PB88-225206

Rail-Highway Crossing Resource Allocation Procedure

USER'S GUIDE, THIRD EDITION

Federal Railroad Administration
Office of Safety Analysis
Washington, DC 20590

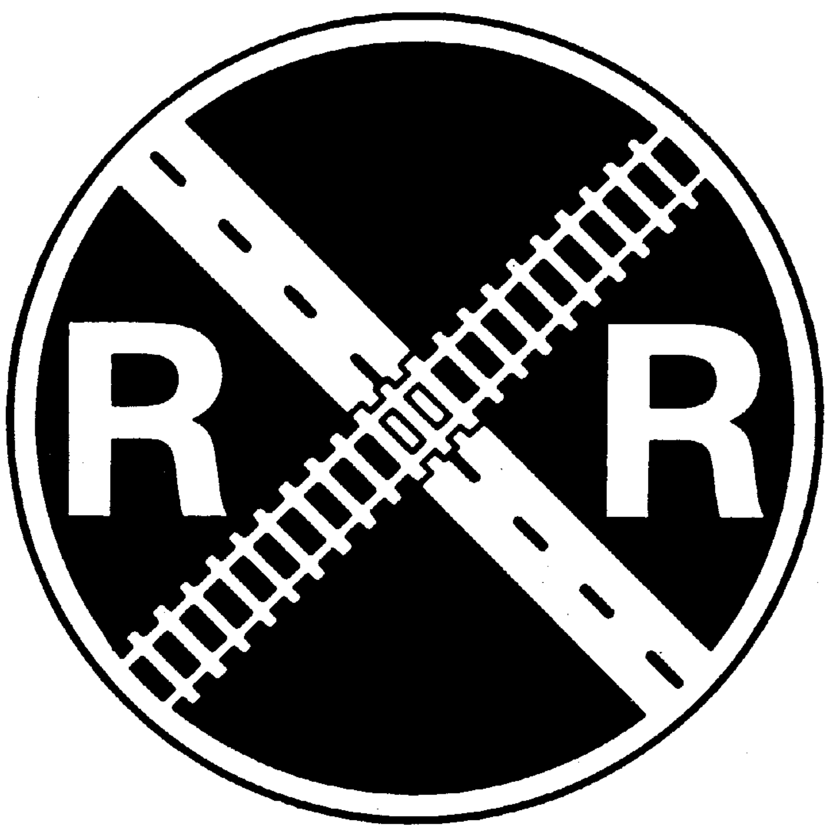
DOT/FRA/OS-87/10
DOT-TSC-FRA-87-1

August 1987

U.S. Department of Transportation

Federal Railroad Administration

Federal Highway Administration



Technical Report Documentation Page

1. Report No. DOT/FRA/OS-87/10	2. Government Accession No. PB88-225206/AS	3. Recipient's Catalog No.
4. Title and Subtitle RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE -USER's GUIDE, THIRD EDITION		5. Report Date August 1987
		6. Performing Organization Code DTS-73
7. Author(s) Edwin H. Farr		8. Performing Organization Report No. DOT-TSC- FRA-87- 1
9. Performing Organization Name and Address U.S. Department of Transportation Research and Special Programs Administration Transportation Systems Center Cambridge, MA 02142		10. Work Unit No. (TRAIS) RR780/R7027
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Railroad Administration Office of Safety Analysis Washington, DC 20590		13. Type of Report and Period Covered Final Report April 1986 - January 1987
		14. Sponsoring Agency Code RRS-21

15. Supplementary Notes

16. Abstract

The Highway Safety Acts of 1973 and 1976, the Surface Transportation Acts of 1978 and 1982 and the Surface Transportation and Uniform Relocation Assistance Act of 1987 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 severity Prediction formulas, which predict the number of acidents and casualties 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 third edition of the guide incorporates recalibrated accident and severity prediction formulas using recent inventory and accident experience, and a more flexible and more complete software system.

17. Key Words Rail-Highway Crossing Grade Crossing Railroad Safety Resource Allocation	18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	122	A06 14.95

Form DOT F1700.7 (8-72) Reproduction of completed page authorized

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 Analysis. 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.

