accident and Casualty Prediction Report Program is shown in Figures 5-1, 5-2, and 5-3 for crossings ranked by accidents, fatal accidents and combined casualty index, respectively.

The Accident and Casualty Prediction Formula Program and its input and output files are currently designed for use with the 1982 data file which has seven years of accident history appended to each crossing record. At a future time, if accident data beyond 1982 is to be added, appropriate modifications to the programs and data files will be required to accommodate the additional data.

5.2 COMPUTER PROGRAMS FOR RESOURCE ALLOCATION MODEL

5.2.1 Resource Allocation Model for Active Warning Devices

This section is a description of the computer programs for the resource allocation model discussed in Section 4. As in the case of the Accident and Casualty Prediction Formula Program, complete information is supplied for making the necessary computer runs, provided the required input data are available and in the format specified in Section 5.1.2.

The resource allocation model is run by a sequence of three FORTRAN programs. The first program calculates the accident or casualty reduction/cost ratios for all crossings and determines if a crossing is a candidate for standard highway stop signs, the second program runs the resource allocation algorithm, and the third program generates the output in a report format. The three programs are run sequentially according to the following steps.

1. Execute the Accident or Casualty Reduction/Cost Ratio Program.

2. Sort the output from step 1 in descending order of accident reduction/cost ratio.

3. Execute the Resource Allocation Program.

PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED ACCIDENTS PER YEAR
INVENTORY DATE: APRIL 1983

RANK	PREDICTED ACCIDENTS PER YEAR	XING ID #	ST	RR	# OF ACCIDENTS 78	79	80	81	82	DATE OF CHNG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	U-R/ HWY TYP CODE	AADT
1	0.622723	002153K	OH	NW	0	3	1	0	0		7	6	2	6	1	1	25	YES	4	1 9	6380
2	0.562409	002126N	OH	NW	2	0	1	0	1		7	2	2	6	1	1	35	YES	2	1 6	9190
3	0.554902	000118P	MI	MIRR	0	4	0	0	0		4	0	8	15	1	1	45	YES	2	1 7	1750
4	0.547862	000213K	MI	AA	0	2	0	1	1		7	0	2	4	3	1	15	YES	2	1 7	6950
5	0.494767	002972B	AL	ASAB	0	2	1	0	1		4	20	0	2	1	1	30	YES	2	1 9	4200
6	0.439817	000124T	MI	MIRR	0	2	0	0	1		7	0	8	15	1	1	45	YES	2	1 6	3530
7	0.414115	002081J	OH	NW	0	1	0	1	0		4	6	3	6	3	1	49	YES	2	1 6	5100
8	0.398576	000120R	MI	MIRR	1	1	0	0	1		4	0	8	15	1	1	45	YES	2	1 9	1130
9	0.340831	002778H	FL	ASAB	1	0	1	1	0		7	8	0	0	2	1	25	YES	3	1 6	650
10	0.331321	003640K	CO	ATSF	1	0	1	0	0		7	2	13	25	2	1	45	YES	2	1 6	1500
11	0.315651	002087A	OH	NW	0	0	2	0	0		4	8	3	6	1	1	49	YES	2	1 9	2740
12	0.315590	003566H	CO	ATSF	1	1	0	0	0		7	0	5	10	1	1	30	YES	2	1 9	4500
13	0.314638	003395J	CO	ATSF	0	0	0	1	2		4	0	3	5	1	1	60	YES	2	0 8	500
14	0.308170	000223R	MI	AA	0	0	0	0	2		7	0	2	4	1	1	15	YES	2	1 6	10610
15	0.292314	003655A	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	30	YES	4	1 6	13200
16	0.289450	002090H	OH	NW	0	1	0	1	0		7	2	3	6	1	1	49	YES	2	1 9	3030
17	0.284528	003648P	CO	ATSF	1	0	1	0	0		7	2	13	25	1	1	30	YES	1	1 9	1000
18	0.284186	002121E	OH	NW	1	0	0	0	0		7	6	2	6	1	1	35	YES	5	1 6	25040
19	0.249200	002773Y	FL	ASAB	0	0	1	0	0		7	4	0	0	7	5	35	YES	2	1 6	11871
20	0.248118	002706E	FL	ASAB	0	0	0	0	2		7	2	0	0	1	1	25	YES	2	1 6	5865
21	0.241376	002713P	FL	ASAB	0	0	0	0	1		7	4	0	0	1	1	25	YES	4	1 9	31515
22	0.238628	003638J	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	45	YES	2	1 6	3800
23	0.236279	002088G	OH	NW	0	0	1	0	0		7	8	2	6	1	1	49	YES	2	1 6	12890
24	0.236150	003631L	CO	ATSF	1	0	0	0	0		7	2	13	25	1	1	25	YES	2	1 6	5000
25	0.232715	002119D	OH	NW	0	0	0	1	0		7	6	2	6	1	1	35	YES	2	1 6	13140
26	0.231857	003639R	CO	ATSF	0	0	0	1	0		7	2	13	25	1	1	45	YES	2	1 7	4250
27	0.229986	002973H	AL	ASAB	1	1	0	0	0		4	20	0	2	1	1	25	YES	2	1 9	1080
28	0.227675	000341T	MI	GTW	0	1	0	0	0		7	0	2	4	1	1	10	YES	4	1 4	12800
29	0.223212	003229S	CO	ATSF	1	0	0	0	0		7	1	5	10	5	1	30	YES	2	1 6	2000
30	0.221769	000206A	MI	AA	0	0	0	0	2		7	0	2	4	1	1	40	YES	2	1 6	880
31	0.219486	003612G	CO	ATSF	0	0	0	0	1		7	2	15	30	1	1	45	YES	2	0 7	2200
32	0.218659	003538E	CO	ATSF	1	0	0	0	0		7	4	5	10	2	1	30	YES	2	1 4	4000
33	0.213592	002124A	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 9	9590
34	0.210632	003467K	CO	ATSF	0	0	1	0	0		7	0	5	10	1	1	60	YES	4	0 9	2350
35	0.210502	003262S	CO	ATSF	0	2	0	0	0		8	0	5	10	2	1	90	YES	2	0 7	2500
36	0.209582	000153D	MI	MIRR	0	0	1	0	0		7	0	4	7	1	1	40	YES	2	0 6	8500
37	0.209341	003232A	CO	ATSF	0	1	0	0	0		7	1	4	8	5	1	30	YES	2	1 6	1500
38	0.208419	002132S	OH	NW	0	0	0	0	1		7	6	2	6	1	1	25	YES	2	1 7	5260
39	0.208373	000151P	MI	MIRR	1	0	0	0	1		4	0	4	7	2	1	40	YES	2	0 9	200
40	0.205480	002125G	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 6	7060
41	0.201344	000122E	MI	MIRR	0	1	0	0	0		7	0	8	15	1	1	45	YES	2	1 7	2610
42	0.199579	002085L	OH	NW	0	0	1	0	0		4	8	3	6	1	1	49	YES	2	1 9	2430
43	0.194678	002980T	AL	ASAB	1	0	1	0	0		4	4	0	0	1	1	30	YES	2	1 9	1800
44	0.193351	002141R	OH	NW	1	0	0	0	0		7	6	2	6	2	1	25	YES	2	1 9	2050
45	0.191866	002734H	FL	ASAB	0	1	0	0	0		7	6	0	0	1	1	25	YES	2	1 4	8201
46	0.188739	002115B	OH	NW	0	0	1	0	0		7	2	2	6	1	1	49	YES	2	1 9	3720
47	0.188165	002981A	AL	ASAB	0	1	1	0	0		4	4	0	0	1	1	30	YES	2	1 9	1440
48	0.182885	000233W	MI	AA	1	0	0	0	0		7	0	2	4	1	1	30	YES	2	1 7	5920
49	0.182287	000212D	MI	AA	0	1	0	0	0		7	0	2	4	2	1	15	YES	2	1 9	4000
50	0.181690	000229G	MI	AA	0	1	0	0	0		7	2	0	0	1	0	10	YES	4	1 4	6500

FIGURE 5-1. SAMPLE OUTPUT FROM THE ACCIDENT AND CASUALTY PREDICTION REPORT PROGRAM (PREDICTED ACCIDENTS PER YEAR)

PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED FATAL ACCIDENTS PER YEAR
INVENTORY DATE: APRIL 1983

RANK	PREDICTED FATAL ACCIDENTS PER YEAR	XING ID #	ST	RR	# OF ACCIDENTS 78	79	80	81	82	DATE OF CHNG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	U-R/ HWY TYP CODE	AADT
1	0.047902	000118P	MI	MIRR	0	4	0	0	0		4	0	8	15	1	1	45	YES	2	1 7	1750
2	0.039501	003262S	CO	ATSF	0	2	0	0	0		8	0	5	10	2	1	90	YES	2	0 7	2500
3	0.038748	003395J	CO	ATSF	0	0	0	1	2		4	0	3	5	1	1	60	YES	2	0 8	500
4	0.037967	000124T	MI	MIRR	0	2	0	0	1		7	0	8	15	1	1	45	YES	2	1 6	3530
5	0.034407	000120R	MI	MIRR	1	1	0	0	1		4	0	8	15	1	1	45	YES	2	1 9	1130
6	0.031440	002126N	OH	NW	2	0	1	0	1		7	2	2	6	1	1	35	YES	2	1 6	9190
7	0.029935	002081J	OH	NW	0	1	0	1	0		4	6	3	6	3	1	49	YES	2	1 6	5100
8	0.027386	003467K	CO	ATSF	0	0	1	0	0		7	0	5	10	1	1	60	YES	4	0 9	2350
9	0.027001	003640K	CO	ATSF	1	0	1	0	0		7	2	13	25	2	1	45	YES	2	1 6	1500
10	0.022695	002153K	OH	NW	0	3	1	0	0		7	6	2	6	1	1	25	YES	4	1 9	6380
11	0.022673	002090H	OH	NW	0	1	0	1	0		7	2	3	6	1	1	49	YES	2	1 9	3030
12	0.022278	002087A	OH	NW	0	0	2	0	0		4	8	3	6	1	1	49	YES	2	1 9	2740
13	0.021839	003263Y	CO	ATSF	0	1	0	0	0		7	0	4	8	2	1	90	YES	2	0 8	100
14	0.021577	003612G	CO	ATSF	0	0	0	0	1		7	2	15	30	1	1	45	YES	2	0 7	2200
15	0.019447	003638J	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	45	YES	2	1 6	3800
16	0.018895	003639R	CO	ATSF	0	0	0	1	0		7	2	13	25	1	1	45	YES	2	1 7	4250
17	0.018222	003352R	CO	ATSF	0	0	1	0	0		4	0	3	6	2	2	79	YES	2	0 9	50
18	0.017968	002972B	AL	ASAB	0	2	1	0	1		4	20	0	2	1	1	30	YES	2	1 9	4200
19	0.017935	000153D	MI	MIRR	0	0	1	0	0		7	0	4	7	1	1	40	YES	2	0 6	8500
20	0.017831	000151P	MI	MIRR	1	0	0	0	1		4	0	4	7	2	1	40	YES	2	0 9	200
21	0.017535	003621F	CO	ATSF	0	0	0	1	0	7/79	7	2	13	25	1	1	45	YES	2	0 8	1600
22	0.017532	003566H	CO	ATSF	1	1	0	0	0		7	0	5	10	1	1	30	YES	2	1 9	4500
23	0.017381	000122E	MI	MIRR	0	1	0	0	0		7	0	8	15	1	1	45	YES	2	1 7	2810
24	0.016676	002088G	OH	NW	0	0	1	0	0		7	8	2	6	1	1	49	YES	2	1 6	12890
25	0.015869	003685A	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	30	YES	4	1 6	13200
26	0.015446	003648P	CO	ATSF	1	0	1	0	0		7	2	13	25	1	1	30	YES	1	1 9	1000
27	0.015378	003347U	CO	ATSF	0	0	1	0	0		4	0	3	6	2	2	79	NO	2	1 9	300
28	0.015260	000206A	MI	AA	0	0	0	0	2		7	0	2	4	1	1	40	YES	2	1 6	880
29	0.014964	003366Y	CO	ATSF	1	0	0	0	0		6	0	3	6	5	1	60	YES	2	0 8	50
30	0.014784	002115B	OH	NW	0	0	1	0	0		7	2	2	6	1	1	49	YES	2	1 9	3720
31	0.014633	002121E	OH	NW	1	0	0	0	0		7	6	2	6	1	1	35	YES	5	1 6	25040
32	0.014246	003373J	CO	ATSF	0	0	1	0	0		4	0	3	6	2	1	60	YES	2	0 8	60
33	0.014086	002085L	OH	NW	0	0	1	0	0		4	8	3	6	1	1	49	YES	2	1 9	2430
34	0.013962	003377L	CO	ATSF	0	0	1	0	0		4	0	3	6	1	1	60	YES	2	0 8	100
35	0.013861	003289B	CO	ATSF	1	0	0	0	0		4	0	3	6	1	1	90	NO	1	0 8	30
36	0.013764	000213K	MI	AA	0	2	0	1	1		7	0	2	4	3	1	15	YES	2	1 7	6950
37	0.013726	000142R	MI	MIRR	1	0	0	0	0		4	0	8	15	1	1	45	YES	2	0 9	150
38	0.013682	002031F	OH	NW	0	0	0	0	1		7	0	2	4	1	1	40	YES	2	0 6	3140
39	0.013670	002065A	OH	NW	0	0	0	0	1		4	0	3	6	1	1	49	YES	2	0 9	470
40	0.013556	003228K	CO	ATSF	0	0	0	1	0		4	0	4	8	1	1	90	NO	1	0 9	20
41	0.013403	003616J	CO	ATSF	0	1	0	0	0		7	2	13	25	1	1	45	YES	2	0 7	100
42	0.013267	003370N	CO	ATSF	1	0	0	0	0		4	0	3	6	1	1	60	YES	2	0 9	100
43	0.013093	003268H	CO	ATSF	0	1	0	0	0		4	0	5	10	1	1	90	NO	1	0 9	10
44	0.012556	002083X	OH	NW	1	0	0	0	0		7	6	3	6	1	1	49	YES	2	1 9	1290
45	0.011983	002119D	OH	NW	0	0	0	1	0		7	6	2	6	1	1	35	YES	2	1 6	13140
46	0.011940	002124A	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 9	9590
47	0.011853	002058P	OH	NW	0	0	0	1	0		4	0	3	6	1	1	40	YES	2	0 8	590
48	0.011653	000167L	MI	MIRR	2	0	0	0	0		4	0	4	7	1	1	40	NO	2	0 9	120
49	0.011594	003229S	CO	ATSF	1	0	0	0	0		7	1	5	10	5	1	30	YES	2	1 6	2000
50	0.011487	002125G	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 6	7060

FIGURE 5-2. SAMPLE OUTPUT FROM THE ACCIDENT AND CASUALTY PREDICTION REPORT PROGRAM (PREDICTED FATAL ACCIDENTS PER YEAR)

PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED COMBINED CASUALTY INDEX C.C.I.*
INVENTORY DATE: APRIL 1983

RANK	PREDICTED C.C.I.* PER YEAR	XING ID #	ST	RR	# OF ACCIDENTS 78	79	80	81	82	DATE OF CHNG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	U-R/ HWY TYP CODE	AADT
1	2.545034	000118P	MI	MIRR	0	4	0	0	0		4	0	8	15	1	1	45	YES	2	1 7	1750
2	2.034148	003262S	CO	ATSF	0	2	0	0	0		8	0	5	10	2	1	90	YES	2	0 7	2500
3	2.034142	003395J	CO	ATSF	0	0	0	1	2		4	0	3	5	1	1	80	YES	2	0 8	500
4	2.017204	000124T	MI	MIRR	0	2	0	0	1		7	0	8	15	1	1	45	YES	2	1 6	3530
5	1.828053	000120R	MI	MIRR	1	1	0	0	1		4	0	8	15	1	1	45	YES	2	1 9	1130
6	1.722645	002126N	OH	NW	2	0	1	0	1		7	2	2	6	1	1	35	YES	2	1 6	9190
7	1.593919	002081J	OH	NW	0	1	0	1	0		4	6	3	6	3	1	49	YES	2	1 6	5100
8	1.433560	003467K	CO	ATSF	0	0	1	0	0		7	0	5	10	1	1	60	YES	4	0 9	2350
9	1.432788	003640K	CO	ATSF	1	0	1	0	0		7	2	13	25	2	1	45	YES	2	1 6	1500
10	1.295565	002153K	OH	NW	0	3	1	0	0		7	6	2	6	1	1	25	YES	4	1 9	6380
11	1.213653	002090H	OH	NW	0	1	0	1	0		7	2	3	6	1	1	49	YES	2	1 9	3030
12	1.201883	002087A	OH	NW	0	0	2	0	0		4	8	3	6	1	1	49	YES	2	1 9	2740
13	1.145262	003612G	CO	ATSF	0	0	0	0	1		7	2	15	30	1	1	45	YES	2	0 7	2200
14	1.125309	003263Y	CO	ATSF	0	1	0	0	0		7	0	4	8	2	1	90	YES	2	0 8	100
15	1.031939	003638J	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	45	YES	2	1 6	3800
16	1.030232	002972B	AL	ASAB	0	2	1	0	1		4	20	0	2	1	1	30	YES	2	1 9	4200
17	1.007746	003639R	CO	ATSF	0	0	0	1	0		7	2	13	25	1	1	45	YES	2	1 7	4250
18	0.959883	000153D	MI	MIRR	0	0	1	0	0		7	0	4	7	1	1	40	YES	2	0 6	8500
19	0.959014	003566H	CO	ATSF	1	1	0	0	0		7	0	5	10	1	1	30	YES	2	1 9	4500
20	0.949499	000151P	MI	MIRR	1	0	0	0	1		4	0	4	7	2	1	40	YES	2	0 9	200
21	0.943300	003352R	CO	ATSF	0	0	1	0	0		4	0	3	6	2	2	79	YES	2	0 9	50
22	0.931697	003621F	CO	ATSF	0	0	0	1	0	7/79	7	2	13	25	1	1	45	YES	2	0 8	1600
23	0.923457	000122E	MI	MIRR	0	1	0	0	0		7	0	8	15	1	1	45	YES	2	1 7	2610
24	0.899660	002088G	OH	NW	0	0	1	0	0		7	8	2	6	1	1	49	YES	2	1 6	12890
25	0.863521	003655A	CO	ATSF	0	0	0	1	0		7	2	13	25	2	1	30	YES	4	1 6	13200
26	0.846679	003648P	CO	ATSF	1	0	1	0	0		7	2	13	25	1	1	30	YES	1	1 9	1000
27	0.822920	000206A	MI	AA	0	0	0	0	2		7	0	2	4	1	1	40	YES	2	1 6	880
28	0.808137	002121E	OH	NW	1	0	0	0	0		7	6	2	6	1	1	35	YES	5	1 6	25040
29	0.797832	003347U	CO	ATSF	0	0	1	0	0		4	0	3	6	2	2	79	NO	2	1 9	300
30	0.797379	000213K	MI	AA	0	2	0	1	1		7	0	2	4	3	1	15	YES	2	1 7	6950
31	0.791378	002115B	OH	NW	0	0	1	0	0		7	2	2	6	1	1	49	YES	2	1 9	3720
32	0.774657	003366Y	CO	ATSF	1	0	0	0	0		6	0	3	6	5	1	60	YES	2	0 8	50
33	0.759922	002085L	OH	NW	0	0	1	0	0		4	8	3	6	1	1	49	YES	2	1 9	2430
34	0.744689	003373J	CO	ATSF	0	0	1	0	0		4	0	3	6	2	1	60	YES	2	0 8	60
35	0.734638	002031F	OH	NW	0	0	0	0	1		7	0	2	4	1	1	40	YES	2	0 6	3140
36	0.732402	003377L	CO	ATSF	0	0	1	0	0		4	0	3	6	1	1	60	YES	2	0 8	100
37	0.726703	000142R	MI	MIRR	1	0	0	0	0		4	0	8	15	1	1	45	YES	2	0 9	150
38	0.723979	002065A	OH	NW	0	0	0	0	1		4	0	3	6	1	1	49	YES	2	0 9	470
39	0.716477	003289B	CO	ATSF	1	0	0	0	0		4	0	3	6	1	1	90	NO	1	0 8	30
40	0.712148	003618J	CO	ATSF	0	1	0	0	0		7	2	13	25	1	1	45	YES	2	0 7	100
41	0.700132	003228K	CO	ATSF	0	0	0	1	0		4	0	4	8	1	1	90	NO	1	0 9	20
42	0.695938	003370N	CO	ATSF	1	0	0	0	0		4	0	3	6	1	1	60	YES	2	0 9	100
43	0.676122	002083X	OH	NW	1	0	0	0	0		7	6	3	6	1	1	49	YES	2	1 9	1290
44	0.675789	003268H	CO	ATSF	0	1	0	0	0		4	0	5	10	1	1	90	NO	1	0 9	10
45	0.661770	002119D	OH	NW	0	0	0	1	0		7	6	2	6	1	1	35	YES	2	1 6	13140
46	0.654226	002124A	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 9	9590
47	0.634949	002058P	OH	NW	0	0	0	1	0		4	0	3	6	1	1	40	YES	2	0 8	590
48	0.629381	002125G	OH	NW	1	0	0	0	0		7	2	2	6	1	1	35	YES	2	1 6	7060
49	0.623671	000167L	MI	MIRR	2	0	0	0	0		4	0	4	7	1	1	40	NO	2	0 9	120
50	0.620485	003229S	CO	ATSF	1	0	0	0	0		7	1	5	10	5	1	30	YES	2	1 6	2000

FIGURE 5-3. SAMPLE OUTPUT FROM THE ACCIDENT AND CASUALTY PREDICTION REPORT PROGRAM (PREDICTED COMBINED CASUALTY INDEX PER YEAR)

4. Sort the output from step 3 in descending order of accident or casualty reduction/cost ratio.

5. Execute the Resource Allocation Report Program.

The Accident or Casualty Reduction/Cost Ratio Program and variable dictionary are shown in Exhibits B-1 and B-2. This program reads three input files:

1. Output from the Accident and Casualty Prediction Formula Program , Exhibit A-5,

2. Cost, effectiveness and funding data and

3. User options for running of the Resource Allocation Program

The second input file of cost, effectiveness and funding data is to be generated by the user. Suggested values for cost and effectiveness data are given in Section 4.2.4 and 4.2.5. A sample input file of this type is shown in Exhibit B-3. The first line of input contains the cost data in three fields, each of length 10. The first entry on the line is the cost of upgrading a passive crossing to a flashing light; the second entry is the cost of upgrading a passive crossing to a gate; and the third entry is the cost of upgrading a flashing light to a gate. The second line of input contains the standard effectiveness data in three fields, each of length 10. The order is the same as for the cost data on the first line. The third line of input contains extended effectiveness data in twelve fields, each of length 10. These twelve fields represent four sets of extended effectiveness data based on trains and tracks. Fields 1-3 contain effectiveness values for crossings with single tracks and less than 11 trains, fields 4-6 are the effectiveness values for crossings with single tracks, and 11 or more trains, fields 7-9 are the effectiveness values for crossings with multiple tracks, less than 11 trains, and fields 10-12 are the effectiveness values for crossings with multiple tracks and 11 or more trains. The order of the 3 effectiveness values within each of these 4 sets is the same as that of the cost and standard effectiveness data. The fourth and last line of this input file consists of one field of length 10 containing the maximum amount of available funding in dollars. This value is to be established by the user.