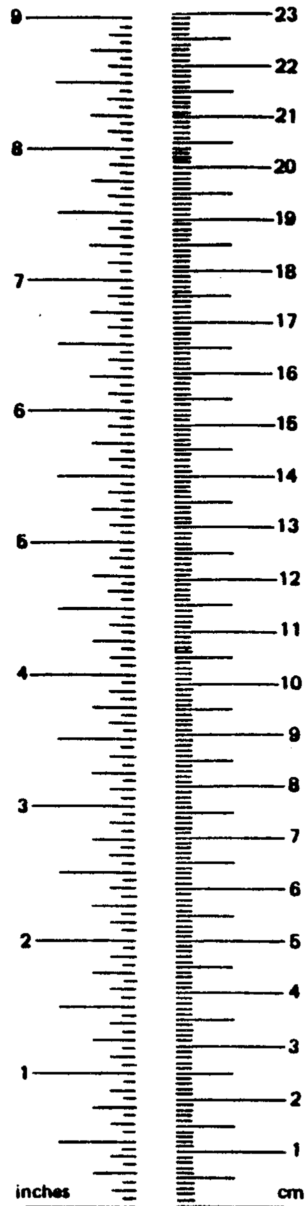
This user's guide provides complete information for application of the DOT procedures. Preparation of this third edition was the overall responsibility of Edwin H. Farr of TSC. Randhir Chhatwal of Bedford Research Inc., under contract to TSC, was responsible for development and description of computer programs required for application of the procedures.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

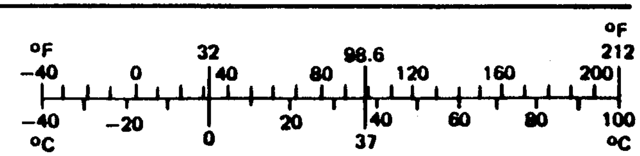
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



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1. INTRODUCTION

1.1 PURPOSE

This is the third edition of a document intended to provide interested persons with complete information on applying the DOT Rail-Highway Crossing Resource Allocation Procedure. The material is presented in non-technical terms with references given to the relevant technical reports.

1.2 BACKGROUND

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Assistance Acts of 1978 and 1982 and the Surface Transportation and Uniform Relocation Assistance Act of 1987 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[1*]. The first analytical method included in the DOT Procedure is the DOT Accident and Severity Prediction Formula, which computes the

*References begin on page 84.

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 select 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.

This third edition differs from the second edition[2] in two principal ways: the accident and severity prediction formulas have been recalibrated with recent accident experience and the computer programs have been expanded and rewritten in the SAS programming language. Although the new formulas are slightly better than the old, the old formulas are still valid and quite useable. Other refinements of the DOT Procedure of smaller magnitude have been included. A summary report on the DOT Procedure is available which should complement the material contained in the present report[3].

1.3 ORGANIZATION OF GUIDE

Chapter 2 provides a technical overview of the DOT Procedure and its two major elements, the DOT accident and severity 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 197,000 public at-grade rail-highway crossings in the United States. At an average cost of over $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., decisions on 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 <u>recommend</u> 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 inaccuracies in assumptions regarding warning device cost and effectiveness are normal and may cause inappropriate recommendations. To ensure

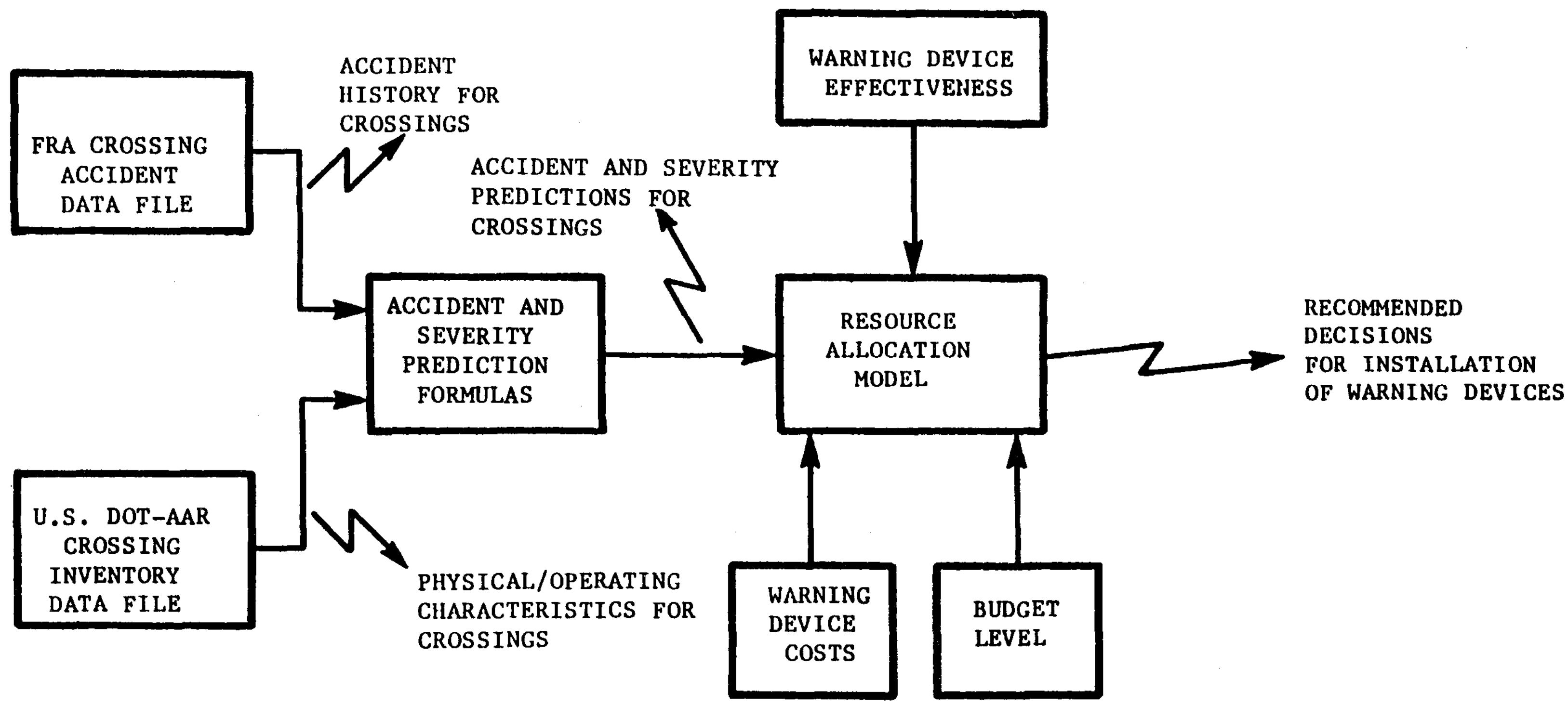

FIGURE 2-1. DOT RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE

accuracy of the input data, they 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 should include highway congestion, school bus and hazardous materials traffic, restricted sight distance, visual clutter, 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 could 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 system that passes 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 4.2.6, 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[4]. 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 severity 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 severity 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 or 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 well-known formulas[5,17] shows the DOT formulas to have significantly improved performance in this regard.

The formulas presented here were developed using the April 1986 Inventory and the accidents for the years 1981, 1982, 1983, 1984, and 1985. These formulas are considered better than those listed in the previous edition of this User's Guide[2]. However, the results show that the new formulas are only slightly better and the old formulas are still useable for ranking crossings according to their expected number of accidents per year. In addition, the new formulas are a refinement and simplification of the old formulas.

The functions of the DOT accident and severity 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 System (RAIRS). The accident and severity 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 the expected number of accidents per year at a crossing. If desired, predicted accident severity is then obtained in the second step using another set of formulas as described in Section 3.3. The severity calculations depend on the use of predicted accident results from the first step. The severity predictions for a crossing are expressed in three ways: (1) expected number of fatal accidents per year, (2) expected number of casualty accidents per year, and (3) total combined casualty index (a weighted combination of fatal and injury accidents per year).

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 unnormalized 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 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".