The third and final input file to the Accident or Casualty Reduction/Cost Ratio Program is generated interactively by the program at the time of execution. (See subroutine Query Exhibit B-1.) The program prompts the user with a series of four queries. The user response to the first query determines whether standard or extended effectiveness values will be used throughout the resource allocation model. A response of "0" introduces the use of standard effectiveness values, "1" the use of extended effectiveness values. The second and third queries determine the accident or casualty measure (AC) used throughout the model. A user response of "0" to the second query, "should accident severity be used or not", will introduce the use of final predicted accidents (A) as the accident or casualty measure (AC). A response of "1" will generate the third query "should severity consider fatalities only or combined casualty index". A response of "0" to this third query will introduce the use of predicted fatal accidents as the accident or casualty measure, "1" the use of combined casualty index. The fourth and final query determines if crossings recommended for active devices which are also candidates for standard stop sign upgrades will be noted in the final report.

The Accident or Casualty Reduction/Cost Ratio Program in Exhibit B-1 performs the following algorithm:

1. Query program option parameters.
2. Write program option parameters to temporary file.
3. Read cost, effectiveness and total resources available data.
4. While not at end of crossings input file
   - 4a. Select next crossing with current warning device class not equal to 8.
   - 4b. Determine if current crossing is a possible candidate for stop signs.
   - 4c. Select three effectiveness values for current crossing.
   - 4d. Calculate three effectiveness/cost ratios.
   - 4e. Determine accident or casualty measure (AC).
   - 4f. Calculate accident or casualty reduction/cost ratios for current crossing.
   - 4g. Append accident or casualty reduction/cost ratio and stop sign candidate flag to current crossing record and write to output file.
5. Stop execution when end of input file is reached.

The calculation of the accident or casualty reduction/cost ratio for each crossing depends on the crossings current warning device and the number of tracks at the crossing (see Calculate Ben/Cos section, Exhibit B-1). If the crossing already has gates (warning device class 8), it is deleted from consideration.

If the crossing has flashing lights or other active devices (warning device classes 5, 6 and 7), an accident or casualty reduction/cost ratio (ACR/C) for upgrading to gates is calculated according to the equation:

$$ACR/C = AC\ (EFFECT_3/COST_3)$$

where AC is either the number of predicted accidents, fatal accidents or the combined casualty index for the crossing from the accident and casualty prediction formulas and $COST_3$ and $EFFECT_3$ are the cost and effectiveness of the upgrade, as discussed in Section 4. It is important to note here that, if the user has chosen to implement standard effectiveness values throughout the resource allocation model, $EFFECT_j$ simply represents the single effectiveness value for a crossing upgrade. However, if extended effectiveness values are in use, $EFFECT_j$ can have one of four values depending on the crossing's number of trains and tracks (see Section 4.2.5 on extended effectiveness values).

If the crossing is passive (warning device classes 1-4) but has multiple tracks, an accident or casualty reduction/cost ratio for upgrading to gates is calculated according to equation:

$$ACR/C = AC\ (EFFECT_2/COST_2)$$

This forces gates to be installed at multiple track passive crossings in accordance with Federal guidelines. If the crossing is passive but has only one track, an accident or casualty reduction/cost ratio is calculated for upgrading to flashing lights according to the equation:

$$ACR/C = AC\ (EFFECT_1/COST_1)$$

The incremental accident or casualty reduction/cost ratio equation for installing a gate at the passive crossing,

$$ACR/C = AC\ (EFFECT_2\text{-}EFFECT_1)/(COST_2\text{-}COST_1)$$

is not calculated by the Accident or Casualty Reduction/Cost Ratio Program, but is calculated later by the Resource Allocation Program. However, in the case where $EFFECT_2/COST_2$ is greater than $EFFECT_1/COST_1$, the Accident or Casualty Reduction/Cost Ratio Program calculates a ratio given by the equation:

$$ACR/C = AC\ (EFFECT_2/COST_2)$$

for all passive crossings, regardless of the number of tracks. In this case, the installation of gates is always more cost-effective than installation of flashing lights. The Resource Allocation Program does not calculate the incremental accident or casualty reduction/cost ratio in this case. For convenience of storage, all accident or casualty reduction/cost ratios are multiplied by 10^6; i.e., they are expressed in accidents per million dollars.

In addition to calculating the accident or casualty reduction/cost ratio for each crossing this program also determines if a crossing is a possible candidate for standard stop signs. (See Stop Qualification Section, Exhibit B-1) For a crossing to qualify for consideration for standard stop signs it must meet the following criteria:

1. Total trains per day greater than 10

2. No existing standard stop signs

3. Present warning device class less than 5

4. Crossing must be single track

5. For rural area crossings the annual average daily traffic must be less than 400

6. For urban area crossings the annual average daily traffic must be less than 1500

7. Crossing must be local highway type.

If a crossing meets all of the above conditions, the variable STPFLG is given a value of 1. If it does not, it receives a value of zero. This variable is then written to the output file with current crossing record for reference in the Resource Allocation Report Program.

Sample output from the Accident or Casualty Reduction/Cost Ratio Program is shown in Exhibit B-4. Field descriptions for this output are given in Exhibit B-5. This output must be sorted in descending order of accident or casualty reduction/cost ratio (the first 10 columns), and then used as input to the Resource Allocation Program.

The Resource Allocation Program (Exhibit C-1) performs the algorithm described in Section 4, recommending the crossings to be improved and the warning device to be installed. A variable dictionary for the program is given in Exhibit C-2. The program reads each crossing in order, starting with the highest accident or casualty reduction/cost ratio.

If the crossing is passive with single track, an additional incremental accident or casualty reduction/cost ratio is calculated for making an upgrade to gates given by the following equation:

$$ACR/C = AC\ (EFFECT_2 - EFFECT_1)/(COST_2 - COST_1).$$

It is temporarily assumed that a flashing light will be recommended at the crossing. Since this is only a temporary decision, this crossing is not written to the output file immediately. Instead, it is stored in a separate list of crossings until it is determined whether or not sufficient funding is available to install a gate.

Every time a crossing is read in, the accident or casualty reduction/cost ratio calculated by the first program is compared with the incremental accident or casualty reduction/cost ratio calculated for the crossings stored in the temporary decision list. All crossings stored in the temporary list with incremental accident or casualty reduction/cost ratios greater than the accident or casualty reduction/cost ratio for the crossing that has just been read are recommended for gates, and that decision is finalized by removing the crossing from the temporary list and writing it into the output file. If the crossing that has just been read is passive with single track, it is added to the temporary list as described above. Otherwise a gate is recommended and the crossing is immediately written to the output file. Each time a crossing is written either to the output file or the temporary list, the cost of the recommended upgrade is added to the cumulative amount spent. When this amount exceeds the maximum amount allowed, those passive single track crossings still on the temporary decision list are recommended for flashing lights and are written to the output file as final decisions. The minimum accident or casualty reduction/cost ratio for the run is written to a separate file to be read by the Resource Allocation Report Program for use in calculating the decision criteria.

Sample output and output field descriptions from the Resource Allocation Program are shown in Exhibits C-3 and C-4. This output is then sorted in descending order of accident or casualty reduction/cost ratio (columns 1-10) for input into the Resource Allocation Report Program.

The Resource Allocation Report Program is shown in Exhibit C-5. This program calculates the decision criteria and generates the output in a report format. The decision criteria, DC_1, DC_2, DC_3 and DC_4, are calculated from equations 4-4, 4-5, 4-6 and 4-7, respectively, described in Section 4.2.6. If the crossing being considered is passive, single-track, the program calculates DC_1 and DC_2. If the crossing is passive, multiple-track, DC_3 is calculated. If the crossing has flashing lights, DC_4 is calculated. Sample output from the Resource Allocation Report Program is shown in Figures 5-4 to 5-8.

5.2.2 Resource Allocation Model for Standard Highway Stop Signs

The Standard Stop Sign Report Program, shown in Exhibit D-1, determines if a crossing is a candidate for standard highway stop signs and, in report format, produces a listing of these candidate crossings ranked by either predicted accidents, fatal accidents or combined casualty index. The input file to this program is the output file from the Accident or Casualty Prediction Formula Program (see Exhibit A-5). This file must first be sorted in descending order on the field the user chooses qualifying crossings to be ranked on. For example, if the user requires a listing of all crossings that qualify for standard stop sign upgrades, ranked by combined casualty index, they would first sort the input file in descending order on the combined casualty index field. The criteria for determining stop sign candidacy in this program are the same as those stated in the description of the Accident or Casualty Reduction/Cost Ratio Program. Sample output from the Standard Stop Sign Report Program is shown in Figure 5-9.

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED ACCIDENTS
FOR (STATE)

TOTAL BUDGET: $ 3000000

WARNING DEVICE	P-->FL	P-->G	FL-->G
COST:	$43800.	$65300.	$58700.

EXTENDED EFFECTIVENESS VALUES:

	TRAINS <= 10		TRAINS >= 11	
UPGRADE OPTION	SINGLE TRACK	MULTIPLE TRACK	SINGLE TRACK	MULTIPLE TRACK
PASSIVE - FL	.75	.65	.61	.57
PASSIVE - G	.90	.86	.80	.78
FLASHING - G	.89	.65	.69	.63

CROSSING ID #	PREDICTED ACCIDENTS PER YEAR	ACCIDENTS REDUCTION COST RATIO (ACC/$MILL)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	TOTAL # OF TRAINS	CUMULATIVE COST ($THOUSAND)	CUMULATIVE REDUCED ACCIDENTS PER YEAR	DECISION CRITERIA VALUES DC1	DC2	DC3	DC4
002128N	0.562409	8.527157	GATE	LIGHT	1	8	59	0.500544				.282
002153K	0.622723	7.319916	GATE	LIGHT	1	12	117	0.930223				.254
000118P	0.554902	6.798189	GATE	CROSSBUCK	1	15	183	1.374145	.253	.620		
000213K	0.547862	6.066612	GATE	LIGHT	3	4	241	1.730255				.386
002972B	0.494767	6.061464	GATE	CROSSBUCK	1	22	307	2.126069	.283	.696		
003395J	0.314638	5.387630	LIGHT	CROSSBUCK	1	5	351	2.362047	.446	1.094		
000124T	0.439817	5.169916	GATE	LIGHT	1	15	409	2.665521				.360
002081J	0.414115	4.946551	GATE	CROSSBUCK	3	12	475	2.988531			.440	
000120R	0.398576	4.883017	GATE	CROSSBUCK	1	15	540	3.307392	.352	.864		
003566H	0.315590	4.784919	GATE	LIGHT	1	10	599	3.588267				.502
000223R	0.308170	4.672418	GATE	LIGHT	1	4	657	3.862538				.514
002087A	0.315651	4.396058	LIGHT	CROSSBUCK	1	14	701	4.055085	.444	1.091		
002090H	0.289450	4.388587	GATE	LIGHT	1	8	760	4.312695				.547
002778H	0.340831	3.774107	GATE	LIGHT	2	8	818	4.534235				.636
002706E	0.248118	3.761930	GATE	LIGHT	1	2	877	4.755060				.638
002713P	0.241376	3.659706	GATE	LIGHT	1	4	936	4.969885				.656
003640K	0.331321	3.555914	GATE	LIGHT	2	27	995	5.178617				.655
000341T	0.227675	3.451976	GATE	LIGHT	1	4	1053	5.381248				.696
000208A	0.221769	3.362426	GATE	LIGHT	1	4	1112	5.578622				.714
003648P	0.284528	3.344532	GATE	LIGHT	1	27	1171	5.774946				.557
002121E	0.284186	3.340516	GATE	LIGHT	1	12	1229	5.971034				.557
002980T	0.194678	3.333519	LIGHT	CROSSBUCK	1	4	1273	6.117042	.720	1.768		
002124A	0.213592	3.238443	GATE	LIGHT	1	8	1332	6.307139				.742
002981A	0.188165	3.222003	LIGHT	CROSSBUCK	1	4	1376	6.448263	.745	1.829		
002973H	0.229986	3.202999	LIGHT	CROSSBUCK	1	22	1419	6.588554	.610	1.497		
003467K	0.210632	3.193567	GATE	LIGHT	1	10	1478	6.776016				.752
000153D	0.209582	3.177647	GATE	LIGHT	1	7	1537	6.962544				.756
003655A	0.292314	3.137275	GATE	LIGHT	2	27	1596	7.146702				.742
002125G	0.205480	3.115458	GATE	LIGHT	1	8	1654	7.329579				.771
002734H	0.191866	2.909045	GATE	LIGHT	1	6	1713	7.500340				.826
002115B	0.188739	2.861632	GATE	LIGHT	1	8	1772	7.668318				.839
000509J	0.166321	2.847971	LIGHT	CROSSBUCK	1	2	1815	7.793059	.843	2.070		
002085L	0.199579	2.779522	LIGHT	CROSSBUCK	1	14	1859	7.914802	.703	1.725		
002088G	0.236279	2.777379	GATE	LIGHT	1	14	1918	8.077834				.670
003631L	0.236150	2.775870	GATE	LIGHT	1	27	1977	8.240778				.671
000692S	0.162082	2.775377	LIGHT	CROSSBUCK	1	1	2020	8.362340	.865	2.124		
000233W	0.182885	2.772870	GATE	LIGHT	1	4	2079	8.525107				.866

FIGURE 5-4. SAMPLE OUTPUT FROM RESOURCE ALLOCATION REPORT PROGRAM
(ACCIDENT REDUCTION)

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED FATAL ACCIDENTS
FOR (STATE)

TOTAL BUDGET: $ 3000000

WARNING DEVICE	P-->FL	P-->G	FL-->G
COST:	$43800.	$65300.	$58700.

EXTENDED EFFECTIVENESS VALUES:

	TRAINS <= 10		TRAINS >= 11	
UPGRADE OPTION	SINGLE TRACK	MULTIPLE TRACK	SINGLE TRACK	MULTIPLE TRACK
PASSIVE - FL	.75	.65	.61	.57
PASSIVE - G	.90	.86	.80	.78
FLASHING - G	.89	.65	.69	.63

CROSSING ID #	PREDICTED FATAL ACCIDENTS PER YEAR	FATAL ACC. REDUCTION COST RATIO (ACC/$MILL)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	TOTAL # OF TRAINS	CUMULATIVE COST ($THOUSAND)	CUMULATIVE REDUCED FATAL ACC PER YEAR	DC1	DC2	DC3	DC4
000118P	0.047902	0.586848	GATE	CROSSBUCK	1	15	65	0.038321	.189	.463		
003395J	0.038748	0.534042	GATE	CROSSBUCK	1	5	131	0.073194	.233	.572		
002126N	0.031440	0.476690	GATE	LIGHT	1	8	189	0.101176				.325
000124T	0.037967	0.446289	GATE	LIGHT	1	15	248	0.127373				.269
000120R	0.034407	0.421523	GATE	CROSSBUCK	1	15	313	0.154898	.263	.644		
003467K	0.027386	0.415221	GATE	LIGHT	1	10	372	0.179271				.373
002081J	0.029935	0.357565	GATE	CROSSBUCK	3	12	437	0.202620			.392	
002090H	0.022673	0.343760	GATE	LIGHT	1	8	496	0.222799				.450
003640K	0.027001	0.289788	GATE	LIGHT	2	27	555	0.239810				.517
002087A	0.022278	0.272929	GATE	CROSSBUCK	1	14	620	0.257632	.406	.995		
000153D	0.017935	0.271925	GATE	LIGHT	1	7	679	0.273594				.569
002153K	0.022695	0.266770	GATE	LIGHT	1	12	737	0.289253				.450
003566H	0.017532	0.265822	GATE	LIGHT	1	10	796	0.304857				.582
003612G	0.021577	0.253631	GATE	LIGHT	1	32	855	0.319745				.473
003263Y	0.021839	0.241832	GATE	LIGHT	2	8	914	0.333941				.640
003352R	0.018222	0.239987	GATE	CROSSBUCK	2	6	979	0.349612			.645	
003377L	0.013962	0.239070	LIGHT	CROSSBUCK	1	6	1023	0.360083	.647	1.588		
003289B	0.013861	0.237349	LIGHT	CROSSBUCK	1	6	1066	0.370479	.652	1.600		
000151P	0.017831	0.234839	GATE	CROSSBUCK	2	7	1132	0.385814			.659	
002065A	0.013670	0.234072	LIGHT	CROSSBUCK	1	6	1176	0.396066	.661	1.622		
003228K	0.013556	0.232128	LIGHT	CROSSBUCK	1	8	1219	0.406233	.666	1.636		
000206A	0.015260	0.231374	GATE	LIGHT	1	4	1278	0.419815				.669
003370N	0.013267	0.227168	LIGHT	CROSSBUCK	1	6	1322	0.429765	.681	1.671		
002115B	0.014784	0.224153	GATE	LIGHT	1	8	1381	0.442923				.690
003268H	0.013093	0.224202	LIGHT	CROSSBUCK	1	10	1424	0.452743	.690	1.694		
003639R	0.018895	0.222106	GATE	LIGHT	1	27	1483	0.465781				.540
002972B	0.017968	0.220134	GATE	CROSSBUCK	1	22	1548	0.480156	.503	1.234		
003638J	0.019447	0.208715	GATE	LIGHT	2	27	1607	0.492408				.718
002031F	0.013682	0.207441	GATE	LIGHT	1	4	1666	0.504585				.746
003621F	0.017535	0.206117	GATE	LIGHT	1	27	1724	0.516684				.582
000122E	0.017381	0.204307	GATE	LIGHT	1	15	1783	0.528677				.587
003347U	0.015378	0.202535	GATE	CROSSBUCK	2	6	1848	0.541903			.764	
002058P	0.011853	0.202961	LIGHT	CROSSBUCK	1	6	1892	0.550793	.762	1.871		
000167L	0.011653	0.199536	LIGHT	CROSSBUCK	1	7	1936	0.559533	.775	1.903		
002088G	0.016676	0.196020	GATE	LIGHT	1	14	1995	0.571039				.612
002085L	0.014086	0.196171	LIGHT	CROSSBUCK	1	14	2039	0.579631	.641	1.574		
000142R	0.013726	0.191163	LIGHT	CROSSBUCK	1	15	2082	0.588004	.658	1.615		

FIGURE 5-5. SAMPLE OUTPUT FROM RESOURCE ALLOCATION REPORT PROGRAM
(FATAL ACCIDENT REDUCTION)

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED COMBINED CASUALTY INDEX C.C.I*
FOR (STATE)

TOTAL BUDGET: $ 3000000

WARNING DEVICE	P-->FL	P-->G	FL-->G
COST:	$43800.	$65300.	$58700.

EXTENDED EFFECTIVENESS VALUES:

UPGRADE OPTION	TRAINS <= 10 SINGLE TRACK	TRAINS <= 10 MULTIPLE TRACK	TRAINS >= 11 SINGLE TRACK	TRAINS >= 11 MULTIPLE TRACK
PASSIVE - FL	.75	.65	.61	.57
PASSIVE - G	.90	.86	.80	.78
FLASHING - G	.89	.65	.69	.63

CROSSING ID #	PREDICTED C.C.I.* PER YEAR	C.C.I.* REDUCTION COST RATIO (ACC/$MILL)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	TOTAL # OF TRAINS	CUMULATIVE COST ($THOUSAND)	CUMULATIVE REDUCED C.C.I.* PER YEAR	DECISION CRITERIA VALUES DC1	DC2	DC3	DC4
000118P	2.545034	31.179593	GATE	CROSSBUCK	1	15	65	2.036027	.193	.474		
003395J	2.034142	28.035646	GATE	CROSSBUCK	1	5	131	3.866755	.242	.593		
002126N	1.722645	26.118469	GATE	LIGHT	1	8	189	5.399909				.322
000124T	2.017204	23.711591	GATE	LIGHT	1	15	248	6.791779				.275
000120R	1.828053	22.395743	GATE	CROSSBUCK	1	15	313	8.254221	.269	.660		
003467K	1.433560	21.735409	GATE	LIGHT	1	10	372	9.530089				.387
002081J	1.593919	19.039159	GATE	CROSSBUCK	3	12	437	10.773346			.401	
002090H	1.213653	18.401212	GATE	LIGHT	1	8	496	11.853497				.457
003640K	1.432786	15.377426	GATE	LIGHT	2	27	555	12.756152				.530
002153K	1.295565	15.228955	GATE	LIGHT	1	12	613	13.650092				.428
002087A	1.201883	14.724447	GATE	CROSSBUCK	1	14	679	14.611598	.409	1.003		
000153D	0.959883	14.553589	GATE	LIGHT	1	7	737	15.465894				.578
003566H	0.959014	14.540414	GATE	LIGHT	1	10	796	16.319416				.579
003612G	1.145262	13.462190	GATE	LIGHT	1	32	855	17.109647				.485
002972B	1.030232	12.621522	GATE	CROSSBUCK	1	22	920	17.933832	.477	1.171		
003377L	0.732402	12.541135	LIGHT	CROSSBUCK	1	6	964	18.483134	.671	1.647		
000151P	0.949499	12.504885	GATE	CROSSBUCK	2	7	1029	19.299703			.673	
000206A	0.822920	12.476984	GATE	LIGHT	1	4	1088	20.032102				.674
003263Y	1.125309	12.460830	GATE	LIGHT	2	8	1147	20.763553				.675
003352R	0.943300	12.423245	GATE	CROSSBUCK	2	6	1212	21.574791			.677	
002065A	0.723979	12.396897	LIGHT	CROSSBUCK	1	6	1256	22.117775	.679	1.666		
003289B	0.716477	12.268433	LIGHT	CROSSBUCK	1	6	1300	22.655132	.686	1.683		
002115B	0.791378	11.998740	GATE	LIGHT	1	8	1358	23.359458				.701
003228K	0.700132	11.988570	LIGHT	CROSSBUCK	1	8	1402	23.884557	.702	1.722		
003370N	0.695938	11.916753	LIGHT	CROSSBUCK	1	6	1446	24.406511	.706	1.733		
003639R	1.007746	11.845731	GATE	LIGHT	1	27	1505	25.101855				.551
003268H	0.675789	11.571724	LIGHT	CROSSBUCK	1	10	1548	25.608697	.727	1.784		
002031F	0.734638	11.138470	GATE	LIGHT	1	4	1607	26.262525				.755
003638J	1.031939	11.075324	GATE	LIGHT	2	27	1666	26.912647				.736
003621F	0.931697	10.951807	GATE	LIGHT	1	27	1724	27.555518				.596
002058P	0.634949	10.872416	LIGHT	CROSSBUCK	1	6	1768	28.031730	.774	1.899		
000122E	0.923457	10.854949	GATE	LIGHT	1	15	1827	28.668916				.601
000167L	0.623671	10.679305	LIGHT	CROSSBUCK	1	7	1871	29.136670	.788	1.934		
002085L	0.759922	10.583384	LIGHT	CROSSBUCK	1	14	1915	29.600222	.647	1.587		
002088G	0.899660	10.575224	GATE	LIGHT	1	14	1973	30.220988				.617
003347U	0.797832	10.507439	GATE	CROSSBUCK	2	6	2039	30.907124			.801	
000142R	0.726703	10.120754	LIGHT	CROSSBUCK	1	15	2082	31.350413	.676	1.659		