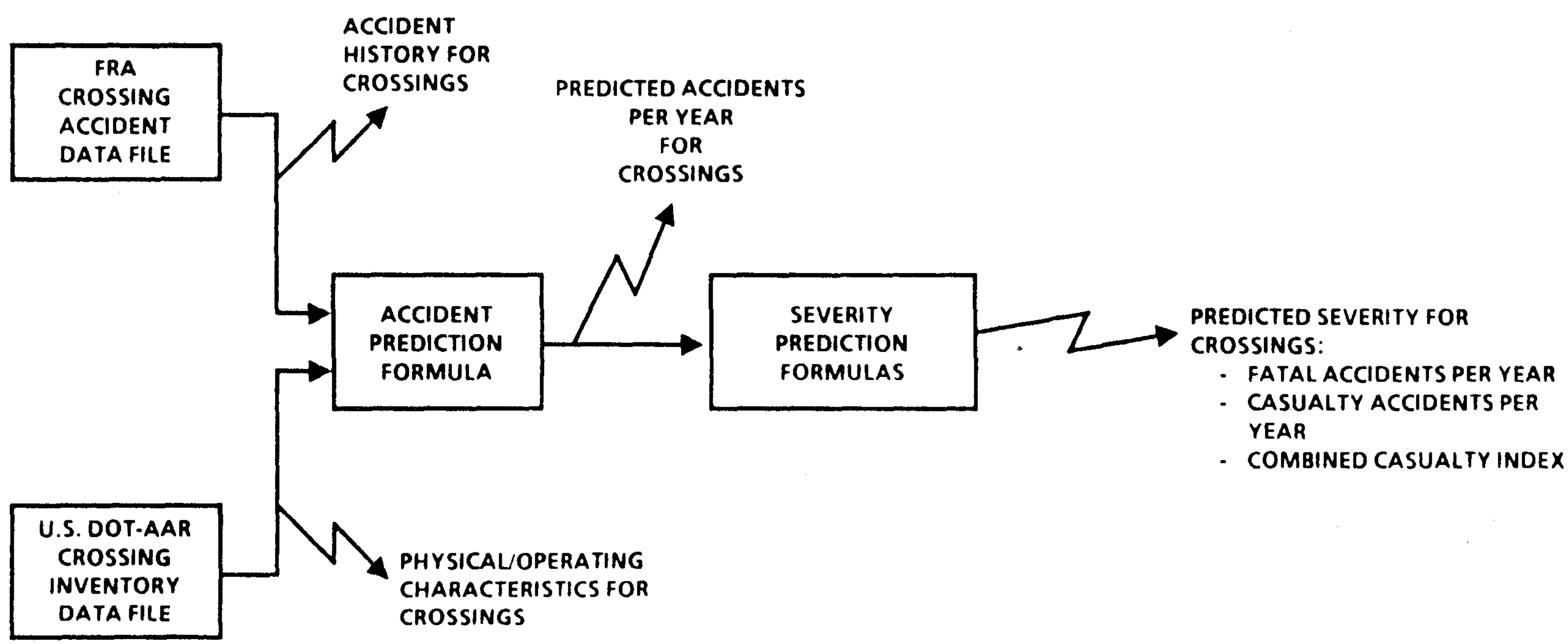

FIGURE 3-1. DOT RAIL-HIGHWAY CROSSING ACCIDENT AND SEVERITY PREDICTION FORMULAS

The above two independent predictions are combined as a weighted average using the general accident prediction formula described in Section 3.2.4. This consists of computing a weighted average value which is then multiplied by a normalizing constant.

3.2.2 Basic Formula

The unnormalized initial prediction of a crossing's accidents (a) is determined from the basic accident prediction formula given in equation (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 1981 through 1985 accident file and the April 1986 Inventory were used to develop the formula.

The resulting basic formula can be expressed as a series of factors which, when multiplied together, yield the unnormalized 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:

$$a = K \times EI \times DT \times MS \times MT \times HP \times HL \qquad (1)$$

where:

a = unnormalized initial accident prediction, in accidents per year at the crossing
K = formula constant
EI = factor for exposure index based on product of highway and train traffic
DT = factor for number of thru trains per day during daylight
MS = factor for maximum timetable speed
MT = factor for number of main tracks
HP = factor for highway paved (yes or no)
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

3. Gates, including the following warning device class:

   Class 8 - Automatic gates with flashing lights

The crossing characteristic factors 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 estimate the unnormalized number of accidents at a crossing with crossbucks, then the passive set of equations should be used. If it is desired to estimate the unnormalized number of accidents at a crossing recently upgraded from one warning device category to another, use the formulas for the prior category and apply the effectiveness factor for the upgrade. See Section 5.1.2 for a more detailed discussion.