FIGURE 5-6. SAMPLE OUTPUT FROM RESOURCE ALLOCATION REPORT PROGRAM
(COMBINED CASUALTY INDEX REDUCTION)

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED ACCIDENTS
FOR (STATE)

TOTAL BUDGET: $ 3000000

WARNING DEVICE	P-->FL	P-->G	FL-->G
COST:	$43800.	$65300.	$58700.
STANDARD EFFECTIVENESS VALUES:	.70	.83	.69

CROSSING ID #	PREDICTED ACCIDENTS PER YEAR	ACCIDENT REDUCTION COST RATIO (ACC/$MILL)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	TOTAL # OF TRAINS	CUMULATIVE COST ($THOUSAND)	CUMULATIVE REDUCED ACCIDENTS PER YEAR	DECISION CRITERIA VALUES DC1	DC2	DC3	DC4
002153K	0.622723	7.319916	GATE	LIGHT	1	12	59	0.429679				.294
000118P	0.554902	7.053121	GATE	CROSSBUCK	1	15	124	0.890248	.242	.641		
002126N	0.562409	6.610942	GATE	LIGHT	1	8	183	1.278310				.325
000213K	0.547862	6.439942	GATE	LIGHT	3	4	241	1.656335				.334
002972B	0.494767	6.288769	GATE	CROSSBUCK	1	22	307	2.066992	.272	.719		
002081J	0.414115	5.263638	GATE	CROSSBUCK	3	12	372	2.410708			.408	
000124T	0.439817	5.169916	GATE	LIGHT	1	15	431	2.714182				.416
000120R	0.398576	5.066131	GATE	CROSSBUCK	1	15	496	3.045000	.337	.892		
002087A	0.315651	5.044657	LIGHT	CROSSBUCK	1	14	540	3.265956	.426	1.126		
003395J	0.314638	5.028455	LIGHT	CROSSBUCK	1	5	584	3.486202	.428	1.130		
002778H	0.340831	4.006360	GATE	LIGHT	2	8	642	3.721375				.537
003640K	0.331321	3.894573	GATE	LIGHT	2	27	701	3.949986				.552
003566H	0.315590	3.709656	GATE	LIGHT	1	10	760	4.167743				.580
002973H	0.229986	3.675572	LIGHT	CROSSBUCK	1	22	804	4.328733	.585	1.546		
000223R	0.308170	3.622437	GATE	LIGHT	1	4	862	4.541370				.593
003655A	0.292314	3.436064	GATE	LIGHT	2	27	921	4.743067				.626
002090H	0.289450	3.402388	GATE	LIGHT	1	8	980	4.942787				.632
003648P	0.284528	3.344532	GATE	LIGHT	1	27	1038	5.139111				.643
002121E	0.284186	3.340516	GATE	LIGHT	1	12	1097	5.335199				.644
002085L	0.199579	3.189616	LIGHT	CROSSBUCK	1	14	1141	5.474904	.674	1.781		
002980T	0.194678	3.111284	LIGHT	CROSSBUCK	1	4	1185	5.611178	.691	1.826		
002981A	0.188165	3.007203	LIGHT	CROSSBUCK	1	4	1228	5.742894	.715	1.890		
002773Y	0.249200	2.929270	GATE	LIGHT	7	4	1287	5.914842				.734
002706E	0.248118	2.916552	GATE	LIGHT	1	2	1346	6.086044				.737
003565B	0.180086	2.878095	LIGHT	CROSSBUCK	1	11	1390	6.212105	.747	1.974		
002713P	0.241376	2.837300	GATE	LIGHT	1	4	1448	6.378655				.758
003638J	0.238628	2.804998	GATE	LIGHT	2	27	1507	6.543308				.766
002088G	0.236279	2.777379	GATE	LIGHT	1	14	1566	6.706340				.774
003631L	0.236150	2.775870	GATE	LIGHT	1	27	1624	6.869284				.774
002119D	0.232715	2.735495	GATE	LIGHT	1	12	1683	7.029858				.786
003639R	0.231857	2.725405	GATE	LIGHT	1	27	1742	7.189839				.789
000341T	0.227675	2.676251	GATE	LIGHT	1	4	1801	7.346935				.803
000509J	0.166321	2.658106	LIGHT	CROSSBUCK	1	2	1844	7.463360	.809	2.138		
000151P	0.208373	2.648540	GATE	CROSSBUCK	2	7	1910	7.636310			.812	
003229S	0.223212	2.623791	GATE	LIGHT	5	11	1968	7.790327				.819
000206A	0.221769	2.606825	GATE	LIGHT	1	4	2027	7.943348				.825
000692S	0.162082	2.590352	LIGHT	CROSSBUCK	1	1	2071	8.056805	.830	2.194		
003612G	0.219486	2.579988	GATE	LIGHT	1	32	2130	8.208250				.833
003538E	0.218659	2.570263	GATE	LIGHT	2	14	2188	8.359124				.836
000196W	0.158062	2.526099	LIGHT	CROSSBUCK	1	2	2232	8.469767	.851	2.249		
002124A	0.213592	2.510703	GATE	LIGHT	1	8	2291	8.617145				.856
003467K	0.210632	2.475912	GATE	LIGHT	1	10	2349	8.762481				.868
000153D	0.209582	2.463569	GATE	LIGHT	1	7	2408	8.907093				.873
003232A	0.209341	2.460742	GATE	LIGHT	5	9	2467	9.051539				.874

FIGURE 5-7. SAMPLE OUTPUT FROM RESOURCE ALLOCATION REPORT PROGRAM
(ACCIDENT REDUCTION, STANDARD EFFECTIVENESS VALUES)

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED ACCIDENTS
FOR (STATE)

TOTAL BUDGET: $ 3000000

WARNING DEVICE	P-->FL	P-->G	FL-->G
COST:	$43800.	$65300.	$58700.

EXTENDED EFFECTIVENESS VALUES:

	TRAINS <= 10		TRAINS >= 11	
UPGRADE OPTION	SINGLE TRACK	MULTIPLE TRACK	SINGLE TRACK	MULTIPLE TRACK
PASSIVE - FL	.75	.65	.61	.57
PASSIVE - G	.90	.86	.80	.78
FLASHING - G	.89	.65	.69	.63

CROSSING ID #	PREDICTED ACCIDENTS PER YEAR	ACCIDENTS REDUCTION COST RATIO (ACC/$MILL)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	TOTAL # OF TRAINS	CUMULATIVE COST ($THOUSAND)	CUMULATIVE REDUCED ACCIDENTS PER YEAR	DECISION CRITERIA VALUES DC1	DC2	DC3	DC4	MEETS STOP SIGN RQMNT
002126N	0.562409	8.527157	GATE	LIGHT	1	8	59	0.500544				.282	NO
002153K	0.622723	7.319916	GATE	LIGHT	1	12	117	0.930223				.254	NO
000118P	0.554902	6.798189	GATE	CROSSBUCK	1	15	183	1.374145	.253	.820			NO
000213K	0.547862	6.066812	GATE	LIGHT	3	4	241	1.730255				.396	NO
002972B	0.494767	6.061464	GATE	CROSSBUCK	1	22	307	2.126069	.283	.896			NO
003395J	0.314638	5.387630	LIGHT	CROSSBUCK	1	5	351	2.362047	.446	1.094			NO
000124T	0.439817	5.169916	GATE	LIGHT	1	15	409	2.665521				.360	NO
002081J	0.414115	4.946551	GATE	CROSSBUCK	3	12	475	2.988531			.440		NO
000120R	0.398576	4.883017	GATE	CROSSBUCK	1	15	540	3.307392	.352	.864			YES
003566H	0.315590	4.784919	GATE	LIGHT	1	10	599	3.588267				.502	NO
000223R	0.308170	4.672418	GATE	LIGHT	1	4	657	3.862538				.514	NO
002087A	0.315651	4.396058	LIGHT	CROSSBUCK	1	14	701	4.055085	.444	1.091			NO
002090H	0.289450	4.388587	GATE	LIGHT	1	8	760	4.312695				.547	NO
002778H	0.340831	3.774107	GATE	LIGHT	2	8	818	4.534235				.636	NO
002706E	0.248118	3.761930	GATE	LIGHT	1	2	877	4.755060				.638	NO
002713P	0.241376	3.659706	GATE	LIGHT	1	4	936	4.969885				.656	NO
003640K	0.331321	3.555914	GATE	LIGHT	2	27	995	5.178617				.655	NO
000341T	0.227675	3.451976	GATE	LIGHT	1	4	1053	5.381248				.696	NO
000206A	0.221769	3.362426	GATE	LIGHT	1	4	1112	5.578622				.714	NO
003648P	0.284528	3.344532	GATE	LIGHT	1	27	1171	5.774946				.557	NO
002121E	0.284186	3.340516	GATE	LIGHT	1	12	1229	5.971034				.557	NO
002980T	0.194678	3.333519	LIGHT	CROSSBUCK	1	4	1273	6.117042	.720	1.768			NO
002124A	0.213592	3.238443	GATE	LIGHT	1	8	1332	6.307139				.742	NO
002981A	0.188165	3.222003	LIGHT	CROSSBUCK	1	4	1376	6.448263	.745	1.829			NO
002973H	0.229986	3.202899	LIGHT	CROSSBUCK	1	22	1419	6.588554	.610	1.497			NO
003467K	0.210632	3.193567	GATE	LIGHT	1	10	1478	6.776016				.752	NO
000153D	0.209582	3.177647	GATE	LIGHT	1	7	1537	6.962544				.756	NO
003655A	0.292314	3.137275	GATE	LIGHT	2	27	1596	7.146702				.742	NO
002125G	0.205480	3.115458	GATE	LIGHT	1	8	1654	7.329579				.771	NO
002734H	0.191866	2.909045	GATE	LIGHT	1	6	1713	7.500340				.826	NO
002115B	0.188739	2.861632	GATE	LIGHT	1	8	1772	7.668318				.839	NO
000509J	0.166321	2.847971	LIGHT	CROSSBUCK	1	2	1815	7.793059	.843	2.070			NO
002085L	0.199579	2.779522	LIGHT	CROSSBUCK	1	14	1859	7.914802	.703	1.725			NO
002088G	0.236279	2.777379	GATE	LIGHT	1	14	1918	8.077834				.670	NO
003631L	0.236150	2.775870	GATE	LIGHT	1	27	1977	8.240778				.671	NO
000692S	0.162082	2.775377	LIGHT	CROSSBUCK	1	1	2020	8.362340	.865	2.124			NO
000233W	0.182885	2.772870	GATE	LIGHT	1	4	2079	8.525107				.866	NO

FIGURE 5-8. SAMPLE OUTPUT FROM RESOURCE ALLOCATION REPORT PROGRAM

(ACCIDENT REDUCTION, STOP SIGN CANDIDATE INDICATION)

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
POSSIBLE CANDIDATE CROSSINGS FOR STANDARD HIGHWAY
STOP SIGNS FOR (STATE)
* ALL CANDIDATES ARE SINGLE TRACK LOCAL HIGHWAY CROSSINGS

-REFER TO PARAGRAPH 8B-9 OF THE MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES FOR FACTORS TO BE CONSIDERED PRIOR TO MAKING STOP SIGN INSTALLATION DECISIONS

CROSSING ID #	PREDICTED ACCIDENTS PER YEAR	PRESENT WARNING DEVICE	TOTAL TRAINS PER DAY	ANNUAL AVERAGE DAILY TRAFFIC	CROSSING LOCATION URBAN/RURAL
000120R	0.398576	CROSSBUCK	15	1130	URBAN
000142R	0.134108	CROSSBUCK	15	150	RURAL
000139H	0.097773	CROSSBUCK	15	150	RURAL
000114M	0.087151	CROSSBUCK	24	830	URBAN
000115U	0.049283	CROSSBUCK	24	400	URBAN
000130W	0.047232	CROSSBUCK	15	100	RURAL
000129C	0.032680	CROSSBUCK	15	160	RURAL
000149N	0.028619	CROSSBUCK	15	100	RURAL
000148G	0.028619	CROSSBUCK	15	100	RURAL
003514R	0.027217	CROSSBUCK	26	5	RURAL
000143X	0.026842	CROSSBUCK	15	80	RURAL
003512C	0.023792	CROSSBUCK	26	20	RURAL
003513J	0.019360	CROSSBUCK	26	10	RURAL
003508M	0.019360	CROSSBUCK	26	10	RURAL
003590J	0.014427	CROSSBUCK	25	5	RURAL

FIGURE 5-9. SAMPLE OUTPUT FROM STOP SIGN PROGRAM
(PREDICTED ACCIDENTS)

REFERENCES

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3. Mengert, P., Rail-Highway Crossing Hazard Prediction Research Results, FRA-RRS-80-02 (Washington, D.C.: U.S. Department of Transportation, March 1980).

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5. Farr, E., "Rail-Highway Crossing Resource Allocation Model," FRA-RRS-81-001 (Washington, D.C.: U.S. Department of Transportation, April 1981).

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7. Association of American Railroads, "Results of Maintenance Cost Study of Railroad-Highway Grade Crossing Warning Systems, Communications Signal Division." Annual Meeting, October 1982.

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12. Manual on Uniform Traffic Control Devices, Sec. 8B-9, U.S. DOT, FHWA, 1983.

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14. Miller, T. et. al., "Alternative Approaches to Accident Cost Concepts: State of the Art," FHWA/RD-83/079, (Washington, D.C.: U.S. Department of Transportation, January 1984.)

APPENDIX A

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C*************************************************************************
C*
C*              THIS PROGRAM CALCULATES PREDICTED ACCIDENTS USING
C*              THE BASIC FORMULA AND THE ACCIDENT HISTORY FORMULA.
C*              ADDITIONALLY, PREDICTED FATAL ACCIDENTS, INJURY
C*              ACCIDENTS AND A COMBINED CASUALTY INDEX ARE ALSO
C*              CALCULATED AND INCLUDED IN THIS OUTPUT. THE FATAL
C*              AND INJURY ACCIDENTS ALONG WITH COMBINED CASUALTY INDEX ARE
C*              COMPUTED BY  THE SUBROUTINE CASLTY.
C*
C*              INPUT MUST BE IN THE 54 CHARACTER FORMAT PLUS
C*              SEVEN YEARS OF ACCIDENT HISTORY.
C*              TOTAL CHARACTERS PER RECORD IS 68.
C*
C*              UNIT 23 - INVENTORY INPUT FILE
C*              UNIT 20 - INVENTORY OUTPUT FILE WITH BASIC PRED. ACC.,
C*                        FINAL PRED. ACC., ALSO FATAL AND INJURY
C*                        ACCIDENTS ALONG WITH COMBINED CASULTY
C*                        INDEX.
C*              UNIT  5 - SUMMARY OUTPUT FILE
C*
C*************************************************************************
C
C
        PARAMETER AH=7             ! # OF YEARS OF ACCIDENT HISTORY AVAILABLE
C                                    MUST CHANGE IF UPDATED
C
        INTEGER ITEM1(5),YEAR,MONTH,OLDCL,NEWCL,NS,NT,DS,DT,SPEED
        INTEGER MTRKS,OTRKS,ITEM2,PAVE,LANES,FC10,FC1,AADT
        INTEGER ITEM3,ACC(AH),NREC,T,C,D,CLASS,TRAINS,TRACKS
        INTEGER THRU,SWITCH,URBAN(9),RURAL(9),HT,K,TA,CURYER,INDEX
        INTEGER OFFSET,I
C
        REAL HTOT,FTOT,CTOT,ITOT,ATOT,XT1,XT2,XT3,XT4,XT5,XT6,X,H
        REAL EFFECT(12),EFF(6),N,TO,A,FATALK,FATAL,INJURY,CMBCAS
C
        COMMON/FATCOM/SPEED,THRU,SWITCH,FC10,A,TRACKS,FATALK
        COMMON/FATC2/FATAL,INJURY,CMBCAS
C
        DATA CURYER/82/            ! YEAR OF MOST CURRENT DATA - MUST CHANGE
C                                     IF UPDATED
C
        DATA FATALK/50.0/
        DATA (EFFECT(I),I=1,6)/.75,.90,.89,.61,.80,.69/
        DATA (EFFECT(I),I=7,12)/.65,.86,.65,.57,.78,.63/
        DATA (RURAL(I),I=1,9)/1,2,0,0,0,3,4,5,6/
        DATA (URBAN(I),I=1,9)/1,2,0,3,0,4,5,0,6/
C
C
C*************************************************************************
           OPEN(UNIT=23,FILE='ACP.DAT')
C
C
        NREC=0
        HTOT=0.0
        FTOT=0.0
        CTOT=0.0
        ITOT=0.0
        ATOT=0.0
C*
C*           READ DATA FROM TAPE
C*
00100   READ(23,1000,END=900) ITEM1,YEAR,MONTH,OLDCL,NEWCL,STOPS,NS,NT,
     *       DS,DT,SPEED,MTRKS,OTRKS,ITEM2,PAVE,LANES,FC10,FC1,
     *       AADT,ITEM3,ACC
01000   FORMAT(5A4,2I2,3I1,4I2,I3,I1,I2,A1,4I1,I6,A2,7I2)

C
C
C
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM

```
      TRAINS=NS+NT+DS+DT
      TRACKS=MTRKS+OTRKS
      THRU=NT+DT
      SWITCH=NS+DS
      T=TRAINS
      C=AADT
      D=DT
      CLASS=NEWCL
C
C
C*    ***********************************
C*    *  CALCULATE BASIC PREDICTED      *
C*    *          ACCIDENTS              *
C*    ***********************************
C
C
      IF(YEAR.GT.77) CLASS=OLDCL
      IF(OLDCL.EQ.9) CLASS=NEWCL
      GO TO (200,200,200,200,300,300,300,400),CLASS
      GO TO 100
C
C
C              CROSSBUCKS EQUATION
C
C*
C*             DETERMINE HIGHWAY TYPE AND URBAN/RURAL
C*
 200  IF(FC1.EQ.0) GO TO 220
      IF(FC10.NE.0) GO TO 210
      HT=RURAL(FC1)
      GO TO 230
 210  IF(FC10.NE.1) GO TO 220
      HT=URBAN(FC1)
      GO TO 230
 220  HT=0
C*
C*            EQUATION
C*
 230  XT1=0.3839*ALOG10(C*T+0.2)  ! EXPOSURE INDEX FACTOR
      XT2=0.1538*ALOG10(D+0.2)    ! THRU TRAIN FACTOR
      XT3=0.3080*PAVE             ! HIGHWAY PAVED FACTOR
      XT4=0.003855*SPEED          ! SPEED FACTOR
      XT5=0.04991*HT              ! HIGHWAY TYPE FACTOR
      XT6=0.1047*TRACKS           ! TRACKS FACTOR
      X=XT1+XT2-XT3+XT4-XT5+XT6
      H=0.00984*EXP(2*X)
      GO TO 500
C
C
C              FLASHING LIGHTS EQUATION
C
 300  XT1=0.3400*ALOG10(C*T+0.2)  ! EXPOSURE INDEX FACTOR
      XT2=0.05415*ALOG10(D+0.2)   ! THRU TRAIN FACTOR
      XT3=0.05442*TRACKS          ! TRACKS FACTOR
      XT4=0.06900*LANES           ! NUMBER HIGHWAY LANES FACTOR
      X=XT1+XT2+XT3+XT4
      H=0.00551*EXP(2*X)
      GO TO 500
C
C
C              GATES EQUATION
C
 400  XT1=0.3588*ALOG10(C*T+0.2)  ! EXPOSURE INDEX FACTOR
      XT2=0.1456*TRACKS           ! TRACKS FACTOR
      XT3=0.05180*LANES           ! NUMBER HIGHWAY LANES FACTOR
      X=XT1+XT2+XT3
      H=0.00162*EXP(2*X)
C
C
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (Cont.)

```
C*      ************************************************
C*      *                                              *
C*      *  MODIFY FOR UPGRADES/DOWNGRADES BY EFFECTIVENESS *
C*      *                                              *
C*      ************************************************
C
C*
C*              CALCULATE WHICH EFFECTIVENESS VALUES TO USE
C*
 500    IF(CLASS.EQ.NEWCL) GO TO 600
        OFFSET=0
        IF(TRACKS.GT.1) GOTO 425
        IF(TRAINS.GE.11) OFFSET=3
        GOTO 450
C
 425    OFFSET=6
        IF(TRAINS.GE.11) OFFSET=9
C*
C*              CALCULATE UPGRADE/DOWNGRADE EFFECTIVENESS VALUES
C*
 450    DO 475 INDEX=1,3
        EFF(INDEX)=1-EFFECT(INDEX+OFFSET)       ! UPGRADE VALUES
 475    EFF(INDEX+3)=1/EFF(INDEX)               ! DOWNGRADE VALUES
C*
C*              MODIFY FOR UPGRADE/DOWNGRADE
C*
        IF(OLDCL.GT.NEWCL) GO TO 550
        K=2
        IF(NEWCL.NE.8) K=1
        IF(OLDCL.GT.4) K=3
        GO TO 555
 550    K=5
        IF(OLDCL.NE.8) K=4
        IF(NEWCL.GT.4) K=6
 555    H=H*EFF(K)


C*      *******************************************
C*      *                                         *
C*      *  CALCULATE FINAL PREDICTED ACCIDENTS    *
C*      *                                         *
C*      *******************************************



C
C
C*              CALCULATE NUMBER OF ACCIDENT DATA YEARS
C
 600    TA=CURYER-YEAR
        IF(TA.LT.0) TA=0
        IF(TA.GT.5) TA=5
        T=TA
C
C
C*              CALCULATE NUMBER OF ACCIDENTS
C
        N=0.
        IF(TA.EQ.0) GO TO 800
        DO 700 INDEX=AH,(AH-TA+1),-1
 700    N=N+ACC(INDEX)
C
C
C*              CALCULATE FINAL PREDICTED ACCIDENTS
C
 800    TO=1./(.05+H)
        A=(H*TO+N)/(T+TO)
C
C
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (Cont.)

```
C*       *******************************************
C*       *                                         *
C*       *  CALCULATE CASUALTY ACCIDENTS AND INDEX  *
C*       *                                         *
C*       *******************************************
C
         CALL CASLTY
C
C
C
C                  ACCUMULATE RECORD TOTALS
C
C
         HTOT=HTOT+H
         FTOT=FTOT+FATAL
         ITOT=ITOT+INJURY
         CTOT=CTOT+CMBCAS
         ATOT=ATOT+A
         NREC=NREC+1
C
C                  WRITE DATA TO OUTPUT FILE
C
         WRITE(20,2000) FATAL,INJURY,CMBCAS,A,H,ITEM1,YEAR,MONTH,OLDCL,
     *            NEWCL,STOPS,NS,NT,DS,DT,SPEED,MTRKS,OTRKS,ITEM2,
     *            PAVE,LANES,FC10,FC1,AADT,ITEM3,ACC
02000    FORMAT(5F10.7,5A4,2I2,3I1,4I2,I3,I1,I2,A1,4I1,I6,A2,7I2)
C
C
         GO TO 100
C
C
C
C
C*       ****************************************
C*       *                                      *
C*       *  WRITE TOTALS TO TTY AND EXIT PROGRAM *
C*       *                                      *
C*       ****************************************
C
 900     WRITE(5,3500) FTOT,ITOT,CTOT,HTOT,ATOT,NREC
 3500    FORMAT(' TOTAL FATAL PREDICTED ACCIDENTS  =   ',F10.3 /
     *          ' TOTAL INJURY PREDICTED ACCIDENTS =   ',F10.3 /
     *          ' TOTAL COMBINED CASUALTY INDEX    =   ',F10.3 /
     *          ' TOTAL BASIC PREDICTED ACCIDENTS  =   ',F10.3 /
     *          ' TOTAL FINAL PREDICTED ACCIDENTS  =   ',F10.3 /
     *          ' TOTAL NUMBER OF CROSSINGS  =  ',I6)
C
         CLOSE(UNIT=23)
         CALL EXIT
C
         END
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (Cont.)

```
      SUBROUTINE CASLTY
C*************************************************************
C*
C*
C*    THIS SUBROUTINE CALCULATES PREDICTED FATAL
C*    ACCIDENTS ,INJURY ACCIDENTS AND THE COMBINED
C*    CASUALTY INDEX USING THE PREDICTED ACCIDENT
C*    VALUE CALCULATED IN THE CALLING PROGRAM AND
C*    VARIABLES PASSED THROUGH A COMMON STATEMENT.
C*
C*
C*************************************************************
C
C
C
      INTEGER TRACKS,THRU,SWITCH,SPEED,FC10
      REAL A,CI,CF,MS,TT,TS,UR,URB,FATL,FATAL,FATPRB
      REAL TRK,TK,INJ,INJURE,INJURY,CMBCAS,INJPRB
C
      COMMON/FATCOM/SPEED,THRU,SWITCH,FC10,A,TRACKS,FATALK
      COMMON/FATC2/FATAL,INJURY,CMBCAS
C
      DATA CI/4.280/          ! INJURY CONSTANT
      DATA CF/695.0/          ! FATALITY CONSTANT
C
C
C*************************************************************
C
C
C              FATAL ACCIDENT FORMULA
C
 100  MS=POWER(SPEED,-1.074)           ! SPEED FACTOR
      TT=POWER(THRU+1,-0.1025)         ! THRU TRAIN FACTOR
      TS=POWER(SWITCH+1,0.1025)        ! SWITCH TRAIN FACTOR
      URB=0.1880*FC10
      UR=EXP(URB)                      ! URBAN/RURAL FACTOR
      FATL=1+(CF*MS*TT*TS*UR)
      FATPRB=1/FATL                    ! FATAL ACC. PROB.  GIVEN AN ACC
      FATAL=FATPRB*A                   ! PRED. FATAL ACCIDENTS
C
C
C
C              INJURY ACCIDENT FORMULA
C
 200  MS=POWER(SPEED,-0.2334)          ! SPEED FACTOR
      TRK=0.1176*TRACKS
      TK=EXP(TRK)                      ! TRACKS FACTOR
      URB=0.1844*FC10
      UR=EXP(URB)                      ! URBAN/RURAL FACTOR
      INJ=1+(CI*MS*TK*UR)
      INJURE=1-FATPRB
      INJPRB=INJURE/INJ                ! INJURY ACC. PROB. GIVEN AN ACC.
      INJURY=INJPRB*A                  ! PRED. INJURY ACCIDENTS
      CMBCAS=INJURY+FATAL*FATALK       ! PRED. COMBINED CASUALTY INDEX
C
C
 300  RETURN
C
      END
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (Cont.)

```
      REAL FUNCTION POWER(BASE,EXPON)
C*******************************************
C*
C*
C*    THIS FUNCTION EXPONENTIATES THE
C*    GIVEN BASE TO THE GIVEN
C*    POWER AND RETURNS.
C*
C*
C*******************************************
C
C
      INTEGER BASE
      REAL EXPON
C
C
C*******************************************
C
C
      POWER=BASE**EXPON
C
      RETURN
C
      END
```

EXHIBIT A-1. ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (Cont.)

VARIABLE NAME	VARIABLE TYPE	DEFINITION
A	R	FINAL PREDICTED ACCIDENTS PER YEAR
AADT	I	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC
ACC	I	ACCIDENT HISTORY FOR 1976 THRU 1982
AH	I	NUMBER YEARS OF ACCIDENT HISTORY INPUT
ATOT	R	TOTAL PREDICTED ACCIDENTS FOR RUN
BASE	I	BASE NUMBER
C	R	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC
CURYER	I	YEAR OF MOST RECENT ACCIDENT HISTORY DATA
CF	R	FATALITY CONSTANT USED IN CALCULATING PREDICTED FATAL ACCIDENTS
CI	R	INJURY CONSTANT USED IN CALCULATING PREDICTED INJURY ACCIDENTS
CLASS	I	WARNING DEVICE CLASS USED TO CALCULATE H
CMBCAS	R	PREDICTED COMBINED CASUALTY INDEX
CTOT	R	TOTAL PREDICTED COMBINED CASUALTY INDEX FOR RUN
D	I	NUMBER OF DAYLIGHT THRU TRAINS
DT	I	NUMBER OF DAYLIGHT THRU TRAINS
DS	I	NUMBER OF DAYLIGHT SWITCH TRAINS
EFF	R	EFFECTIVENESS MULTIPLIERS UPGRADE/DOWNGRADE
EFFECT	R	12 EXTENDED EFFECTIVENESS VALUES
EXPON	R	POWER TO WHICH BASE IS RAISED
FATAL	R	PREDICTED FATAL ACCIDENTS PER YEAR
FATPRB	R	FATAL ACCIDENT PROBABILITY GIVEN AN ACCIDENT
FATALK	R	WEIGHTING FACTOR USED TO CALCULATE COMBINED CASUALTY INDEX
FC1	I	UNITS DIDGET OF FUNCTIONAL CLASSIFICATION OF ROAD
FC10	I	TENS DIDGET OF FUNCTIONAL CLASSIFICATION OF ROAD
FTOT	R	TOTAL PREDICTED FATAL ACCIDENTS FOR RUN
H	R	BASIC PREDICTED ACCIDENTS PER YEAR = a
HT	I	HIGHWAY TYPE FACTOR
HTOT	R	TOTAL BASIC PREDICTED ACCIDENTS FOR RUN
I	I	DO LOOP INDEX
INDEX	I	DO LOOP INDEX
INJURY	R	PREDICTED INJURY ACCIDENTS PER YEAR
INJPRB	R	INJURY ACCIDENT PROBABILITY GIVEN AN ACCIDENT
ITEM1	A	HOLDS DATA THAT IS INPUT AND OUTPUT ONLY
ITEM2	A	HOLDS DATA THAT IS INPUT AND OUTPUT ONLY
ITEM3	A	HOLDS DATA THAT IS INPUT AND OUTPUT ONLY
ITOT	R	TOTAL PREDICTED INJURY ACCIDENTS FOR RUN
K	I	CATEGORY OF UPGRADE/DOWNGRADE 1: PASSIVE TO FLASHING LIGHTS 2: PASSIVE TO GATES 3: FLASHING LIGHTS TO GATES 4: FLASHING LIGHTS TO PASSIVE 5: GATES TO PASSIVE 6: GATES TO FLASHING LIGHTS
LANES	I	NUMBER OF HIGHWAY LANES

EXHIBIT A-2. VARIABLE DICTIONARY ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINITION
MONTH	I	MONTH OF CHANGE IN WARNING DEVICE
MTRKS	I	NUMBER OF MAIN TRACKS
MS	R	SPEED FACTOR CALCULATION
N	I	NUMBER OF ACCIDENTS IN T YEARS
NEWCL	I	PRESENT WARNING DEVICE CLASS
NREC	I	TOTAL NUMBER CROSSINGS IN RUN
NS	I	NUMBER OF NIGHT SWITCH TRAINS
NT	I	NUMBER OF NIGHT THRU TRAINS
OFFSET	I	VALUE DETERMINES SET OF EXTENDED EFFECTIVENESS VALUES USED
OTRKS	I	NUMBER OF OTHER TRACKS
OLDCL	I	FORMER WARNING DEVICE
PAVE	I	IS HIGHWAY PAVED? 1: YES, 2: NO
RURAL	I	LOOKUP TABLE FOR RURAL HIGHWAY TYPES
SPEED	I	MAXIMUM TIMETABLE TRAIN SPEED
STOPS	I	NUMBER OF STANDARD STOP SIGNS ON SITE
SWITCH	I	NUMBER OF SWITCH TRAINS
T	I	NUMBER OF YEARS OF ACCIDENT HISTORY USED IN CALCULATING PRED. ACC.
THRU	I	NUMBER OF THRU TRAINS
TK	R	TRACKS FACTOR CALCULATION
TO	R	1/(.05+H) WEIGHTING FACTOR USED IN ACCIDENT PRED. FORMULA
TRAINS	I	NUMBER OF TRAINS
TRACKS	I	NUMBER OF TRACKS
TS	R	SWITCH TRAIN FACTOR
TT	R	THRU TRAIN FACTOR
UR	R	URBAN RURAL FACTOR
URBAN	I	LOOKUP TABLE FOR URBAN HIGHWAY TYPES
YEAR	I	YEAR OF CHANGE IN WARNING DEVICE CLASS

EXHIBIT A-2. VARIABLE DICTIONARY ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM (CONT)

```
ID NUMBER | STATE | COUNTY | CITY | RAILROAD | UPGRADE YEAR | UPGRADE MONTH | FORMER CLASS | PRESENT CLASS | STOP SIGNS PRESENT | NIGHT SWITCH TRNS. | NIGHT THRU TRNS. | DAY SWITCH TRNS. | DAY THRU TRNS. | SPEED | MAIN TRACKS | OTHER TRACKS | AMTRAK | PAVED | LANES | FUNC. CLASS | AADT | % TRACK | 76 ACC. | 77 ACC. | 78 ACC. | 79 ACC. | 80 ACC. | 81 ACC. | 82 ACC.

000101L390958120MIRR7001040 0 0 1 0  61 021219  506206 0 0 0 0 0 0 0
000102T390958120MIRR7001040 0 0 1 0  61 021219  347406 0 0 0 0 0 0 0
000105N390958120MIRR7001040 0 0 1 0  61 021219   90906 0 0 0 0 0 0 0
000106V390958120MIRR7001070 0 0 2 0  61 021216  661806 0 0 0 0 0 0 0
000108J390958120MIRR7001080 116 116 252 021216  661806 0 1 0 0 0 0 0
000110K390958120MIRR7001080 719 719 252 021216  463206 0 0 0 0 0 0 0
000112Y390958120MIRR7001080 015 015 252 021217  243506 0 0 0 0 0 0 0
000114M390958120MIRR7001040 012 012 451 021219   83006 0 0 0 0 0 0 0
000115U261154840MIRR7001040 012 012 451 022219   40005 0 0 0 0 0 0 0
000118P261154840MIRR7001040 0 7 0 8 451 021217  175006 0 0 0 4 0 0 0
000119W261154840MIRR7001070 0 7 0 8 451 021216  360007 0 0 0 0 0 0 0
000120R261154840MIRR7001040 0 7 0 8 451 021219  113005 0 0 1 1 0 0 1
000122E261154840MIRR7001070 0 7 0 8 451 021217  261008 0 0 0 1 0 0 0
000124T261154840MIRR7001070 0 7 0 8 451 021216  353007 0 0 0 2 0 0 1
000125A261154840MIRR7001040 0 7 0 8 451 021217   49006 0 0 0 0 0 0 0
000126G261154434MIRR7001070 0 7 0 8 451 121207  296007 0 0 0 0 0 0 0
000128V261154434MIRR7001042 0 7 0 8 451 021209   59005 0 0 0 0 0 0 0
000129C261154434MIRR7001040 0 7 0 8 451 022209   16005 0 0 0 0 0 0 0
000130W261154434MIRR7001040 0 7 0 8 451 021209   10005 0 0 0 0 0 0 0
000132K261154434MIRR7001042 0 7 0 8 451 021209   24005 0 0 0 0 0 0 0
000134Y261154434MIRR7001042 0 7 0 8 451 021208   53006 0 0 0 0 0 0 0
000139H261151340MIRR7001040 0 7 0 8 451 022209   15005 0 0 0 1 0 0 0
000140C261151340MIRR7001042 0 7 0 8 451 021209   17005 0 0 0 0 0 0 0
000142R261151340MIRR7001040 0 7 0 8 451 021209   15005 0 0 1 0 0 0 0
000143X261151340MIRR7001040 0 7 0 8 451 022209    8005 0 0 0 0 0 0 0
000146T261151340MIRR7001070 0 7 0 8 451 021207  193007 0 0 0 0 0 0 0
000148G261151340MIRR7001040 0 7 0 8 451 022209   10005 0 0 0 0 0 0 0
000149N261151340MIRR7001040 0 7 0 8 451 022209   10005 0 0 0 0 0 0 0
000151P261151340MIRR7001040 0 3 0 4 401 121209   20005 0 0 1 0 0 0 1
000152W261151340MIRR7001040 0 3 0 4 401 021209   10005 0 0 0 0 0 0 0
000153D261151340MIRR7001070 0 3 0 4 401 021206  850009 0 0 0 0 1 0 0
000154K261151340MIRR7001070 0 3 0 4 401 121208  170006 0 0 0 0 0 0 0
000155S261151340AA  7001040 0 0 0 0 400 121209   44005 0 0 0 0 0 0 0
000156Y261151340AA  7001040 0 0 0 0 400 121209   40005 0 0 0 0 0 0 0
000158M261151340MIRR7001040 0 3 0 4 401 022209   10005 0 0 0 0 0 0 0
000159U261151340MIRR7001040 0 3 0 4 401 022209    6005 0 0 0 0 0 0 0
000160N261151340MIRR7001040 0 3 0 4 401 022209    6005 0 0 0 0 0 0 0
000163J261150239MIRR7001040 0 3 0 4 401 022209    7005 0 0 0 0 0 0 0
000164R261150239MIRR7001060 0 3 0 4 401 021207   67006 0 0 0 0 0 0 0
000165X261150239MIRR7001040 0 3 0 4 401 022109   10005 0 0 0 0 0 0 0
000167L261150239MIRR7001040 0 3 0 4 401 022209   12005 0 0 2 0 0 0 0
000170U261150239MIRR7001040 0 3 0 4 401 022209   10005 0 0 0 0 0 0 0
000171B261153250MIRR7001040 0 3 0 4 401 022209   15005 0 0 0 1 0 0 0
000172H261153250MIRR7001070 0 1 0 1 251 021217   12006 0 0 0 0 0 0 0
000174W261153250MIRR7001070 0 1 0 1 251 021219   10005 0 0 0 0 0 0 0
000175D261153250MIRR7001040 0 1 0 1 251 221216   12007 0 0 0 1 0 0 0
000176K261613250MIRR7001070 0 2 0 2 451 021207   12007 0 0 0 0 0 0 0
000177S261613250MIRR7001042 0 2 0 2 451 022209    5005 0 0 0 0 0 0 0
000181G261613250MIRR7001042 0 2 0 2 451 022208    8006 0 0 0 0 0 0 0
000182N261613250MIRR7001042 0 2 0 2 451 021209    8005 0 0 0 0 0 0 0
000183V261613250MIRR7001070 0 2 0 2 451 021207  134007 0 0 0 0 0 0 0
000184C261613250MIRR7001040 0 2 0 2 451 022209    6005 0 0 0 0 0 0 0
000186R261613250MIRR7001070 0 2 0 2 451 021207   10007 0 0 0 0 0 0 0
000187X261613250MIRR7001042 0 2 0 2 451 022209    9005 0 0 0 0 0 0 0
000190F261610150MIRR7001042 0 2 0 2 451 022209    4005 0 0 0 0 0 0 0
000192U261610150MIRR7001042 0 2 0 2 451 022208   18006 0 0 0 0 0 0 0
000193B261610150MIRR7001042 0 2 0 2 451 022209    4005 0 0 0 0 0 0 0
000194H261610150AA  7001040 0 1 0 1  51 022209    5005 0 0 0 0 0 0 0
000195P261614430AA  7001040 0 1 0 1  51 022209    5005 0 0 0 0 0 0 0
000196W261614430AA  7001040 0 1 0 1 151 021207  700007 0 0 0 0 1 0 0
000198K261614430AA  7001010 0 0 0 0  50 121209   50005 0 0 0 0 0 0 0
000199S261614430AA  7001042 0 1 0 1 151 022208   20006 0 0 0 0 0 0 0
000202X261614430AA  7001040 0 1 0 1  51 021209   15005 0 0 0 0 0 0 0
000203E261614430AA  7001040 0 1 0 1  51 021209  273005 0 0 0 0 0 0 0
000204L261614430AA  7001040 0 0 0 0 451 121207 1138007 0 0 0 0 0 0 0
```

EXHIBIT A-3. SAMPLE INPUT TO ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM

DATA FIELD	COLUMN	LENGTH	DATA TYPE*	FIELD DESCRIPTION
1	1	7	A	CROSSING ID NUMBER
2	8	2	I	STATE FIPS CODE
3	10	3	I	COUNTY FIPS CODE
4	13	4	I	CITY FIPS CODE
5	17	4	A	FRA RAILROAD CODE
6	21	4	I	YEAR AND MONTH OF LAST CHANGE IN WARNING DEVICE
7	25	1	I	FORMER WARNING DEVICE CLASS
8	26	1	I	PRESENT WARNING DEVICE CLASS
9	27	1	I	STANDARD STOP SIGNS
10	28	2	I	NUMBER NIGHT SWITCH TRAINS
11	30	2	I	NUMBER NIGHT THRU TRAINS
12	32	2	I	NUMBER DAYLIGHT SWITCH TRAINS
13	34	2	I	NUMBER DAYLIGHT THRU TRAINS
14	36	3	I	MAXIMUM TIMETABLE TRAIN SPEED
15	39	1	I	NUMBER MAIN TRACKS
16	40	2	I	NUMBER OTHER TRACKS
17	42	1	I	DO PASSENGER TRAINS OPERATE OVER CROSSING? -- 1: YES 2: NO
18	43	1	I	IS HIGHWAY PAVED? -- 1: YES, 2: NO
19	44	1	I	NUMBER OF TRAFFIC LANES
20	45	2	I	FUNCTIONAL CLASSIFICATION OF ROAD
21	47	6	I	ESTIMATED ANNUAL AVERAGE DAILY TRAFFIC
22	53	2	I	ESTIMATED PERCENT TRUCK TRAFFIC
23	55	2	I	NUMBER OF ACCIDENTS IN 1976
24	57	2	I	NUMBER OF ACCIDENTS IN 1977
25	59	2	I	NUMBER OF ACCIDENTS IN 1978
26	61	2	I	NUMBER OF ACCIDENTS IN 1979
27	63	2	I	NUMBER OF ACCIDENTS IN 1980
28	65	2	I	NUMBER OF ACCIDENTS IN 1981
29	67	2	I	NUMBER OF ACCIDENTS IN 1982

*DATA TYPE:

A - Alphanumeric
I - Integer

EXHIBIT A-4. INPUT DATA FIELD DESCRIPTION FOR THE ACCIDENT AND CASUALTY PREDICTION PROGRAM

PREDICTED FATAL ACCIDENTS	INJURY INDEX	COMBINED CASUALTY INDEX	FINAL PREDICTED ACCIDENTS	BASIC PREDICTED ACCIDENTS / ID NUMBER / STATE / COUNTY / CITY / RAILROAD / UPGRADE YEAR	UPGRADE MONTH / FORMER CLASS / PRESENT CLASS / STOP SIGNS PRESENT	NIGHT SWITCH TRNS.	NIGHT THRU. TRANS.	DAY SWITCH TRANS.	DAY THRU TRANS.	SPEED / MAIN TRACKS	OTHER TRACKS / AMTRAK / PAVE / LANES / FUNC. CLASS	AADT / % TRUCK	76 ACC.	77 ACC.	78 ACC.	79 ACC.	80 ACC.	81 ACC.	82 ACC.
0.0479015	0.1499603	2.5450343	0.5549022	0.2218064000118P261154840MIRR70	1040	0	7	0	8	451	021217	175006	0	0	0	4	0	0	0
0.0395014	0.0590800	2.0341480	0.2105020	0.0837629003262S 80111470ATSF70	1080	0	5	0	5	901	111207	250013	0	0	0	2	0	0	0
0.0387477	0.0967565	2.0341419	0.3146376	0.1002538003395J 80892150ATSF70	1040	0	2	0	3	601	021208	50000	0	0	0	0	0	1	2
0.0379669	0.1188591	2.0172035	0.4398175	0.2219830000124T261154840MIRR70	1070	0	7	0	8	451	021216	353007	0	0	0	2	0	0	1
0.0344068	0.1077138	1.8280525	0.3985763	0.1734927000120R261154840MIRR70	1040	0	7	0	8	451	021219	113005	0	0	1	1	0	0	1
0.0314401	0.1506410	1.7226451	0.5624091	0.2299002002126N391530070NW 70	1070	1	4	1	2	351	021216	919006	0	0	2	0	1	0	1
0.0299346	0.0971885	1.5939193	0.4141151	0.4493574002081J391034890NW 70	1040	1	3	5	3	491	221216	510006	0	0	0	1	0	1	0
0.0273859	0.0642656	1.4335601	0.2106319	0.2252648003467K 81012050ATSF70	1070	0	5	0	5	601	021409	235000	0	0	0	0	1	0	0
0.0270009	0.0827401	1.4327856	0.3313209	0.2338485003640K 80052270ATSF70	1070	0	12	2	13	451	121216	150000	0	0	1	0	1	0	0
0.0226948	0.1608225	1.2955647	0.6227233	0.3066206002153K391530070NW 70	1070	1	4	5	2	251	021419	638006	0	0	0	3	1	0	0
0.0226727	0.0800160	1.2136530	0.2894495	0.1686115002090H391034890NW 70	1070	1	3	1	3	491	021219	303006	0	0	0	1	0	1	0
0.0222778	0.0879933	1.2018830	0.3156514	0.2071853002087A391034890NW 70	1040	2	3	6	3	491	021219	274006	0	0	0	0	2	0	0
0.0215770	0.0664132	1.1452617	0.2194859	0.2485760003612G 80352236ATSF70	1070	0	15	2	15	451	021207	220004	0	0	0	0	0	0	1
0.0218393	0.0333427	1.1253088	0.1183461	0.0695411003263Y 80111470ATSF70	1070	0	4	0	4	901	111208	10000	0	0	0	1	0	0	0
0.0194469	0.0595922	1.0319389	0.2386281	0.3077179003638J 80052270ATSF70	1070	0	12	2	13	451	121216	380000	0	0	0	0	0	1	0
0.0179684	0.1318135	1.0302317	0.4947670	0.1656499002972B 10690930ASAB70	1042	20	2	0	0	301	021219	420007	0	0	0	2	1	0	1
0.0188951	0.0629897	1.0077455	0.2318569	0.2852583003639R 80052270ATSF70	1070	0	12	2	13	451	021217	425000	0	0	0	0	0	1	0
0.0179348	0.0631426	0.9598828	0.2095819	0.2226442000153D261151340MIRR70	1070	0	3	0	4	401	021206	850009	0	0	0	0	1	0	0
0.0175323	0.0823995	0.9590138	0.3155896	0.2070859003566H 80410430ATSF70	1070	0	5	0	5	301	021219	450000	0	0	1	1	0	0	0
0.0178314	0.0579309	0.9494988	0.2083731	0.0819486000151P261151340MIRR70	1040	0	3	0	4	401	121209	20005	0	0	1	0	0	0	1
0.0182223	0.0321857	0.9432999	0.1132639	0.0638774003352R 80712355ATSF70	1041	0	3	0	3	792	011209	5000	0	0	0	0	1	0	0
0.0175349	0.0549536	0.9316972	0.1812947	0.1088436003621F 80351544ATSF79	7472	0	12	2	13	451	021208	160000	0	0	0	0	0	1	0
0.0173809	0.0544126	0.9234573	0.2013444	0.2030454000122E261154840MIRR70	1070	0	7	0	8	451	021217	261006	0	0	0	1	0	0	0
0.0166759	0.0658667	0.8996604	0.2362785	0.2997139002088G391034890NW 70	1070	2	4	6	2	491	021216	1289004	0	0	0	0	1	0	0
0.0158685	0.0700957	0.8635209	0.2923144	0.5857661003655A 80310600ATSF70	1070	0	12	2	13	301	121416	1320000	0	0	0	0	0	1	0
0.0154458	0.0743891	0.8466786	0.2845276	0.1620804003648P 80310600ATSF70	1070	0	12	2	13	301	021119	100000	0	0	1	0	1	0	0
0.0152603	0.0599052	0.8229202	0.2217690	0.0937053000206A261610150AA 70	1070	0	2	0	2	401	021216	88007	0	0	0	0	0	0	2
0.0146332	0.0764746	0.8081366	0.2841859	0.5271071002121E391530070NW 70	1070	1	4	5	2	351	021516	2504004	0	1	1	0	0	0	0
0.0153785	0.0289092	0.7978323	0.1121775	0.0626927003347U 80712440ATSF70	1040	0	3	0	3	792	012219	30000	0	0	0	0	1	0	0
0.0137643	0.1091629	0.7973788	0.5478617	0.2144596000213K261610150AA 70	1070	0	2	0	2	151	221217	695006	0	0	0	2	0	1	1
0.0147840	0.0521754	0.7913776	0.1887391	0.1760136002115B391531881NW 70	1070	1	4	1	2	491	021219	372006	0	0	0	0	1	0	0
0.0149639	0.0264610	0.7746569	0.1198392	0.0712441003366Y 80892410ATSF70	1060	0	3	0	3	601	421208	5000	0	0	1	0	0	0	0
0.0140857	0.0556361	0.7599217	0.1995788	0.1990543002085L391034890NW 70	1040	2	3	6	3	491	021219	243006	0	0	0	0	1	0	0
0.0142460	0.0323912	0.7446892	0.1140894	0.0647837003373J 80892150ATSF70	1040	0	3	0	3	601	121208	6000	0	0	0	0	1	0	0
0.0136818	0.0505467	0.7346384	0.1670984	0.1364293002031F390937000NW 70	1070	0	2	0	2	401	021206	314001	0	0	0	0	0	0	1
0.0139617	0.0343171	0.7324023	0.1118129	0.0622971003377L 80892150ATSF70	1040	0	3	0	3	601	021208	10000	0	0	0	0	1	0	0
0.0137261	0.0403970	0.7267033	0.1341078	0.0884830000142R261151340MIRR70	1040	0	7	0	8	451	021209	15005	0	0	1	0	0	0	0
0.0136698	0.0404909	0.7239788	0.1327535	0.0867677002065A391034285NW 70	1040	0	3	0	3	491	021209	47006	0	0	0	0	0	0	1
0.0138612	0.0234148	0.7164765	0.0767116	0.0283892003289B 80891410ATSF70	1040	0	3	0	3	901	012108	3000	0	0	1	0	0	0	0
0.0134029	0.0420041	0.7121481	0.1385736	0.0942652003616J 80351544ATSF70	1070	0	12	2	13	451	021207	10000	1	0	0	1	0	0	0
0.0135563	0.0223174	0.7001325	0.0734608	0.0256178003228K 80991440ATSF70	1040	0	4	0	4	901	012109	2000	0	0	0	0	0	1	0
0.0132666	0.0326086	0.6959384	0.1062461	0.0563789003370N 80892410ATSF70	1040	0	3	0	3	601	021209	10000	0	0	1	0	0	0	0
0.0125558	0.0483320	0.6761223	0.1736968	0.1476966002083X391034890NW 70	1070	1	3	5	3	491	021219	129006	0	0	1	0	0	0	0
0.0130934	0.0211165	0.6757887	0.0697747	0.0225412003268H 80111470ATSF70	1040	0	5	0	5	901	012109	1000	0	0	0	1	0	0	0
0.0119829	0.0626239	0.6617702	0.2327153	0.2880049002119D391530070NW 70	1070	1	4	5	2	351	021216	1314006	0	0	0	0	0	1	0
0.0119403	0.0572104	0.6542262	0.2135917	0.2328111002124A391530070NW 70	1070	1	4	1	2	351	021219	959006	0	0	1	0	0	0	0
0.0118529	0.0423052	0.6349491	0.1402554	0.0964942002058P391034285NW 70	1040	0	3	0	3	401	021208	59006	0	0	0	0	0	1	0
0.0114869	0.0550378	0.6293808	0.2054802	0.2126778002125G391530070NW 70	1070	1	4	1	2	351	021216	706006	0	0	1	0	0	0	0
0.0116529	0.0410261	0.6236714	0.1361731	0.0302770000167L261150239MIRR70	1040	0	3	0	4	401	022209	12005	0	0	2	0	0	0	0
0.0115941	0.0407804	0.6204846	0.2232124	0.2590854003229S 80991440ATSF70	1070	0	5	1	5	301	411216	200000	0	0	1	0	0	0	0

EXHIBIT A-5. SAMPLE OUTPUT FROM ACCIDENT AND CASUALTY PREDICTION FORMULA PROGRAM

```
C*****************************************************************
C*
C*         THIS PROGRAM PRINTS THE OUTPUT OF THE ACCIDENT AND
C*         CASUALTY PREDICTION FORMULA PROGRAM IN REPORT FORMAT
C*         THIS PROGRAM GENERATES ONE OF THREE POSSIBLE REPORTS
C*         UPON EXECUTION. THE FIRST REPORT IS A RANKING
C*         OF CROSSINGS BY FINAL PREDICTED ACCIDENTS, THE
C*         SECOND BY FATAL ACCIDENTS, AND THE THIRD BY
C*         COMBINED CASUALTY INDEX. BEFORE EXECUTION OF
C*         THIS PROGRAM THE INVENTORY INPUT DATA FILE MUST BE SORTED
C*         IN DESCENDING ORDER ON THE FIELD THE USER WISHES
C*         CROSSINGS TO BE RANKED BY. IF THE INPUT FILE IS
C*         NOT SORTED ON THE CORRECT FIELD THE RANKED
C*         OUTPUT RESULTS WILL NOT BE ACCURATE....


C*
C*              UNIT 20 - INVENTORY INPUT FILE WITH FINAL PREDICTED
C*                        ACCIDENTS
C*              UNIT 21 - REPORT OUTPUT FILE
C*
C*****************************************************************
C
C
C
        PARAMETER AH=7             ! # OF YEARS OF ACCIDENT HISTORY AVAILABLE
C
        INTEGER ID(2),STATE,ISTATE(56),COUNTY,CITY,RROAD,
     *          YEAR,MONTH,OLDCL,NEWCL,STOPS,NS,NT,DS,DT,
     *          SPEED,MTRKS,OTRKS,AMTRAK,PAVED,LANES,FC10,
     *          FC1,AADT,TRUCKS,ACC(AH),PAVE(2),PAGE,RANK,
     *          DAY(2),THRU,SWIT,TRAINS,TRACKS,TITLE(3)
     *          ,CHOICE
C
        REAL FATAL,INJURY,A,H,CMBCAS,AC
C
        DATA PAVE/'YES','NO '/
        DATA ISTATE/'AL','AK','  ','AZ','AR','CA','  ','CO','CT','DE',
     1          'DC','FL','GA','  ','HI','ID','IL','IN','IA','KS',
     2          'KY','LA','ME','MD','MA','MI','MN','MS','MO','MT',
     3          'NE','NV','NH','NJ','NM','NY','NC','ND','OH','OK',
     4          'OR','PA','PR','RI','SC','SD','TN','TX','UT','VT',
     5          'VA','VI','WA','WV','WI','WY'/
C
C
C*****************************************************************
C
C
C
        PAGE=0
        RANK=0
C
        CALL DATE(DAY)
C
C
C
C*           INPUT REPORT TYPE AND TITLE OF REPORT


         WRITE(5,66)
00066    FORMAT(T10,' PLEASE ENTER REPORT TITLE :')

         READ(5,77) TITLE
00077    FORMAT(3A5)

         WRITE(5,88)
```

EXHIBIT A-6. ACCIDENT AND CASUALTY PREDICTION FORMULA REPORT PROGRAM

```
00088    FORMAT(//,T5,'SHOULD REPORT INCLUDE ACCIDENT ',
     *            'PREDICTION RESULTS FOR : '//
     *           T10,'PREDICTED ACCIDENTS        (ENTER 1 )'/
     *           T10,'FATAL     ACCIDENTS        (ENTER 2 )'/
     *           T10,'COMBINED CASUALTY INDEX    (ENTER 3 )'/)


         READ(5,99) CHOICE
00099    FORMAT(I)
C
C
C
C*               NEW PAGE!! PRINT PAGE HEADINGS

  100   PAGE=PAGE+1
        LINE=10
        WRITE(21,110) DAY,PAGE
  110   FORMAT('1',T3,2A5,T54,'PUBLIC RAIL-HIGHWAY CROSSINGS',
     *          T120,'PAGE ',I3)
C
        CALL HEADER(CHOICE)
C
C
C*               READ INVENTORY INPUT FILE
C
  200   READ(20,210,END=900) FATAL,INJURY,CMBCAS,A,H,ID,STATE,COUNTY,
     *          CITY,RROAD,YEAR,MONTH,OLDCL,NEWCL,STOPS,NS,NT,
     *          DS,DT,SPEED,MTRKS,OTRKS,AMTRAK,PAVED,LANES,
     *          FC10,FC1,AADT,TRUCKS,ACC
  210   FORMAT(5F10.7,A4,A3,I2,I3,I4,A4,2I2,3I1,4I2,I3,I1,I2,
     *          3I1,2A1,I6,I2,7I2)
C
C
C
C
        K=PAVED
        RANK=RANK+1
        SWIT=NS+DS
        THRU=NT+DT
        TRACKS=MTRKS+OTRKS
C
C
C*               DETERMINE ACCIDENT OR CASUALTY MEASURE TO BE USED
C
C
        AC=A
        IF(CHOICE.EQ.2) AC=FATAL
        IF(CHOICE.EQ.3) AC=CMBCAS


C*               WRITE DATA TO REPORT FILE
C
        IF(YEAR.LT.77) GO TO 230
C
        WRITE(21,220) RANK,AC,ID,ISTATE(STATE),RROAD,
     *          ACC(AH-4),ACC(AH-3),ACC(AH-2),ACC(AH-1),ACC(AH),
     *          MONTH,YEAR,
     *          NEWCL,SWIT,DT,THRU,TRACKS,MTRKS,SPEED,PAVE(K),
     *          LANES,FC10,FC1,AADT
  220   FORMAT(2X,I6,T12,F10.6,T26,A4,A3,T37,A2,
     *          T40,A4,T46,5I3,T63,I2,'/',I2,T71,I1,T75,I3,T81,I2,
     *          T88,I2,T93,I2,T99,I2,T104,I3,T110,A3,T115,I2,
     *          T120,A1,T122,A1,T125,I6)
        GO TO 250
C
C
```

EXHIBIT A-6. ACCIDENT AND CASUALTY PREDICTION FORMULA REPORT PROGRAM (Cont.)

```
00230   WRITE(21,240) RANK,AC,ID,ISTATE(STATE),RROAD,
     *         ACC(AH-4),ACC(AH-3),ACC(AH-2),ACC(AH-1),ACC(AH),
     *         NEWCL,SWIT,DT,THRU,TRACKS,
     *         MTRKS,SPEED,PAVE(K),LANES,FC10,FC1,AADT
 240    FORMAT(2X,I6,T12,F10.6,T26,A4,A3,
     *         T37,A2,T40,A4,T46,5I3,T71,I1,T75,I3,
     *         T81,I2,T88,I2,T93,I2,T99,I2,T104,I3,T110,A3,T115,I2,
     *         T120,A1,T122,A1,T125,I6)
C
C
C
 250    LINE=LINE+1
        IF(LINE.LT.60) GO TO 200
        GO TO 100
C
C
C
 900    CALL EXIT
C
        END


        SUBROUTINE HEADER (WHICH)
        INTEGER WHICH


        GOTO(300,900,600) WHICH


00300   WRITE(21,120)
 120    FORMAT(T49,'RANKED BY PREDICTED ACCIDENTS PER YEAR'/
     *         T56,'INVENTORY DATE: APRIL 1983'/)
C
        WRITE(21,140)
 140    FORMAT(T120,'U-R/',/T7,'RANK',
     *         T14,'PREDICTED',
     *         T27,'XING',T46,'# OF ACCIDENTS',
     *         T63,'DATE',T74,'TOTL',T80,'DAY',T86,'TOTL',T120,'HWY'/
     *         T14,'ACCIDENTS',T27,'ID #',
     *         T37,'ST',T41,'RR',T47,'-- -- -- -- --',
     *         T64,'OF',T70,'WD',T74,'SWIT',T80,'THRU',T86,'THRU',
     *         T92,'TOTL',T98,'MAIN',T104,'TTBL',
     *         T110,'HWY',T115,'HWY',T120,'TYP',/
     *         T14,'PER YEAR',T47,'78 79 80 81 82',
     *         T63,'CHNG',T70,'CL',T74,'TRNS',T80,'TRNS',
     *         T86,'TRNS',T92,'TRKS',T98,'TRKS',
     *         T104,'SPD',T110,'PVD',T115,'LNS',
     *         T120,'CODE',T127,'AADT'//)
C
C
         GOTO 999
C
C
00600   WRITE(21,122)
 122    FORMAT(T49,'RANKED BY PREDICTED COMBINED CASUALTY INDEX C.C.I.*'
     *         /T56,'INVENTORY DATE: APRIL 1983'/)
C
```

EXHIBIT A-6. ACCIDENT AND CASUALTY PREDICTION FORMULA REPORT PROGRAM (Cont.)

```
      WRITE(21,142)
  142 FORMAT(T120,'U-R/',/T7,'RANK',
     *         T14,'PREDICTED',
     *         T27,'XING',T46,'# OF ACCIDENTS',
     *         T63,'DATE',T74,'TOTL',T80,'DAY',T86,'TOTL',T120,'HWY'/
     *         T14,'C.C.I.*',T27,'ID #',
     *         T37,'ST',T41,'RR',T47,'-- -- -- -- --',
     *         T64,'OF',T70,'WD',T74,'SWIT',T80,'THRU',T86,'THRU',
     *         T92,'TOTL',T98,'MAIN',T104,'TTBL',
     *         T110,'HWY',T115,'HWY',T120,'TYP',/T14,'PER YEAR',
     *         T47,'78 79 80 81 82',
     *         T63,'CHNG',T70,'CL',T74,'TRNS',T80'TRNS',
     *         T86,'TRNS',T92,'TRKS',T98,'TRKS',
     *         T104,'SPD',T110,'PVD',T115,'LNS',
     *         T120,'CODE',T127,'AADT'//)
C
C
       GOTO 999
C
C
00900 WRITE(21,123)
  123 FORMAT(T49,'RANKED BY PREDICTED FATAL ACCIDENTS PER YEAR'/
     *         T58,'INVENTORY DATE: APRIL 1983'/)
C
      WRITE(21,143)
  143 FORMAT(T14,'PREDICTED',T120,'U-R/',/T7,'RANK',
     *         T14,'FATAL',
     *         T27,'XING',T46,'# OF ACCIDENTS',
     *         T63,'DATE',T74,'TOTL',T80,'DAY',T86,'TOTL',T120,'HWY'/
     *         T14,'ACCIDENTS',T27,'ID #',
     *         T37,'ST',T41,'RR',T47,'-- -- -- -- --',
     *         T64,'OF',T70,'WD',T74,'SWIT',T80,'THRU',T86,'THRU',
     *         T92,'TOTL',T98,'MAIN',T104,'TTBL',
     *         T110,'HWY',T115,'HWY',T120,'TYP',/
     *         T14,'PER YEAR',T47,'78 79 80 81 82',
     *         T63,'CHNG',T70,'CL',T74,'TRNS',T80,'TRNS',
     *         T86,'TRNS',T92,'TRKS',T98,'TRKS',
     *         T104,'SPD',T110,'PVD',T115,'LNS',
     *         T120,'CODE',T127,'AADT'//)
C
C
00999 RETURN
      END
```

EXHIBIT A-6. ACCIDENT AND CASUALTY PREDICTION FORMULA REPORT PROGRAM (Cont.)

APPENDIX B

```
C***********************************************************************
C*
C*              THIS PROGRAM CALCULATES AN INITIAL BENEFIT/COST RATIO
C*              FOR EACH CROSSING WHICH DOES NOT CURRENTLY HAVE GATES.
C*              INPUT MUST BE IN THE 70 CHARACTER FORMAT PLUS SIX
C*              YEARS OF ACCIDENT HISTORY. IN ADDITION,
C*              THIS PROGRAM ALSO QUALIFIES CROSSINGS FOR
C*              STANDARD STOP SIGN UPGRADES.
C*
C*              UNIT 20 - INVENTORY INPUT FILE WITH FINAL PREDICTED
C*                        ACCIDENTS
C*              UNIT 21 - INITIAL BENEFIT/COST RATIO OUTPUT FILE
C*              UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL INPUT FILE
C*
C***********************************************************************
C
        INTEGER EFFLAG,SEVFLG,SOPFLG,NOSTOP
        INTEGER ID(2),CLASS,NS,NT,DS,DT,MTRKS,OTRKS
        INTEGER FC10,FC1,AADT,STOPS,TRAINS,TRACKS,STPFLG
        INTEGER OFFSET,INDEX
C
        REAL COST(3),EFFECT(12),FATAL,INJURY,CMBCAS,A,RATIO(3),BENCOS
        REAL RAT,AC
C
        COMMON/FLAGS/EFFLAG,SEVFLG,SOPFLG,NOSTOP
C
C
C***********************************************************************
C
C
C*
C*              REQUEST PROGRAM OPTIONS
C*
        CALL QUERY
C
C
C
C*
C*              OPEN INPUT AND OUTPUT FILES
C*
        OPEN(UNIT=20,FILE='ALA.DAT')
        OPEN(UNIT=21,FILE='TEMP.DAT')
        OPEN(UNIT=22,FILE='BENCOS.DAT')
C
C
C*
C*              SAVE FLAGS FOR NEXT PROGRAM
C*
        WRITE(24,1000)EFFLAG,SEVFLG,SOPFLG,NOSTOP
 1000   FORMAT(5I)
C
C
C*
C*              READ STANDARD COST AND EFFECTIVENESS DATA
C*
C
        READ(22,2000) COST
 2000   FORMAT(3F10.0)
C
C
        READ(22,3000) EFFECT(1),EFFECT(2),EFFECT(3)
 3000   FORMAT(3F10.2)
C
C
        IF(EFFLAG.EQ.0)GOTO 100
C
```

EXHIBIT B-1. ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM

```
C
C*
C*              READ EXTENDED EFFECTIVENESS DATA
C*
      READ(22,4000) EFFECT
 4000 FORMAT(12F10.2)
C
C
C
C*    **************************************
C*    *                                    *
C*    *       MAIN PROCESSING LOOP         *
C*    *       SELECT NEXT CROSSING         *
C*    *                                    *
C*    **************************************

C
 100  READ(20,5000,END=500)FATAL,INJURY,CMBCAS,A,ID,CLASS,
     *                 STOPS,NS,NT,DS,DT,MTRKS,OTRKS,
     *                 FC10,FC1,AADT
 5000 FORMAT(4F10.7,10X,A4,A3,18X,2I1,4I2,3X,
     *        I1,I2,3X,2I1,I6)
C
C
C*
C*              DELETE CROSSINGS WHICH CURRENTLY HAVE GATES
C*
      IF(CLASS.EQ.8) GOTO 100
C
C
C*
C*              TOTAL TRAINS AND TRACKS FOR CURRENT CROSSING
C*
      TRAINS=NS+NT+DS+DT
      TRACKS=MTRKS+OTRKS
C
C
C
C*    ****************************
C*    *                          *
C*    *  STOP SIGN QUALIFICATION *
C*    *                          *
C*    ****************************
C
      STPFLG=0
C
      IF(STOPS.GE.1) GOTO 150
      IF(CLASS.GE.5) GOTO 150
      IF(FC1.NE.9) GOTO 150
      IF(TRAINS.LE.10) GOTO 150
      IF(TRACKS.NE.1) GOTO 150
      IF(FC10.NE.1) GOTO 125
      IF(AADT.LT.1500) STPFLG=1
      GOTO 150
 125  IF(AADT.LT.400) STPFLG=1
C
C
C*    ********************************
C*    *                              *
C*    *  EFFECTIVENESS QUALIFICATION *
C*    *                              *
C*    ********************************
C
 150  OFFSET=0
      IF(EFFLAG.EQ.0) GOTO 180
      IF(TRACKS.GT.1) GOTO 175
      IF(TRAINS.GE.11) OFFSET=3
      GOTO 180
 175  OFFSET=6
      IF(TRAINS.GE.11) OFFSET=9
C
C
```