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 formula makes it possible to construct look-up tables of numerical values for the crossing characteristic factors. To evaluate the basic formula at a particular crossing whose Inventory characteristics are known, the values of the factors

TABLE 3-1. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS

GENERAL FORM OF BASIC FORMULA: $a = K \times EI \times DT \times MS \times MT \times HP \times HL$

CROSSING CHARACTERISTIC FACTORS							
CROSSING CATEGORY	FORMULA CONSTANT	EXPOSURE INDEX FACTOR	DAY THROUGH TRAINS FACTOR	MAXIMUM TIMETABLE SPEED FACTOR	MAIN TRACKS FACTOR	HIGHWAY PAVED FACTOR	HIGHWAY LANES FACTOR
	K	EI	DT	MS	MT	HP	HL
PASSIVE	0.0006938	$((c \times t + 0.2)/0.2)^{0.37}$	$((d + 0.2)/0.2)^{0.178}$	$e^{0.0077ms}$	1.0	$e^{-0.5966(hp-1)}$	1.0
FLASHING LIGHTS	0.0003351	$((c \times t + 0.2)/0.2)^{0.4106}$	$((d + 0.2)/0.2)^{0.1131}$	1.0	$e^{0.1917mt}$	1.0	$e^{0.1826(hl-1)}$
GATES	0.0005745	$((c \times t + 0.2)/0.2)^{0.2942}$	$((d + 0.2)/0.2)^{0.1781}$	1.0	$e^{0.1512mt}$	1.0	$e^{0.1420(hl-1)}$

c = number of highway vehicles per day

t = number of trains per day

mt = number of main tracks

d = number of through trains per day during daylight

hp = highway paved? yes = 1.0 and no = 2.0

ms = maximum timetable speed, mph

hl = number of highway lanes

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 weaker relationship to predicted accidents.

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.

Use of accident history, along with the unnormalized prediction obtained from the basic formula, improves the overall prediction. This improvement comes about 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, or the timing of highway and train traffic. The most accurate predictions, in theory, will result from the 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 good performance from both the accident prediction formula and use of the most relevant data. Accident history information more than 5 years old 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.

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

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

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0006938	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	2.43	1	1.37	5	1.04	1	1.00			2	1.00
	6 - 10	3.95	2	1.53	10	1.08	2	1.00	2 (no)	0.55	3	1.00
	11 - 20	4.96	3	1.64	15	1.12	3	1.00	-		4	1.00
	21 - 30	5.99	4	1.72	20	1.17	4	1.00			5	1.00
	31 - 50	7.12	5	1.79	25	1.21	5	1.00			6	1.00
	51 - 80	8.51	6	1.84	30	1.26	6	1.00			7	1.00
	81 - 120	9.98	7	1.89	35	1.31					8	1.00
	121 - 200	11.88	8	1.94	40	1.36					9	1.00
	201 - 300	14.00	9	1.98	45	1.41						
	301 - 400	15.85	10	2.01	50	1.47						
	401 - 500	17.39	11-10	2.16	55	1.53						
	501 - 600	18.73	21-30	2.37	60	1.59						
	601 - 700	19.93	31-40	2.51	65	1.65						
	701 - 1000	22.01	41-60	2.67	70	1.71						
	1001 - 1300	24.61			75	1.78						
	1301 - 1600	26.81			80	1.85						
	1601 - 2000	29.05			85	1.92						
	2001 - 2500	31.28			90	2.00						
	2501 - 3000	33.98										
	3001 - 4000	37.15										
	4001 - 6000	42.39										
	6001 - 8000	48.01										
	8001 - 10000	52.69										
	10001 - 15000	59.49										
	15001 - 20000	67.38										
	20001 - 25000	73.95										
	25001 - 30000	79.65										
	30001 - 40000	87.08										
	40001 - 50000	95.57										
	50001 - 60000	102.93										
	60001 - 70000	109.50										
	70001 - 90000	118.24										
	90001 - 110000	128.42										
	110001 - 130000	137.38										
	130001 - 180000	151.02										
	180001 - 230000	167.48										
	230001 - 300000	187.14										
	300001 - 370000	200.86										

K = formula constant
"c" x "t" - number of highway vehicles per day, "c", multiplied by the number of trains per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day through trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HL = highway lanes factor

*Less than one train per day.