EXHIBIT B-1. ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM (Cont.)

```
C*       ******************************
C*       *                            *
C*       *  CALCULATE BEN/COS RATIOS  *
C*       *                            *
C*       ******************************
C
  180    DO 190 INDEX=1,3
  190    RATIO(INDEX)=EFFECT(INDEX+OFFSET)/COST(INDEX)
C
C
C*
C*               IF GATES ARE ALWAYS MORE COST-EFFECTIVE THAN
C*               FLASHING LIGHTS, USE A GATES ONLY POLICY
C*
         IF(RATIO(2).GT.RATIO(1)) RATIO(1)=RATIO(2)
C
C
C
C*
C*               DETERMINE ACCIDENT OR CASUALTY MEASURE TO BE USED
C*
C*
C*
         AC=A

C
         IF(SEVFLG.EQ.1) AC=FATAL
C
         IF(SOPFLG.EQ.1) AC=CMBCAS
C
C
C
C*
C*               SINGLE TRACK PASSIVE CROSSINGS
C*
C*
         RAT=RATIO(1)
C*
C*
C*               MULTIPLE TRACK PASSIVE CROSSINGS - GATES ONLY!
C*
C*
         IF(TRACKS.GT.1) RAT=RATIO(2)
C*
C*
C*               CROSSINGS WITH FLASHING LIGHTS
C*
C*
         IF(CLASS.GT.4) RAT=RATIO(3)
C*
C
C
C*
C*               CALCULATE BENEFIT/COST RATIO
C*
         BENCOS=AC*RAT*10.**6
C
C
C
C
C
C*
C*               WRITE RESULTS
C*
 400     WRITE(21,6000) BENCOS,FATAL,INJURY,CMBCAS,A,ID,CLASS,TRAINS,
     *                  TRACKS,FC10,FC1,AADT,STPFLG
 6000    FORMAT(F10.6,4F10.7,A4,A3,I1,I2,I3,2I1,I6,I1)
         GO TO 100
C
C
C
C
```

EXHIBIT B-1. ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM (Cont.)

```
 500    CLOSE(UNIT=20)
        CLOSE(UNIT=21)
        CLOSE(UNIT=22)
C
C
        CALL EXIT
C
        END
```

```
        SUBROUTINE QUERY
C*********************************************************
C*
C*              THIS SUBROUTINE REQUESTS OPTIONS TO
C*              BE FOLLOWED BY THE BENCOS PROGRAM
C*              AND THE RESORS PROGRAM.  THE OPTIONS
C*              ARE SELF-EXPLANATORY.
C*
C*********************************************************
C
C
        INTEGER EFFLAG,SEVFLG,SOPFLG,NOSTOP
C
        COMMON/FLAGS/EFFLAG,SEVFLG,SOPFLG,NOSTOP
C
C*********************************************************
C
C
C
C*
C*              SET FLAG DEFAULTS
C*
        EFFLAG=1
        SEVFLG=0
        SOPFLG=0
        NOSTOP=0
C
C
C
C*
C*              QUERY OPTIONS
C*
        WRITE(5,1000)
 1000   FORMAT('   Should basic or extended effectiveness values be used?'/
     *         '   (Enter   0 - basic; 1 - extended):')
C
        READ(5,1500) EFFLAG
 1500   FORMAT(I)
C
C
C
        WRITE(5,2000)
 2000   FORMAT('   Should accident severity be used or not used?'/
     *         '   (Enter   0 - not used; 1 - used):')
C
        READ(5,2500) SEVFLG
 2500   FORMAT(I)
```

EXHIBIT B-1. ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM (Cont.)

```
C
C
      IF(SEVFLG.EQ.0) GOTO 3700
      WRITE(5,3000)
 3000 FORMAT('   Should severity consider fatalities only or'
     *      ' combined casualty index?'/
     *      '    (Enter   0 - fatalities only; 1 - combined index):')
C
      READ(5,3500) SOPFLG
 3500 FORMAT(I)
C
C
C
03700 WRITE(5,4000)
04000 FORMAT('   Should standard stop sign qualifiers be noted '
     *      ,'in the final report ?'/
     *      '      (enter  0 - no; 1 - yes):')
C
      READ(5,4500) NOSTOP
 4500 FORMAT(I)
C
C
C
C
 6000 RETURN
C
      END
```

EXHIBIT B-1. ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM (Cont.)

VARIABLE NAME	VARIABLE TYPE	DESCRIPTION
A	R	PREDICTED ACCIDENTS
AADT	I	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC
BENCOS	R	ACCIDENT REDUCTION/COST RATIO
CLASS	I	PRESENT WARNING DEVICE CLASS
CMBCAS	R	PREDICTED COMBINED CASUALTY INDEX
COST	R	THRU CURRENT WARNING DEVICE UPGRADE COSTS; COST(1): COST OF UPGRADING FROM PASSIVE TO FLASHING COST(2); COST OF UPGRADING FROM PASSIVE TO GATES COST(3): COST OF UPGRADING FROM FLASHING TO GATES
DS	I	NUMBER OF DAYLIGHT SWITCH TRAINS
DT	I	NUMBER OF DAYLIGHT THRU TRAINS
EFFECT	R	SET OF WARNING DEVICE UPGRADE EFFECTIVENESS VALUES: NOTE: THIS VARIABLE COULD CONTAIN EITHER, THREE STANDARD WARNING DEVICE UPGRADE VALUES OR A SET OF TWELVE EXTENDED VALUES BASED ON CROSSING TRAINS AND TRACK TOTALS.
EFFLAG	I	THIS FLAG DETERMINES WHICH SET OF WARNING DEVICE UPGRADE EFFECTIVENESS VALUES WILL BE USED, 1 -EXTENDED, BASED ON TRAINS AND TRACKS, 0 - STANDARD
FATAL	R	PREDICTED FATAL ACCIDENTS PER YEAR
FC1	I	UNITS DIGET OF FUNCTIONAL CLASSIFICATION OF ROAD
FC10	I	TENS DIGET OF FUNCTIONAL CLASSIFICATION OF ROAD
ID	I	CROSSING IDENTIFICATION NUMBER
INJURY	R	PREDICTED INJURY ACCIDENTS PER YEAR
MTRKS	I	NUMBER OF MAIN TRACKS
NOSTOP	I	FLAG WHICH DETERMINES IF STOP SIGNS SHOULD BE CONSIDERED AS AN UPGRADE DEVICE, 0 - NO, 1 - YES
NS	I	NUMBER OF NIGHT SWITCH TRAINS
NT	I	NUMBER OF NIGHT THRU TRAINS
OFFSET	I	VALUE DETERMINES WHICH ONE OF FOUR SETS OF EXTENDED EFFECTIVENESS UPGRADE VALUES WILL BE USED ON THE CURRENT CROSSING
OTRKS	I	NUMBER OF OTHER TRACKS
RATIO	R	THIS VARIABLE HOLDS EFFECTIVENESS/COST RATIOS, RATIO(1): PASSIVE TO FLASHING UPGRADE EFF. VALUE/COST(1) RATIO(2): PASSIVE TO GATE UPGRADE EFF. VALUE/COST(2) RATIO(3): FLASHING TO GATE UPGRADE EFF. VALUE/COST(3)
SEVFLG	I	FLAG WHICH DETERMINES IF ACCIDENT SEVERITY SHOULD BE USED AS A PROBABILITY MEASURE, 1 - YES, 0 - NO
SOPFLG	I	FLAG WHICH DETERMINES IF FATALITIES ONLY OR COMBINED CASUALTY INDEX SHOULD BE USED AS A PROBABILITY MEASURE, 1 - COMBINED CASUALTY INDEX 0 - FATALITIES ONLY
STOPS	I	NUMBER OF STANDARD STOP SIGNS ON SITE
STPFLG	I	FLAG, DOES THIS CROSSING QUALIFY FOR A STOP SIGN UPGRADE, 1 - YES, 0 - NO
TRACKS	I	NUMBER OF TRACKS
TRAINS	I	NUMBER OF TRAINS

EXHIBIT B-2. VARIABLE DICTIONARY FOR THE ACCIDENT OR CASUALTY REDUCTION/OR COST RATIO PROGRAM

NUMBER OF TRACKS	* * * * *	SINGLE	* * * * *				* * * * *	MULTIPLE	* * * * *			
NUMBER OF TRAINS PER DAY	**** ≤10	****		****	>10	****	**** ≤10	****		****	>10	****
UPGRADE CATEGORY	P→FL	P→G	FL→G	P→FL	P→G	FL→G	P→FL	P→G	FL→G	P→FL	P→G	FL→G
WARNING DEVICE COST	43800.	65300.	58700.									
STANDARD EFFECTIVENESS VALUES	.70	.83	.69									
EXTENDED EFFECTIVENESS VALUES	.75	.90	.89	.61	.80	.69	.65	.86	.65	.57	.78	.63
TOTAL BUDGET	30000000.											

EXHIBIT B-3. SAMPLE DATA INPUT TO ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM

INITIAL ACR/C RATIO	PREDICTED FATAL ACCIDENTS	INJURY INDEX	COMBINED CASUALTY INDEX	FINAL PREDICTED ACCIDENTS / ID NUMBER / PRESENT CLASS / TOTAL TRAINS	TOTAL TRACKS / FUNC. CLASS	AADT / STOP SIGN QUALIFIER
8.527157	0.0314401	0.1506410	1.7226451	0.5824091002126N7 8	116	91900
7.728090	0.0479015	0.1499603	2.5450343	0.5549022000118P415	117	17500
7.319916	0.0226948	0.1608225	1.2955847	0.6227233002153K712	119	63800
6.890591	0.0179684	0.1318135	1.0302317	0.4947670002972B422	119	42000
6.066612	0.0137643	0.1091629	0.7973788	0.5478617000213K7 4	317	69500
5.550948	0.0344068	0.1077138	1.8280525	0.3985763000120R415	119	11301
5.387630	0.0387477	0.0987565	2.0341419	0.3148376003395J4 5	108	5000
5.169916	0.0379669	0.1188591	2.0172035	0.4398175000124T715	116	35300
4.948551	0.0299346	0.0971885	1.5939193	0.4141151002081J412	316	51000
4.784919	0.0175323	0.0823995	0.9590138	0.3155896003566H710	119	45000
4.672418	0.0077424	0.0736917	0.4608100	0.3081696000223R7 4	116	106100
4.396058	0.0222778	0.0879933	1.2018830	0.3156514002087A414	119	27400
4.388587	0.0226727	0.0800160	1.2136530	0.2894495002090H7 8	119	30300
3.774107	0.0099900	0.0812515	0.5807508	0.3408309002778H7 8	216	6500
3.761930	0.0081110	0.0643279	0.4698784	0.2481183002706E7 2	116	58650
3.659706	0.0075006	0.0626844	0.4377142	0.2413761002713P7 4	119	315150
3.555914	0.0270009	0.0827401	1.4327858	0.3313209003640K727	216	15000
3.451976	0.0037338	0.0511024	0.2377906	0.2276753000341T7 4	114	128000
3.362426	0.0152603	0.0599052	0.8229202	0.2217690000206A7 4	116	8800
3.344532	0.0154458	0.0743891	0.8466786	0.2845276003648P727	119	10000
3.340516	0.0146332	0.0764746	0.8081366	0.2841859002121E712	116	250400
3.333519	0.0073088	0.0517990	0.4172411	0.1946775002980T4 4	119	18000
3.238443	0.0119403	0.0572104	0.6542262	0.2135917002124A7 8	119	95900
3.222003	0.0070643	0.0500682	0.4032834	0.1881650002981A4 4	119	14400
3.202999	0.0069117	0.0597894	0.4053722	0.2299858002973H422	119	10800
3.193567	0.0273859	0.0642656	1.4335801	0.2106319003467K710	109	23500
3.177647	0.0179348	0.0631426	0.9598828	0.2095819000153D7 7	106	85000
3.137275	0.0158685	0.0700957	0.8635209	0.2923144003655A727	216	132000
3.115458	0.0114869	0.0550378	0.6293808	0.2054802002125G7 8	116	70800
2.909045	0.0057661	0.0498794	0.3381827	0.1918662002734H7 6	114	82010
2.861632	0.0147840	0.0521754	0.7913776	0.1887391002115B7 8	119	37200
2.847971	0.0080838	0.0483743	0.4525861	0.1663215000509J4 2	108	1600
2.779522	0.0140857	0.0556361	0.7599217	0.1995788002085L414	119	24300
2.777379	0.0166759	0.0658667	0.8996604	0.2362785002088G714	116	128900
2.775870	0.0106426	0.0604418	0.5925698	0.2361501003631L727	116	50000
2.775377	0.0075721	0.0472348	0.4258384	0.1620820000692S4 1	108	8500
2.772870	0.0094118	0.0479575	0.5185471	0.1828848000233W7 4	117	59200
2.759457	0.0109662	0.0389734	0.5872835	0.2492002002773Y7 4	716	118710
2.754762	0.0022664	0.0409437	0.1542656	0.1816905000229G7 2	114	65000
2.744271	0.0178314	0.0579309	0.9494988	0.2083731000151P4 7	209	2000
2.735495	0.0119829	0.0626239	0.6617702	0.2327153002119D712	116	131400
2.725405	0.0188951	0.0629897	1.0077455	0.2318569003639R727	117	42500
2.706534	0.0045314	0.0431424	0.2697141	0.1580616000196W4 2	107	70000
2.691695	0.0044602	0.0424524	0.2654642	0.1775309000221C7 4	114	47900
2.579988	0.0215770	0.0664132	1.1452617	0.2194859003612G732	107	22000
2.561085	0.0194469	0.0595922	1.0319389	0.2386281003638J727	216	38000
2.550344	0.0060630	0.0495689	0.3527165	0.1682081001897N7 6	108	32100
2.539234	0.0020891	0.0377404	0.1421961	0.1674753002173W7 2	117	36700
2.533519	0.0136818	0.0505467	0.7346384	0.1670984002031F7 4	106	31400
2.508054	0.0093540	0.0471999	0.5149020	0.1800865003565B411	117	15000
2.486282	0.0083767	0.0475699	0.4664060	0.1639829000420E7 4	106	26000
2.449897	0.0075957	0.0538256	0.4336117	0.2084188002132S712	117	52600
2.415807	0.0077443	0.0463422	0.4335549	0.1593347000490U7 2	102	50000
2.401634	0.0118529	0.0423052	0.6349491	0.1402554002058P4 6	108	5900
2.395636	0.0115941	0.0407804	0.6204846	0.2232124003229S711	516	20000
2.366740	0.0173809	0.0544126	0.9234573	0.2013444000122E715	117	26100
2.346762	0.0103878	0.0526092	0.5721984	0.2186586003538E714	214	40000
2.331731	0.0116529	0.0410261	0.6236714	0.1361731000167L4 7	109	1200
2.320853	0.0016668	0.0293382	0.1126772	0.1355378000463J4 2	116	33400
2.318090	0.0106635	0.0382867	0.5714620	0.2093414003232A7 9	516	15000
2.273176	0.0136698	0.0404909	0.7239788	0.1327535002065A4 6	109	4700

EXHIBIT B-4. SAMPLE OUTPUT FROM ACCIDENT OR CASUALTY REDUCTION/COST RATIO PROGRAM

FIELD	COLUMN	LENGTH	DATA TYPE	FIELD DESCRIPTION
1	1	10	F	ACCIDENT REDUCTION/COST RATIO IN ACCIDENTS PER MILLION DOLLARS
2	11	10	F	PREDICTED FATAL ACCIDENTS PER YEAR
3	21	10	F	PREDICTED INJURY ACCIDENTS PER YEAR
4	31	10	F	PREDICTED COMBINED CASUALTY INDEX
5	41	10	F	PREDICTED ACCIDENTS
6	51	7	A	CROSSING IDENTIFICATION #
7	58	1	I	PRESENT WARNING DEVICE CLASS
7	59	2	I	NUMBER TRAINS
8	61	3	I	NUMBER TRACKS
9	64	1	I	TENS DIDGET FUNCTIONAL CLASSIFICATION OF ROAD
10	65	1	I	UNITS DIDGET FUNCTIONAL CLASSIFICATION OF ROAD
11	66	6	I	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC
12	72	1	I	STOP SIGN QUALIFIER

*DATA TYPE

I - Integer
F - Fixed Decimal
A - Alphanumeric

EXHIBIT B-5. FIELD DESCRIPTIONS FOR OUTPUT FROM THE ACCIDENT OR CASUALTY REDUCTION COST RATIO PROGRAM

APPENDIX C

```
C**********************************************************************
C*
C*              THIS PROGRAM RUNS THE RESORCE ALLOCATION ALGORITHM
C*              AFTER THE INITIAL BENEFIT/COST RATIO HAS BEEN CALCULATED.
C
C*              UNIT 20 - INITIAL BENEFIT/COST RATIO INPUT FILE SORTED
C*                        IN DESCENDING ORDER OF BENEFIT/COST RATIO
C*              UNIT 21 - FINAL BENEFIT/COST RATIO OUTPUT FILE
C*              UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL INPUT FILE
C*              UNIT 23 - OUTPUT FILE FOR LOWEST COST/BENEFIT RATIO
C*              UNIT 24 - USER REQUEST/PROG. OPTIONS FILE
C**********************************************************************
C
C
      PARAMETER IDIM=500
C
      INTEGER EFFLAG,SEVFLG,SOPFLG,NOSTOP
      INTEGER MAX,MIN,ID(2),CLASS,TRAINS,TRACKS,OFFSET
      INTEGER INDEX,IFLAG,XID(2,IDIM),PC(IDIM),TRNS(IDIM)
      INTEGER TRKS(IDIM),UR(IDIM),FUN(IDIM),ADT(IDIM),OFF(IDIM)
      INTEGER STP(IDIM),K,GATE,LIGHT,DUMP(12),IND,INDX
      INTEGER AADT,FC10,FC1,STPFLG
C
      REAL COSTS,BCGATE(IDIM),COST(3),EFFECT(12),MAXAMT
      REAL BENCOS,FATAL,INJURY,A,RATIO(3),AC,EVAL,CVAL
      REAL CMBCAS,EFF,COS,BC(IDIM),PA(IDIM),BCMIN,BENFIT
C
      COMMON /AA/ XID,PA,PC,TRNS,TRKS,UR,FUN,ADT,STP,OFF
      COMMON /BB/ MAX,EFFECT,COST,GATE,COSTS,MAXAMT,BCMIN
C
      DATA GATE/'GATE '/
      DATA LIGHT/'LIGHT'/
C
C
C**********************************************************************
C
C*
C*              OPEN FILES
C*
      OPEN(UNIT=20,FILE='ALOC.DAT')
      OPEN(UNIT=21,FILE='TEMP.DAT')
      OPEN(UNIT=22,FILE='BENCOS.DAT')
C
C
C*
C*              READ OPTION FLAGS
C*
      READ(24,1000) EFFLAG,SEVFLG,SOPFLG,NOSTOP
 1000 FORMAT(4I)
C*
C*
C*              INITIALIZE VARIABLES
C*
      MAX=1
      MIN=1
      COSTS=0.
      BCGATE(1)= -9999.
C
C
C*
C*              READ IN COST AND EFFECTIVNESS DATA
C*
      READ(22,2000) COST
 2000 FORMAT(3F10.0)
C
      READ(22,2500) EFFECT(1),EFFECT(2),EFFECT(3)
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM

```
 2500    FORMAT(3F10.2)
C
C
C
         IF(EFFLAG.EQ.0) GOTO 25
C
C*
C*               READ IN EXTENDED EFFECTIVNESS DATA
C*
         READ(22,2700) EFFECT
 2700    FORMAT(12F10.2)
C
         GOTO 50
C
C*
C*               READ IN TOTAL BUDGET AMOUNT
C*
 25      READ(22,2700) DUMP
C
 50      READ(22,3000) MAXAMT
 3000    FORMAT(F10.0)
C
C
C
C
C
C*       ***********************************************
C*       *            MAIN PROCESSING LOOP             *
C*       *                                             *
C*       *            SELECT NEXT CROSSING             *
C*       ***********************************************
C*
C*
C*
 100     READ(21,3500,END=400) BENCOS,FATAL,INJURY,CMBCAS,A,ID,CLASS,
     *           TRAINS,TRACKS,FC10,FC1,AADT,STPFLG
 3500    FORMAT(F10.6,4F10.7,A4,A3,I1,I2,I3,2I1,I6,I1)
C
C
C
C*
C*       ***********************************
C*       *    EFFECTIVENESS QUALIFICATION   *
C*       *                                  *
C*       ***********************************
C*
C*
         OFFSET=0
         IF(EFFLAG.EQ.0) GOTO 150
C
         IF(TRACKS.GT.1) GOTO 125
         IF(TRAINS.GE.11) OFFSET=3
         GOTO 150
C
 125     OFFSET=6
         IF(TRAINS.GE.11) OFFSET=9
C
C
C*       ************************************
C*       *   CALCULATE BENEFIT/COST RATIO    *
C*       *                                   *
C*       ************************************
C*
C*
 150     DO 160 INDEX=1,2
         IND=INDEX+OFFSET
 160     RATIO(INDEX)=EFFECT(IND)/COST(INDEX)
C
C
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM (Cont.)

```
C*          DETERMINE ACCIDENT OR CASUALTY MEASURE TO BE USED
C*
C*
      AC=A
C
      IF(SEVFLG.EQ.1) AC=FATAL
C
      IF(SOPFLG.EQ.1) AC=CMBCAS
C
C
C
      IF(CLASS.LE.4) GOTO 175
C*
C*          SELECT WARNING DEVICE COST AND EFFECTIVENESS VALUES
C*          FOR FLASHING LIGHTS TO GATES UPGRADE
C*
      IND=3+OFFSET
      EVAL=EFFECT(IND)
      CVAL=COST(3)
      GOTO 200
C
 175  IF(TRACKS.LE.1) GO TO 180
C*
C*          SELECT WARNING DEVICE COST AND EFFECTIVENESS VALUES
C*          FOR PASSIVE TO GATES UPGRADE
C*
      IND=2+OFFSET
      EVAL=EFFECT(IND)
      CVAL=COST(2)
      GOTO 200
C
C*
C*          IF GATES ARE ALWAYS MORE COST-EFFECTIVE THAN
C*          FLASHING LIGHTS, USE A GATES ONLY POLICY
C*
 180  IF(RATIO(2).LE.RATIO(1)) GO TO 190
C*
C*          SELECT WARNING DEVICE COST AND EFFECTIVENESS VALUES
C*          FOR PASSIVE TO GATES UPGRADE
C*
      IND=2+OFFSET
      EVAL=EFFECT(IND)
      CVAL=COST(2)
      GOTO 200
C
C*
C*
C*    *******************************************
C*    *       SINGLE TRACK PASSIVE CROSSINGS    *
C*    *                                         *
C*    *******************************************
C*
C*
C*
 190  INDX=2+OFFSET
      IND=1+OFFSET
      EFF=EFFECT(INDX)-EFFECT(IND)
      COS=COST(2)-COST(1)
      BCGATE(MIN)=AC*EFF/COS*10.**6
C
C*
C*          CHECK THE TEMPORARY DECISION LIST
C*
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM (Cont.)

```
  195   IFLAG=0
        IF(BENCOS.LT.BCGATE(MAX)) CALL GATES(IFLAG)
        IF(IFLAG.EQ.1) GO TO 195
        IF(IFLAG.EQ.2) GO TO 400
C
C*
C*              ADD THE SELECTED CROSSING TO THE BOTTOM OF THE
C*              TEMPORARY DECISION LIST
C*
        BC(MIN)=BENCOS
        XID(1,MIN)=ID(1)
        XID(2,MIN)=ID(2)
        PA(MIN)=AC
        PC(MIN)=CLASS
        OFF(MIN)=OFFSET
        TRNS(MIN)=TRAINS
        TRKS(MIN)=TRACKS
        UR(MIN)=FC10
        FUN(MIN)=FC1
        ADT(MIN)=AADT
        STP(MIN)=STPFLG
        MIN=MIN+1
        BCMIN=BENCOS
C
C*
C*              CHECK TO SEE IF THE BUDGET IS EXPENDED
C*
        COSTS=COSTS+COST(1)
        IF(COSTS.GE.MAXAMT) GO TO 400
        GO TO 100
C
C
C*      *******************************************
C*      *       MULTIPLE TRACK PASSIVE            *
C*      *               AND                       *
C*      *       FLASHING LIGHT CROSSINGS          *
C*      *                                         *
C*      *******************************************
C
C*              CHECK THE TEMPORARY DECISION LIST
C*
C*
C*
C*
  200   IFLAG=0
        IF(BENCOS.LT.BCGATE(MAX)) CALL GATES(IFLAG)
        IF(IFLAG.EQ.1) GO TO 200
        IF(IFLAG.EQ.2) GO TO 400
        BENFIT=AC*EVAL
C*
C*
C*
C*              RECOMMEND GATES AT SELECTED CROSSING
C*
C*
C*
        WRITE(20,4000) BENCOS,AC,ID,CLASS,TRAINS,
     *          TRACKS,FC10,FC1,AADT,GATE,CVAL,BENFIT,STPFLG
 4000   FORMAT(F10.6,F10.6,A4,A3,I1,I2,I3,2I1,I6,A5,F7.0,F10.6,I1)
        BCMIN=BENCOS
C*
C*              CHECK TO SEE IF THE BUDGET IS EXPENDED
C*
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM (Cont.)

```
      COSTS=COSTS+CVAL
      IF(COSTS.GE.MAXAMT) GO TO 400
      GO TO 100
C
C
C*
C*            BUDGET EXPENDED; RECOMMEND FLASHING LIGHTS AT THOSE
C*            CROSSINGS STILL ON THE TEMPORARY DECISION LIST
C*
C*
C*
 400  IF(MAX.GE.MIN) GO TO 500
      DO 450 K=MAX,MIN-1
      BENFIT=PA(K)*EFFECT(1+OFF(K))
 450  WRITE(20,4000) BC(K),PA(K),XID(1,K),XID(2,K),PC(K),
     *                 TRNS(K),TRKS(K),UR(K),FUN(K),ADT(K),
     *                 LIGHT,COST(1),BENFIT,STP(K)
 500  WRITE(23,5000) BCMIN
 5000 FORMAT(F8.4)
C
C
C
      CLOSE(UNIT=20)
      CLOSE(UNIT=21)
      CLOSE(UNIT=22)
C
C
      CALL EXIT
C
      END
```

```
      SUBROUTINE GATES(IFLAG)
C****************************************************************
C*
C*            THIS SUBROUTINE RECOMMENDS GATES AT
C*            SINGLE TRACK PASSIVE CROSSINGS.
C*
C****************************************************************
C
C
      PARAMETER IDIM=500
C
      INTEGER IFLAG,IND,OFFSET,XID(2,IDIM),PC(IDIM),TRNS(IDIM)
      INTEGER TRKS(IDIM),UR(IDIM),FUN(IDIM),ADT(IDIM),STP(IDIM)
      INTEGER GATE,MAX,LIGHT,OFF(IDIM)
C
      REAL BENFIT,PA(IDIM),EFFECT(12),COST(3),BCMIN
      REAL BENCOS,COSTS,MAXAMT
C
      COMMON /AA/ XID,PA,PC,TRNS,TRKS,UR,FUN,ADT,STP,OFF
      COMMON /BB/ MAX,EFFECT,COST,GATE,COSTS,MAXAMT,BCMIN

C
C
C****************************************************************
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM (Cont.)

```
C
C
C
C*
C*              TURN ON FLAG TO INDICATE SUBROUTINE GATES HAS
C*              BEEN CALLED
C*
      IFLAG=1
      IND=2+OFF(MAX)
      BENFIT=PA(MAX)*EFFECT(IND)
      BENCOS=BENFIT/COST(2)*10.**6
C*
C*              FINALIZE THE RECOMMENDATION OF GATES AND REMOVE
C*              CROSSING FROM THE TEMPORARY DECISION LIST
C*
      WRITE(20,2000) BENCOS,PA(MAX),XID(1,MAX),XID(2,MAX),
     *               PC(MAX),TRNS(MAX),TRKS(MAX),UR(MAX),
     *               FUN(MAX),ADT(MAX),GATE,COST(2),
     *               BENFIT,STP(MAX)
 2000 FORMAT(F10.6,F10.6,A4,A3,I1,I2,I3,2I1,I6,A5,F7.0,F10.6,I1)
C
C
      MAX=MAX+1
      BCMIN=BENCOS
C*
C*              CHECK TO SEE IF THE BUDGET IS EXPENDED
C*
      COSTS=COSTS+COST(2)-COST(1)
      IF(COSTS.GE.MAXAMT) IFLAG=2
C
C
C
      RETURN
C
      END
```

EXHIBIT C-1. RESOURCE ALLOCATION PROGRAM (Cont.)

VARIABLE NAME	VARIABLE TYPE	DEFINITION
A	R	PREDICTED ACCIDENTS
AADT	I	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC
ADT	I	ANNUAL AVERAGE DAILY VEHICULAR TRAFFIC STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
AC	R	PROBABILITY MEASURE, EITHER PREDICTED ACCIDENTS, FATAL ACCIDENTS, OR COMBINED CASUALTY INDEX
BC	R	ACCIDENT REDUCTION/COST RATIO STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
BCGATE	R	INCREMENTAL ACCIDENT REDUCTION/COST RATIO STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
BCMIN	R	MINIMUM ACCIDENT REDUCTION/COST RATIO FOR RUN
BENCOS	R	ACCIDENT REDUCTION/COST RATIO
BENFIT	R	ACCIDENTS PREVENTED
CLASS	I	PRESENT WARNING DEVICE CLASS
CMBCAS	R	PREDICTED COMBINED CASUALTY INDEX
COST	R	THREE CURRENT WARNING DEVICE UPGRADE COSTS; COST(1): COST OF UPGRADING FROM PASSIVE TO FLASHING COST(2): COST OF UPGRADING FROM PASSIVE TO GATES COST(3): COST OF UPGRADING FROM FLASHING TO GATES
COSTS	R	CUMULATIVE COST OF UPGRADES
EFFECT		SET OF WARNING DEVICE UPGRADE EFFECTIVENESS VALUES NOTE: THIS VARIABLE COULD CONTAIN EITHER THREE STANDARD WARNING DEVICE UPGRADE EFFECTIVENESS VALUES OR A SET OF TWELVE EXTENDED VALUES BASED ON CROSSING TRAIN AND TRACK TOTALS
EFFLAG		THIS FLAG DETERMINES WHICH SET OF WARNING DEVICE UPGRADE EFFECTIVENESS VALUES WILL BE USED, 1 - EXTENDED BASED ON TRAINS AND TRACKS, 0 - STANDARD
FATAL		PREDICTED FATAL ACCIDENTS PER YEAR
FC1	I	UNITS DIDGET OF FUNCTIONAL CLASSIFICATION OF ROAD
FC10	I	TENS DIDGET OF FUNCTIONAL CLASSIFICATION OF ROAD
FUN	I	UNITS DIDGET OF FUNCTIONAL CLASSIFICATION OF ROAD STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
GATE	I	THE WORD "GATE"
ID	I	CROSSING IDENTIFICATION NUMBER
IDIM	I	PARAMETER WHICH DIMENSIONS VARIABLES USED TO STORE INFORMATION FOR PASSIVE CROSSINGS WITH SINGLE TRACK
IFLAG	I	FLAG TO TELL IF SUBROUTINE GATES HAS BEEN CALLED, 0 - NO, 1 - YES, 2 - YES, MONEY RAN OUT
INJURY	R	PREDICTED INJURY ACCIDENTS PER YEAR
LIGHT	I	THE WORD "LIGHT"
MAX	I	INDEX OF THE LARGEST ACCIDENT REDUCTION/COST RATIO STORED IN BCGATE

EXHIBIT C-2. VARIABLE DICTIONARY FOR THE RESOURCE ALLOCATION PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINITION
MAXAMT	R	TOTAL AMOUNT OF MONEY AVAILABLE
MIN	I	INDEX OF SMALLEST ACCIDENT REDUCTION/COST RATIO STORED IN BCGATE
NOSTOP	I	FLAG WHICH DETERMINES IF STOP SIGNS SHOULD BE CONSIDERED AS AN UPGRADE DEVICE, 0 -NO, 1 - YES
OFF	I	OFFSET VALUE STORED FOR PASSIVE CROSSINGS WITH ONE TRACK STATUS
OFFSET	I	VALUE DETERMINES WHICH ONE OF FOUR SETS OF EXTENDED EFFECTIVENESS UPGRADE VALUES WILL BE USED ON THE CURRENT CROSSING
PA	R	PREDICTED ACCIDENTS STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
PC	I	PRESENT WARNING DEVICE CLASS STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
RATIO	R	THIS VARIABLE HOLDS EFFECTIVENESS/COST RATIOS FOR PASSIVE TO LIGHTS, AND PASSIVE TO GATES UPGRADES
SEVFLG	I	FLAG WHICH DETERMINES IF ACCIDENT SEVERITY SHOULD BE USED AS A PROBABILITY MEASURE, 1 -YES, 0 -NO
SOPFLG	I	FLAG WHICH DETERMINES IF FATALITIES ONLY OR COMBINED CASUALTY INDEX SHOULD BE USED AS A PROBABILITY MEASURE, 1 - COMBINED CASUALTY INDEX, 1 - COMBINED INDEX, 0 -FATALITIES ONLY
STP	I	STOP SIGN QUALIFIER STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
STPFLG	I	FLAG WHICH DETERMINES IF A CROSSING QUALIFIES FOR STOP SIGN UPGRADE, 1 - YES, 0 - NO
TRACKS	I	NUMBER OF TRACKS
TRAINS	I	NUMBER OF TRAINS
TRKS	I	NUMBER OF TRACKS STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
TRNS	I	NUMBER OF TRAINS STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
UR	I	TENS DIDGET OF FUNCTIONAL CLASSIFICATION, OF ROAD STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK
XID	I	CROSSING IDENTIFICATION NUMBER STORED FOR PASSIVE CROSSINGS WITH SINGLE TRACK

EXHIBIT C-2. VARIABLE DICTIONARY FOR THE RESOURCE ALLOCATION PROGRAM (CONT)

ACR/C RATIO	PREDICTED ACCIDENT OR CASUALTY MEASURE	ID NUMBER	CLASS	TOTAL TRAINS	TOTAL TRUCKS	FUNC. CLASS	AADT	RECOMMENDED DEVICE	COST	ACCIDENT OR CASUALTY REDUCTION
7.319916	0.622723	002153K	7	12	1	19	6380	GATE	58700.	0.4296790
6.798189	0.554902	000118P	4	15	1	17	1750	GATE	65300.	0.4439220
6.086612	0.547862	000213K	7	4	3	17	6950	GATE	58700.	0.3561100
6.061464	0.494767	002972B	4	22	1	19	4200	GATE	65300.	0.3958140
5.387630	0.314638	003395J	4	5	1	08	500	LIGHT	43800.	0.2359780
5.169916	0.439817	000124T	7	15	1	16	3530	GATE	58700.	0.3034740
4.946551	0.414115	002081J	4	12	3	16	5100	GATE	65300.	0.3230100
4.883017	0.398576	000120R	4	15	1	19	1130	GATE	65300.	0.3188611
4.784919	0.315590	003566H	7	10	1	19	4500	GATE	58700.	0.2808750
4.672418	0.308170	000223R	7	4	1	16	10810	GATE	58700.	0.2742710
4.396058	0.315651	002087A	4	14	1	19	2740	LIGHT	43800.	0.1925470
4.388587	0.289450	002090H	7	8	1	19	3030	GATE	58700.	0.2578100
3.774107	0.340831	002778H	7	8	2	16	650	GATE	58700.	0.2215400
3.761930	0.248118	002706E	7	2	1	16	5865	GATE	58700.	0.2208250
3.659708	0.241376	002713P	7	4	1	19	31515	GATE	58700.	0.2148250
3.555914	0.331321	003640K	7	27	2	16	1500	GATE	58700.	0.2087320
3.451976	0.227675	000341T	7	4	1	14	12800	GATE	58700.	0.2026310
3.362426	0.221769	000206A	7	4	1	16	880	GATE	58700.	0.1973740
3.344532	0.284528	003648P	7	27	1	19	1000	GATE	58700.	0.1963240
3.340516	0.284186	002121E	7	12	1	16	25040	GATE	58700.	0.1960880
3.333519	0.194678	002980T	4	4	1	19	1800	LIGHT	43800.	0.1460080
3.238443	0.213592	002124A	7	8	1	19	9590	GATE	58700.	0.1900970
3.222003	0.188165	002981A	4	4	1	19	1440	LIGHT	43800.	0.1411240
3.202999	0.229986	002973H	4	22	1	19	1080	LIGHT	43800.	0.1402910
3.193567	0.210632	003467K	7	10	1	09	2350	GATE	58700.	0.1874620
3.177647	0.209582	000153D	7	7	1	06	8500	GATE	58700.	0.1865280
3.137275	0.292314	003655A	7	27	2	18	13200	GATE	58700.	0.1841580
3.115458	0.205480	002125G	7	8	1	16	7060	GATE	58700.	0.1828770
2.909045	0.191866	002734H	7	6	1	14	8201	GATE	58700.	0.1707610
2.861632	0.188739	002115B	7	8	1	19	3720	GATE	58700.	0.1679780
2.847971	0.166321	000509J	4	2	1	08	160	LIGHT	43800.	0.1247410
2.779522	0.199579	002085L	4	14	1	19	2430	LIGHT	43800.	0.1217430
2.777379	0.236279	002088G	7	14	1	16	12890	GATE	58700.	0.1630320
2.775870	0.236150	003631L	7	27	1	16	5000	GATE	58700.	0.1629440
2.775377	0.162082	000692S	4	1	1	08	850	LIGHT	43800.	0.1215620
2.772870	0.182885	000233W	7	4	1	17	5920	GATE	58700.	0.1627670
2.759457	0.249200	002773Y	7	4	7	16	11871	GATE	58700.	0.1619800
2.754762	0.181690	000229G	7	2	1	14	6500	GATE	58700.	0.1617050
2.744271	0.208373	000151P	4	7	2	09	200	GATE	65300.	0.1792010
2.735495	0.232715	002119D	7	12	1	16	13140	GATE	58700.	0.1605740
2.725405	0.231857	003639R	7	27	1	17	4250	GATE	58700.	0.1599810
2.706534	0.158062	000196W	4	2	1	07	7000	LIGHT	43800.	0.1185460
2.691695	0.177531	000221C	7	4	1	14	4790	GATE	58700.	0.1580030
2.579988	0.219486	003612G	7	32	1	07	2200	GATE	58700.	0.1514450
2.561085	0.238628	003638J	7	27	2	16	3800	GATE	58700.	0.1503360
2.550344	0.168208	001897N	7	6	1	08	3210	GATE	58700.	0.1497050
2.539234	0.167475	002173W	7	2	1	17	3670	GATE	58700.	0.1490530
2.533519	0.167098	002031F	7	4	1	06	3140	GATE	58700.	0.1487180
2.508054	0.180086	003565B	4	11	1	17	1500	LIGHT	43800.	0.1098530
2.486282	0.163983	000420E	7	4	1	06	2600	GATE	58700.	0.1459450
2.449897	0.208419	002132S	7	12	1	17	5260	GATE	58700.	0.1438090
2.415807	0.159335	000490U	7	2	1	02	5000	GATE	58700.	0.1418080
2.401634	0.140255	002058P	4	6	1	08	590	LIGHT	43800.	0.1051920

EXHIBIT C-3. SAMPLE OUTPUT FROM RESOURCE ALLOCATION PROGRAM

Field	Column	Length	Data Type	Field Description
1	1	10	F	Accident or casualty reduction/cost ratio in accidents per million dollars
2	11	10	F	Accident or casualty measure
3	21	7	A	Crossing identification number
4	28	1	I	Present warning device class
5	29	2	I	Total trains
6	31	3	I	Total tracks
7	34	1	I	Tens digit functional classification of road
8	35	1	I	Units digit functional classification of road
9	36	6	I	Annual average daily vehicular traffic
10	42	5	A	Recommended warning device
11	47	7	F	Cost of warning device upgrade
12	54	10	F	Accidents prevented
13	64	1	I	Stop qualification flag

* DATA TYPE:

I - integer
A - alphanumeric
F - fixed decimal

EXHIBIT C-4. FIELD DESCRIPTIONS FOR OUTPUT FROM THE RESOURCE ALLOCATION PROGRAM