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

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

K	"c" x "t"	EI
0.0003351	0*-	1.00
	1 - 5	3.12
	6 - 10	4.59
	11 - 20	5.92
	21 - 30	7.28
	31 - 50	8.82
	51 - 80	10.76
	81 - 120	12.54
	121 - 200	15.57
	201 - 300	18.70
	301 - 400	21.46
	401 - 500	23.79
	501 - 600	25.84
	601 - 700	27.67
	701 - 1000	30.89
	1001 - 1300	34.97
	1301 - 1600	38.47
	1601 - 2000	42.04
	2001 - 2500	46.07
	2501 - 3000	50.03
	3001 - 4000	55.23
	4001 - 6000	63.94
	6001 - 8000	73.42
	8001 - 10000	81.40
	10001 - 15000	93.15
	15001 - 20000	106.95
	20001 - 25000	118.58
	25001 - 30000	128.76
	30001 - 40000	142.17
	40001 - 50000	157.62
	50001 - 60000	171.16
	60001 - 70000	183.31
	70001 - 90000	199.62
	90001 - 110000	218.78
	110001 - 130000	235.78
	130001 - 180000	261.91
	180001 - 230000	293.77
	230001 - 300000	326.42
	300001 - 370000	359.40

Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
1	1.22	5	1.00	1	1.21			2	1.20
2	1.31	10	1.00	2	1.47	2 (no)	1.00	3	1.44
3	1.37	15	1.00	3	1.78			4	1.72
4	1.41	20	1.00	4	2.15			5	2.08
5	1.45	25	1.00	5	2.61			6	2.49
6	1.47	30	1.00	6	3.16			7	2.99
7	1.50	35	1.00					8	3.59
8	1.52	40	1.00					9	4.31
9	1.54	45	1.00						
10	1.56	50	1.00						
11-20	1.63	55	1.00						
21-30	1.73	60	1.00						
31-40	1.79	65	1.00						
41-60	1.87	70	1.00						
		75	1.00						
		80	1.00						
		85	1.00						
		90	1.00						

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

*Less than one train per day.

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

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

K	"c" x "t"	EI
0.0005745	0*-	1.00
	1 - 5	2.26
	6 - 10	2.98
	11 - 20	3.57
	21 - 30	4.15
	31 - 50	4.76
	51 - 80	5.99
	81 - 120	6.23
	121 - 200	7.15
	201 - 300	8.15
	301 - 400	9.00
	401 - 500	9.69
	501 - 600	10.28
	601 - 700	10.79
	701 - 1000	11.68
	1001 - 1300	12.77
	1301 - 1600	13.67
	1601 - 2000	14.57
	2001 - 2500	15.55
	2501 - 3000	16.20
	3001 - 4000	17.71
	4001 - 6000	19.67
	6001 - 8000	21.72
	8001 - 10000	23.39
	10001 - 15000	25.76
	15001 - 20000	28.44
	20001 - 25000	30.67
	25001 - 30000	32.49
	30001 - 40000	34.87
	40001 - 50000	37.55
	50001 - 60000	39.83
	60001 - 70000	41.84
	70001 - 90000	44.48
	90001 - 110000	47.49
	110001 - 130000	50.11
	130001 - 180000	54.03
	180001 - 230000	58.24
	230001 - 300000	63.26
	300001 - 370000	67.78

Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
1	1.38	5	1.00	1	1.16			2	1.15
2	1.53	10	1.00	2	1.35	2 (no)	1.00	3	1.32
3	1.64	15	1.00	3	1.57			4	1.53
4	1.72	20	1.00	4	1.83			5	1.76
5	1.79	25	1.00	5	2.13			6	2.03
6	1.84	30	1.00	6	2.48			7	2.34
7	1.89	35	1.00					8	2.70
8	1.94	40	1.00					9	3.11
9	1.98	45	1.00						
10	2.01	50	1.00						
11-20	2.16	55	1.00						
21-30	2.37	60	1.00						
31-40	2.51	65	1.00						
41-60	2.68	70	1.00						
		75	1.00						
		80	1.00						
		85	1.00						
		90	1.00						

K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by the number of trains per day, "t"
EI - exposure index factor
MT = main tracks factor
DT = day through trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HL = highway lanes factor

*Less than one train per day.

3.2.4 General Accident Prediction Formula

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

$$B = \frac{T_o}{T_o+T}(a) + \frac{T}{T_o+T}\left(\frac{N}{T}\right) \qquad (2a)$$

$$A = \begin{cases} .8644\ B & \text{Passive} \\ .8887\ B & \text{Flashing lights} \\ .8131\ B & \text{Gates} \end{cases} \qquad (2b)$$

where:

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

a = initial unnormalized accident prediction from basic formula (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 (2a) calculates a weighted average of a crossing's unnormalized predicted accidents from the basic formula (a) and accident history (N/T). Values of (B), obtained from Equation (2a) for different values of the unnormalized initial prediction (a), from (1) and different accident histories (N/T) are tabularized in Tables 3-5 through 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 value of B can be interpolated from the tables or determined directly from the formula.

TABLE 3-5. VALUES OF B, GIVEN THE 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. VALUES OF B, GIVEN THE 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. VALUES OF B, GIVEN THE 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. VALUES OF B, GIVEN THE 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. VALUES OF B, GIVEN THE 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	0.90[illegible]	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 through 3-9, the value of (B) 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 value of (B) is 0.300.

The normalizing constants used in formula (2b) are reset periodically so that the sum of the predicted accidents (from 2a) in each group (passive, flashing lights, gates) for the top 20 percent most hazardous crossings exactly equals the number of accidents which occurred in a recent period for the top 20 percent of that group. Simply stated, the normalizing constant is the ratio of the actual number of accidents to the predicted number of accidents. In theory, these constants could be calculated for subsets of crossings (e.g., for individual States) so that final predictions (A) would reflect the recent experience of that subset. The efficacy of such fine tuning has not been tested by the DOT.

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

1. The value of (B) 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 normalizing constant times (a) or N/T.

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

It is expected that the basic formula (1) and the accident history formula (2a) will not change significantly in the near future. However, the normalizing constants used in (2b) could change slightly from year-to-year as accident experience and Inventory changes are applied. The normalizing constants will be recalculated periodically and will be published annually in FRA's Rail-Highway Crossing Accident/Incident and Inventory Bulletin starting with Bulletin No. 10 to be published in 1988 for Calendar Year 1987.

3.3 DESCRIPTION OF FORMULAS FOR ACCIDENT SEVERITY PREDICTION

3.3.1 Overview

The effort to develop accident severity prediction formulas was motiviated 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 severity prediction formulas described here represent the results of an effort to achieve that objective[6].

Two casualty prediction formulas have been developed; a fatal accident prediction formula and a casualty accident 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 casualty accidents. A fatal accident is defined as an accident which results in at least one fatality independent of injuries or property damage. A casualty accident is an accident which results in at least one fatality or at least one injury independent of property damage.

The severity prediction formulas are designed to be used with the general accident prediction formula (2) to produce the estimates of fatal and casualty accidents per year at crossings. The severity prediction formulas used without the accident prediction formula produce estimates of the probability of a fatal or casualty accident given that an accident occurred. For example, the fatal accident 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 (2) the result is predicted fatal accidents per year at the crossing. As an example, 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 accident rate of .2 x .5 or 0.1 fatal accidents per year.

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

Development of the accident severity prediction formulas involved performing regression analyses of data on crossings which experienced accidents. The dependent variables for the fatality and casualty regression formulas were allowed one of two values indicating whether the accident did or did not result in a fatal or casualty accident. The independent variables represented various characteristics of the accident crossings as described in the inventory. Accident data for 1981 through 1985 and the April, 1986 Inventory data were used for formula development. The regression procedure used is referred to as the "logistic discriminant method" which employs an iterative weighted regression technique. This method is the same as that used in developing the accident prediction formulas[5].