```
C*********************************************************************
C*
C*                THIS PROGRAM COMPUTES THE DECISION
C*                CRITERIA AND PRINTS THE OUTPUT OF
C*                THE RESOURCE ALLOCATION ALGORITHM
C*                IN A REPORT FORMAT.
C*
C*                UNIT 20 - FINAL BENEFIT/COST RATIO INPUT
C*                          FILE SORTED IN DESCENDING ORDER
C*                          OF BENEFIT/COST RATIO
C*                UNIT 21 - REPORT OUTPUT FILE
C*                UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL
C*                          INPUT FILE
C*                UNIT 23 - INPUT FILE FOR LOWEST COST/BENEFIT RATIO
C*                UNIT 24 - USER REQUEST/PROGRAM OPTIONS FILE
C*                UNIT  5 - INTERACTIVE INPUT FILE FOR RUN TITLE
C*
C*********************************************************************
C
C
C
        INTEGER EFFLAG,SEVFLG,SOPFLG,NOSTOP,STPFLG,OFFSET
        INTEGER RURURB(2),ID(2),CLASS,TRACKS,WARN,TITLE(3),FC10,
     *          DEVICE(2,7),DAY(2),PAGE,WHICH,STOP(2),REPTYP(3,8)
C
        REAL COST(3),EFFECT(12),RATIO(4),COSTS,DUMP(12)
C
        COMMON /FIG/ EFFLAG,SEVFLG,SOPFLG,NOSTOP,WHICH
C
        DATA RURURB/'RURAL','URBAN'/
C
        DATA DEVICE/'NONE ','     ',
     *              'OTHER',' SIGN',
     *              'STOP ','SIGN ',
     *              'CROSS','BUCK ',
     *              'SPECI','AL   ',
     *              'HWY S','GNL  ',
     *              'LIGHT','     '/
C
        DATA REPTYP/'ACCI','FATA','COMB','DENT','L AC','INED',
     *              'S   ','CIDE',' CAS','    ','NTS ','UALT',
     *              '    ','    ','Y IN','    ','    ','DEX '
     *             ,'    ','    ','C.C.'
     *             ,'    ','    ','I*  '/
C
C
C
C
C*********************************************************************
C
        OPEN(UNIT=20,FILE='ALOC.DAT')
        OPEN(UNIT=21,FILE='REP.DAT')
        OPEN(UNIT=22,FILE='BENCOS.DAT')
C
C*
C*              READ USER OPTIONS FILE
C*
        READ(24,5) EFFLAG,SEVFLG,SOPFLG,NOSTOP
 5      FORMAT(4I)
C
C
        TCOST=0
        TBEN=0.
C
C
C*              QUERY REPORT TITLE
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM

```
C
      WRITE(5,10)
 10   FORMAT(' ENTER TITLE OF RUN:')
      READ(5,20) TITLE
 20   FORMAT(3A5)
C*
C*
C*            READ STANDARD COST AND EFFECTIVENESS DATA
C
      READ(22,30) COST
 30   FORMAT(3F10.0)
C
      READ(22,40) EFFECT(1),EFFECT(2),EFFECT(3)
 40   FORMAT(3F10.2)
C
C
C
      IF(EFFLAG.EQ.0) GOTO 45
C
C
C*            READ EXTENDED EFFECTIVENESS DATA
C*
      READ(22,42) EFFECT
 42   FORMAT(12F10.2)
      GOTO 47
C
C
 45   READ(22,42) DUMP
C
C
C*            READ TOTAL AMOUNT FUNDS AVAILABLE
C
 47   READ(22,50) MAXAMT
 50   FORMAT(I9)
C
C*
C*            READ MINIMUM ACC.RED./COST RAT. FOR RUN
C*
      READ(23,60) BCMIN
 60   FORMAT(F8.4)
C*
C*
C*
C*            INITIALIZE STOP QUALIFICATIONS VARIABLES
C*
      STOP(1)='      '
      STOP(2)='      '
      IF(NOSTOP.EQ.0) GOTO 61
          STOP(1)=' NO '
          STOP(2)=' YES '
C
C
00061 CALL DATE(DAY)
C
      PAGE=1
C
C
C*
C*             PRINT OVERALL REPORT HEADING
C*
C
      N=SEVFLG+SOPFLG+1
C*
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
      WRITE(21,101) DAY,(REPTYP(N,J),J=1,8),TITLE,MAXAMT,
     *        COST(1),COST(2),COST(3)
 101  FORMAT('1',T8,2A5,T40,
     *        'RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS',
     *        T120,'PAGE   1'/T40,'BASED ON PREDICTED ',8A4/
     *        T60,'FOR ',3A5,/T40,'TOTAL BUDGET:  $',I9/
     *        T43,'WARNING DEVICE    P-->FL    P-->G    FL-->G'/
     *        T45,'COST:',
     *        9X,3(2X,'$',F6)/)
C
C
C
C
      IF(EFFLAG.EQ.0) GOTO 102
C
C*             PRINT EXTENDED EFFECTIVENESS HEADING.
C*
C*
      WRITE(21,79) EFFECT(1),EFFECT(7),EFFECT(4),
     *      EFFECT(10),EFFECT(2),EFFECT(8),EFFECT(5),EFFECT(11),
     *      EFFECT(3),EFFECT(9),EFFECT(6),EFFECT(12)
00079 FORMAT(T40,'EXTENDED EFFECTIVENESS VALUES: '/
     *        T57,'TRAINS <= 10',T77,'TRAINS >= 11'/
     *        T40,'UPGRADE',T54,'SINGLE',T64,'MULTIPLE',
     *        T74,'SINGLE',T84,'MULTIPLE'/
     *        T40,'OPTION',T54,'TRACK',T64,'TRACK',T74,'TRACK',
     *        T84,'TRACK'/
     *        T40,'------',T54,'-----',T64,'-----',T74,'-----'
     *        ,T84,'-----'/
     *        T40,'PASSIVE - FL',T54,F4.2,T64,F4.2,T74,F4.2,
     *        T84,F4.2/
     *        T40,'PASSIVE - G',T54,F4.2,T64,F4.2,T74,F4.2,
     *        T84,F4.2/
     *        T40,'FLASHING - G',T54,F4.2,T64,F4.2,T74,F4.2,
     *        T84,F4.2/)
C*
C*
      LINE=18
      GOTO 110
C*
C*
C*             PRINT STANDARD EFFECTIVENESS HEADING.
C*
C*
00102 WRITE(21,69) EFFECT(1),EFFECT(2), EFFECT(3)
00069 FORMAT(T40,'STANDARD EFFECTIVENESS VALUES:   ',3(F3.2,6X)/)
      LINE=11
      GOTO 110
C
C*             NEW PAGE!! PRINT PAGE HEADINGS
C
C
 105  PAGE=PAGE+1
      WRITE(21,106) DAY,PAGE
 106  FORMAT('1',T8,2A5,T120,'PAGE',I3/)
C
C
      LINE=3
C
C
 110  WHICH=1+NOSTOP*3+SEVFLG+SOPFLG
      CALL HEADER(WHICH)
C
C
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
      LINE=LINE+6
C
C
C
C
C*    ****************************************************
C*    *          MAIN PROCESSING LOOP                   *
C*    *                                                 *
C*    *          SELECT NEXT CROSSING                   *
C*    ****************************************************
C
C
C
 200  READ(20,201,END=999) BENCOS,AVAL,ID,CLASS,TRAINS,TRACKS,
     *         FC10,FC1,AADT,WARN,COSTS,BEN,STPFLG
 201  FORMAT(F10.6,F10.6,A4,A3,I1,I2,I3,2I1,I6,A5,F7.0,F10.6,I1)
C
C
C
C
C*    ******************************************
C*    *      EFFECTIVENESS QUALIFICATION       *
C*    *                                        *
C*    ******************************************
C
C
      OFFSET=0
      IF(EFFLAG.EQ.0) GOTO 204
C
      IF(TRACKS.GT.1) GOTO 202
      IF(TRAINS.GE.11) OFFSET=3
      GOTO 204
C
 202  OFFSET=6
      IF(TRAINS.GE.11) OFFSET=9
C
C*    ***************************************
C*    *   CALCULATE BEN/COS RATIOS          *
C*    *                                     *
C*    ***************************************
C
C
 204  RATIO(1)=EFFECT(OFFSET+1)/COST(1)
      RATIO(2)=(EFFECT(OFFSET+2)-EFFECT(OFFSET+1))/(COST(2)-COST(1))
      RATIO(3)=EFFECT(OFFSET+2)/COST(2)
      RATIO(4)=EFFECT(OFFSET+3)/COST(3)
C
C
C
C
C
C
C
      TCOST=TCOST+COSTS
      TBEN=TBEN+BEN
      KCOST=TCOST/1000. +0.5
C
C
C
C
      IF(CLASS.GT.4) GO TO 230
C
      IF(TRACKS.GT.1) GO TO 220
C
      IF(RATIO(2).GT.RATIO(1)) GO TO 220
C
C
C
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
C*        ********************************
C*        *    SINGLE TRACK PASSIVE      *
C*        *          CROSSING            *
C*        ********************************
C*
C*            CALCULATE DECISION CRITERIA
C*
          DC1=BCMIN/(AVAL*RATIO(1)*10**6)
          DC2=BCMIN/(AVAL*RATIO(2)*10**6)
C
C
          J=STPFLG
C
C*
C*
C*            WRITE CURRENT CROSSING TO REPORT FILE
C*
          WRITE(21,205) ID,AVAL,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
     *          TRAINS,KCOST,TBEN,DC1,DC2,STOP(STPFLG+1)
  205     FORMAT(T2,A4,A3,T10,F10.6,T23,F10.6,T40,A5,T52,2A5,
     *          T63,I2,T71,I2,T79,I6,T90,F10.6,T101,F5.3,
     *          T108,F5.3,T128,A5)
C
C
C*
C*
C*
C
          GOTO 250
C
C
C
C
C
C
C
C
C*        *********************************
C*        *   MULTIPLE TRACK PASSIVE      *
C*        *          CROSSING             *
C*        *********************************
C*
C*           COMPUTE DECISION CRITERIA
C*
  220     DC3=BCMIN/(AVAL*RATIO(3)*10**6)
C
C*
C*
C*          WRITE CURRENT CROSSING TO REPORT FILE
C*
          WRITE(21,211) ID,AVAL,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
     *          TRAINS,KCOST,TBEN,DC3,STOP(STPFLG+1)
  211     FORMAT(T2,A4,A3,T10,F10.6,T23,F10.6,T40,A5,T52,2A5,
     *          T63,I2,T71,I2,T79,I6,T90,F10.6,T115,F5.3,
     *          T128,A5)
C
C
C*
C*
C*
C*
          GOTO 250
C
C
C
C
C
C
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
C*       ********************************
C*       *       FLASHING LIGHTS        *
C*       *           CROSSING           *
C*       ********************************
C*
C*          COMPUTE DECISION CRITERIA
C*
 230     DC4=BCMIN/(AVAL*RATIO(4)*10**6)
C*
C*
C*         WRITE CURRENT CROSSING TO THE REPORT FILE
C*
         WRITE(21,221) ID,AVAL,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
     *          TRAINS,KCOST,TBEN,DC4,STOP(STPFLG+1)
 221     FORMAT(T2,A4,A3,T10,F10.6,T23,F10.6,T40,A5,T52,2A5,
     *          T63,I2,T71,I2,T79,I6,T90,F10.6,T121,F5.3,
     *          T128,A5)
C
C*
C*
C*
C*
C
C
C
 250     LINE=LINE+1
         IF(LINE.GT.60) GO TO 105
         GO TO 200
C
C
C
         CLOSE(UNIT=20)
         CLOSE(UNIT=21)
         CLOSE(UNIT=22)
C
C
 999     CALL EXIT
C
         END

         SUBROUTINE HEADER(WHICH)
C*********************************************************************
C*
C*               THIS SUBROUTINE PRINTS THE APPROPRIATE
C*               HEADER FOR EACH PAGE OF REPORT OUTPUT.
C*
C*********************************************************************
C
C
C
         INTEGER WHICH
C
C
C
C*********************************************************************
C
C
C
C
         GOTO (110,112,111,113,115,114) WHICH
C
C
C*          PAGE HEADER PRED. ACC. REPORT NO STOP OPTION.
C
C
 110     WRITE(21,1110)
 1110    FORMAT(T25,'ACCIDENT',T90,'CUMULATIVE'/T2,'CROSSING',
     *          T12,'PREDICTED',T25,'REDUCTION',T38,'RECOMMENDED',
     *          T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *          T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *          T119,'VALUES'/T4,'ID #',T12,'ACCIDENTS',
     *          T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
     *         T63,'# OF',T71,'# OF',T82,'COST',T90,'ACCIDENTS'/
     *         T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *         T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *         '($THOUSAND)',
     *         T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *         T121,'DC4'/T2,'--------',
     *         T12,'---------',T24,'-----------',T39,'--------',
     *         T52,'-------',T62,'------',T70,'------',T79,
     *         '----------',
     *         T90,'--------',T101,'---',T108,'---',T115,'---',
     *         T121,'---'/)
C
      GOTO 999
C
C
C*      PAGE HEADER COMB./CAS. REPORT NO STOP OPTION.
C
 111  WRITE(21,1111)
01111  FORMAT(T25,'C.C.I.*',T90,'CUMULATIVE',/
     *         T2,'CROSSING',
     *         T12,'PREDICTED',T25,'REDUCTION',T38,'RECOMMENDED',
     *         T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *         T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *         T119,'VALUES'/T4,'ID #',T12,'C.C.I.*',
     *         T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
     *         T63,'# OF',T71,'# OF',T82,'COST',T90,'C.C.I.*'/
     *         T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *         T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *         '($THOUSAND)',
     *         T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *         T121,'DC4'/T2,'--------',
     *         T12,'---------',T24,'-----------',T39,'--------',
     *         T52,'-------',T62,'------',T70,'------',T79,
     *         '----------',
     *         T90,'--------',T101,'---',T108,'---',T115,'---',
     *         T121,'---'/)
C
      GOTO 999
C
C
C*      PAGE HEADER FATALS  REPORT NO STOP OPTION.
C
 112  WRITE(21,1112)
 1112 FORMAT(T12,'PREDICTED',T25,'FATAL ACC.',T90,'CUMULATIVE'/
     *         T2,'CROSSING',
     *         T12,'FATAL',T25,'REDUCTION',T38,'RECOMMENDED',
     *         T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *         T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *         T119,'VALUES'/T4,'ID #',T12,'ACCIDENTS',
     *         T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
     *         T63,'# OF',T71,'# OF',T82,'COST',T90,'FATAL ACC'/
     *         T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *         T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *         '($THOUSAND)',
     *         T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *         T121,'DC4'/T2,'--------',
     *         T12,'---------',T24,'-----------',T39,'--------',
     *         T52,'-------',T62,'------',T70,'------',T79,
     *         '----------',
     *         T90,'--------',T101,'---',T108,'---',T115,'---',
     *         T121,'---'/)
C
      GOTO 999
C
C
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
C*        PAGE HEADER PRED. ACCS. REPORT WITH STOP QUALIFICATION OPTION
C
 113    WRITE(21,1113)
 1113   FORMAT(T25,'ACCIDENTS',T90,'CUMULATIVE',T128,'MEETS'/
     *          T2,'CROSSING',
     *          T12,'PREDICTED',T25,'REDUCTION',T38,'RECOMMENDED',
     *          T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *          T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *          T119,'VALUES',T128,'STOP'/T4,'ID #',T12,'ACCIDENTS',
     *          T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
     *          T63,'# OF',T71,'# OF',T82,'COST',T90,'ACCIDENTS',T128,
     *          'SIGN'/
     *          T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *          T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *          '($THOUSAND)',
     *          T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *          T121,'DC4',T128,'RQMNT'/T2,'--------',
     *          T12,'---------',T24,'-----------',T39,'--------',
     *          T52,'-------',T62,'------',T70,'------',T79,
     *          '----------',
     *          T90,'---------',T101,'---',T108,'---',T115,'---',
     *          T121,'---',T128,'----'/)
C
        GOTO 999
C
C
C*       PAGE HEADER COMB./CAS. REPORT WITH STOP QUALIFICATION OPTION
C
 114    WRITE(21,1114)
01114   FORMAT(T25,'C.C.I.*',
     *          T90,'CUMULATIVE',T128,'MEETS'/
     *          T2,'CROSSING',
     *          T12,'PREDICTED',T25,'REDUCTION',T38,'RECOMMENDED',
     *          T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *          T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *          T119,'VALUES',T128,'STOP'/T4,'ID #',T12,'C.C.I.*',
     *          T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
     *          T63,'# OF',T71,'# OF',T82,'COST',T90,'C.C.I.*',T128,
     *          'SIGN'/
     *          T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *          T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *          '($THOUSAND)',
     *          T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *          T121,'DC4',T128,'RQMNT'/T2,'--------',
     *          T12,'---------',T24,'-----------',T39,'--------',
     *          T52,'-------',T62,'------',T70,'------',T79,
     *          '----------',
     *          T90,'---------',T101,'---',T108,'---',T115,'---',
     *          T121,'---',T128,'----'/)
C
        GOTO 999
C
C
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

```
C*        PAGE HEADER FATALS REPORT WITH STOP QUALIFICATION OPTION
C
 115     WRITE(21,1115)
 1115    FORMAT(T12,'PREDICTED',T25,'FATAL ACC.',T90,'CUMULATIVE'
     *            ,T128,'MEETS'/T2,'CROSSING',
     *            T12,'FATAL',T25,'REDUCTION',T38,'RECOMMENDED',
     *            T52,'PRESENT',T63,'TOTAL',T70,'TOTAL',T79,'CUMULATIVE',
     *            T90,'REDUCED',T101,'DECISION',T110,'CRITERIA',
     *            T119,'VALUES',T128,'STOP'/T4,'ID #',T12,'ACCIDENTS',
     *            T25,'COST RATIO',T40,'WARNING',T52,'WARNING',
     *            T63,'# OF',T71,'# OF',T82,'COST',T90,'FATAL ACC.',T128,
     *            'SIGN'/
     *            T12,'PER YEAR',T25,'(ACC/$MILL)',T40,'DEVICE',
     *            T52,'DEVICE',T62,'TRACKS',T70,'TRAINS',T78,
     *            '($THOUSAND)',
     *            T90,'PER YEAR',T101,'DC1',T108,'DC2',T115,'DC3',
     *            T121,'DC4',T128,'RQMNT'/T2,'---------',
     *            T12,'---------',T24,'-----------',T39,'---------',
     *            T52,'--------',T62,'------',T70,'-------',T79,
     *            '----------',
     *            T90,'---------',T101,'---',T108,'---',T115,'---',
     *            T121,'---',T128,'----'/)
C
 999     RETURN
C
         END
```

EXHIBIT C-5. RESOURCE ALLOCATION REPORT PROGRAM (Cont.)

APPENDIX D

```
C*    C*************************************************************
C*    C                                                            *
C*    C   THIS PROGRAM GENERATES A LISTING, IN REPORT FORMAT,      *
C*    C   OF ALL CROSSINGS THAT QUALIFY FOR STOP SIGNS.            *
C*    C                                                            *
C*    C   UNIT-20 INVENTORY INPUT FILE WITH FINAL PREDICTED ACCIDENTS*
C*    C                                                            *
C*    C   UNIT-21 OUTPUT FILE:  REPORT OUTPUT FILE                 *
C*    C                                                            *
C*    C   NOTE:   THIS PROGRAM GENERATES THREE DIFFERENT REPORTS . *
C*    C         EACH REPORT RANKS CROSSINGS BY ONE OF THE FOLLOWING *
C*    C         MEASURES : PREDICTED ACCIDENTS, PREDICTED FATAL    *
C*    C         ACCIDENTS OR COMBINED CASUALTY INDEX.THE INPUT FILE *
C*    C         SHOULD BE SORTED ON THE MEASURE THAT IS TO BE      *
C*    C         CONTAINED IN THE REPORT.                           *
C*    C                                                            *
C*    C*************************************************************

      INTEGER DEVICE(2,7),REPTYP(3,8),NS,DS,NT,DT,STOPS,
     *        FC10,FC1,AADT,TITLE(3),PAGE,CLASS,ID(2),LINE,
     *        DAY(2),STPFLG,TRAINS,TRACKS,CHOICE,MTRKS,OTRKS,
     *         RURURB(2)
      REAL    FATAL,CMBCAS,INJURY,A,AC
      DATA RURURB/'RURAL','URBAN'/
      DATA DEVICE/'NONE ','     ',
     *            'OTHER',' SIGN',
     *            'STOP ','SIGN ',
     *            'CROSS','BUCK ',
     *            'SPECI','AL   ',
     *            'HWY S','GNL  ',
     *            'LIGHT','     '/
C
      DATA REPTYP/'ACCI','FATA','COMB','DENT','L AC','INED',
     *            'S   ','CIDE',' CAS','    ','NTS ','UALT',
     *            '    ','    ','Y IN','    ','    ','DEX '
     *           ,'    ','    ','C.C.'
     *           ,'    ','    ','I*  '/
C


      OPEN(UNIT=21,FILE='STOP.DAT')
      OPEN(UNIT=20,FILE='ALA.DAT')
      CALL DATE(DAY)


C*         INPUT REPORT TYPE AND TITLE OF REPORT


      WRITE(5,66)
00066 FORMAT(T10,' PLEASE ENTER REPORT TITLE :')

      READ(5,77) TITLE
00077 FORMAT(3A5)

      WRITE(5,88)
00088 FORMAT(//,T5,'SHOULD REPORT INCLUDE ACCIDENT ',
     *        'PREDICTION RESULTS FOR : '//
     *        T10,'PREDICTED ACCIDENTS       (ENTER 1 )'/
     *        T10,'FATAL     ACCIDENTS       (ENTER 2 )'/
     *        T10,'COMBINED CASUALTY INDEX   (ENTER 3 )'/)

      READ(5,99) CHOICE
```

EXHIBIT D-1. STANDARD STOP SIGN REPORT PROGRAM

```
00099   FORMAT(I)

        PAGE=1

C
C*          PRINT STOP REPORT HEADING
C*
        WRITE(21,109) DAY,PAGE,TITLE
00109   FORMAT ('1',T8,2A5,
     *          T40,'RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION',
     *          ' RESULTS',T120,'PAGL ',I3/T40,'CANDIDATE CROSSINGS',
     *          ' FOR STANDARD HIGHWAY STOP SIGNS'/
     *          T52,'FOR ',3A5,/
     *          T40,'* ALL CANDIDATES ARE SINGLE TRACK ',
     *          'LOCAL HIGHWAY CROSSINGS'/T40,'---------------',
     *          '-------------------------------------------'/
     *          T40,'-REFER TO PARAGRAPH 8B-9 OF THE ',
     *          'MANUAL OF UNIFORM'/T40,'TRAFFIC CONTROL DEVICES ',
     *          'FOR FACTORS TO BE CONSIDERED PRIOR TO'/
     *          T40,'MAKING STOP SIGN INSTALLATION ',
     *          'DECISIONS.'/
     *           T40,'------------------------',
     *          '-----------------------------------'/)
        CALL HEADER(CHOICE)
        LINE=18

        PAGE=PAGE+1
        GOTO 100
C
C           NEXT PAGE !! PRINT HEADINGS
C

00111   WRITE(21,105) DAY,PAGE
00105   FORMAT('1',T8,2A5,T120,I3)
        CALL HEADER(CHOICE)
        LINE=7
        PAGE=PAGE+1

C
C*      ***************************************
C*      *                                     *
C*      *      MAIN PROCESSING LOOP           *
C*      *      SELECT NEXT CROSSING           *
C*      *                                     *
C*      ***************************************
C
 100    READ(20,5000,END=500)FATAL,INJURY,CMBCAS,A,ID,CLASS,
     *                  STOPS,NS,NT,DS,DT,MTRKS,OTRKS,
     *                  FC10,FC1,AADT
 5000   FORMAT(4F10.7,10X,A4,A3,18X,2I1,4I2,3X,
     *          I1,I2,3X,2I1,I6)
C
C
C*
C*          TOTAL TRAINS AND TRACKS FOR CURRENT CROSSING
C*
        TRAINS=NS+NT+DS+DT
        TRACKS=MTRKS+OTRKS
C
C
C
```

EXHIBIT D-1. STANDARD STOP SIGN REPORT PROGRAM (Cont.)

```
C*      ****************************
C*      *                          *
C*      *  STOP SIGN QUALIFICATION *
C*      *                          *
C*      ****************************
C
        STPFLG=0
C
        IF(STOPS.GE.1) GOTO 100
C
        IF(CLASS.GE.5) GOTO 100
        IF(FC1.NE.9) GOTO 100
        IF(TRAINS.LE.10) GOTO 100
        IF(TRACKS.NE.1) GOTO 100
        IF(FC10.NE.1) GOTO 125
        IF(AADT.GT.1500) GOTO 100
        GOTO 150
 125    IF(AADT.GT.400) GOTO 100
C

C*
C*           DETERMINE ACCIDENT OR CASUALTY MEASURE
C*
 150    AC=A
        IF(CHOICE.EQ.2) AC=FATAL
        IF(CHOICE.EQ.3) AC=CMBCAS



C*
C*           WRITE CURRENT CROSSING TO REPORT FILE
C*
        WRITE(21,248) ID,AC,(DEVICE(J,CLASS),J=1,2),
     *                 TRAINS,AADT,RURURB(FC10+1)
 248    FORMAT(T26,A4,A3,T38,F10.6,T56,2A5,T72,I2,
     *         T83,I6,T100,A5)



        LINE=LINE+1
        IF(LINE.GE.60) GOTO 111

        GOTO 100


 500    CLOSE(UNIT=20)
        CLOSE(UNIT=21)
        CALL EXIT
        END


      SUBROUTINE  HEADER(WHICH)
C*

C*
        INTEGER WHICH
        GOTO (116,117,118) WHICH
```

EXHIBIT D-1. STANDARD STOP SIGN REPORT PROGRAM (Cont.)

```
C*        PAGE HEADER STOP SIGN QUAL. REPORT (PRED. ACCS.)
C
 116    WRITE(21,1116)
 1116   FORMAT(T84,'ANNUAL'/T26,'CROSSING',T40,
     *          'PREDICTED',T56,'PRESENT',
     *          T70,'TOTAL',T84,'AVERAGE',T98,'CROSSING',/
     *          T28,'ID #',T40,'ACCIDENTS',
     *          T56,'WARNING',
     *          T70,'TRAINS',T84,'DAILY',T98,'LOCATION'/
     *          T40,'PER YEAR',T56,'DEVICE',
     *          T70,'PER DAY',T84,'TRAFFIC',T98,'URBAN/RURAL',/
     *          T26,'--------',T40,'---------',
     *          T56,'-------',
     *          T70,'-------',T84,'-------',T98,'-----------'/)
C
        GOTO 999
C
C
C*       PAGE HEADER STOPS QUAL. REPORT (COMB./CAS)
C
 117    WRITE(21,1117)
 1117   FORMAT(T40,'PREDICTED',T84,'ANNUAL'/T26,'CROSSING',T40,
     *          'COMBINED',T56,'PRESENT',
     *          T70,'TOTAL',T84,'AVERAGE',T98,'CROSSING',/
     *          T28,'ID #',T40,'CAS INDEX',
     *          T56,'WARNING',
     *          T70,'TRAINS',T84,'DAILY',T98,'LOCATION'/
     *          T40,'PER YEAR',T56,'DEVICE',
     *          T70,'PER DAY',T84,'TRAFFIC',T98,'URBAN/RURAL',/
     *          T26,'--------',T40,'---------',
     *          T56,'-------',
     *          T70,'-------',T84,'-------',T98,'-----------'/)
C
        GOTO 999
C
C
C*       PAGE HEADER STOP SIGN  QUAL.  REPORT (FATALS)
C
 118    WRITE(21,1118)
 1118   FORMAT(T40,'PREDICTED',T84,'ANNUAL'/T26,'CROSSING',T40,
     *          'FATAL',T56,'PRESENT',
     *          T70,'TOTAL',T84,'AVERAGE',T98,'CROSSING',/
     *          T28,'ID #',T40,'ACCIDENTS',
     *          T56,'WARNING',
     *          T70,'TRAINS',T84,'DAILY',T98,'LOCATION'/
     *          T40,'PER YEAR',T56,'DEVICE',
     *          T70.'PER DAY',T84,'TRAFFIC',T98,'URBAN/RURAL',/
     *          T26,'--------',T40,'---------',
     *          T56,'-------',
     *          T70,'-------',T84,'-------',T98,'-----------'/)
C
C
  999   RETURN
        END
```

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EXHIBIT D-1. STANDARD STOP SIGN REPORT PROGRAM (Cont.)