3.3.2 Fatality and Casualty Prediction Formulas

The formulas for predicting the probabilities of fatal accidents and casualty 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 represents a characteristic of the crossing as described in the Inventory. The probability of a fatal accident given an accident is expressed as:

$$P(FA|A) = 1/(1 + KF \times MS \times TT \times TS \times UR) \quad (3)$$

where:

P(FA|A)	=	probability of a fatal accident, given an accident
KF	=	formula constant (440.9)
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 a casualty accident, given an accident, is expressed as:

$$P(CA|A) = 1/(1 + KC \times MS \times TK \times UR) \quad (4)$$

where: P(CA|A) = probability of a casualty accident, given an accident
KC = formula constant (4.481)
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 casualty 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 casualtyaccident 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 casualty 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 casualty accident severity.

To obtain predicted numbers of fatal and casualty accidents the fatal and casualty accident probabilities, from equations (3) and (4) are multiplied by predicted accidents from equation (2). Hence, the formula for predicted fatal accidents at a crossing is:

$$FA = P(FA|A) \times A \quad (5)$$

where: FA = predicted fatal accidents per year
P(FA|A) = predicted fatal accident probability from equation (3)
A = predicted accidents per year from equation (2)

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

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

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Formula constant	$KF = 440.9$
Maximum Timetable Train Speed Factor	$MS = ms^{-0.9981}$
Thru Trains Per Day Factor	$TT = (tt + 1)^{-0.0872}$
Switch Trains Per Day Factor	$TS = (ts + 1)^{0.0872}$
Urban - Rural Crossing Factor	$UR = e^{0.3571 ur}$

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

ur = FC10 (tens digit of functional classification). See page A-11.

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

Casualty Accident Probability Formula: $P(CA|A) = 1/(1 + KC \times MS \times TK \times UR)$

CROSSING CHARACTERISTIC FACTOR	EQUATION FOR CROSSING CHARACTERISTIC FACTOR
Formula Constant	$KC = 4.481$
Maximum Timetable Train Speed Factor	$MS = ms^{-0.343}$
Number of Tracks Factor	$TK = e^{0.1153tk}$
Urban - Rural Crossing Factor	$UR = e^{0.296ur}$

where:

ms = maximum timetable train speed, mph

tk = total number of tracks at crossing

ur: urban crossing = 1, rural crossing = 0

ur = FC10 (tens digit of functional classification). See page A-11.

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

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

FORMULA CONSTANT KF	MAXIMUM TIMETABLE TRAIN SPEED	MS	THROUGH TRAINS PER DAY	TT	SWITCH TRAINS PER DAY	TS	URBAN RURAL CROSSING	UR
440.9	1	1.000	0	1.000	0	1.000	0 (rural)	1.000
	5	0.201	1	0.941	1	1.062	1 (urban)	1.344
	10	0.100	2	0.908	2	1.101		
	15	0.067	3	0.886	3	1.128		
	20	0.050	4	0.869	4	1.151		
	25	0.040	5	0.855	5	1.169		
	30	0.034	6	0.844	6	1.185		
	40	0.025	7	0.834	7	1.199		
	50	0.020	9	0.818	9	1.222		
	60	0.017	10	0.811	10	1.233		
	70	0.014	20	0.767	20	1.304		
	80	0.013	30	0.741	30	1.349		
	90	0.011	40	0.723	40	1.382		
	100	0.010	50	0.710	50	1.409		

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

CASUALTY ACCIDENT PROBABILITY FORMULA: P(CA|A) = 1/(1 + KC x MS X TK x UR)

FORMULA CONSTANT KC	MAXIMUM TIMETABLE TRAIN SPEED	MS	TOTAL NUMBER OF TRACKS	TK	URBAN-RURAL CROSSING	UR
4.481	1	1.000	0	1.000	0 (rural)	1.000
	5	0.576	1	1.122	1 (urban)	1.429
	10	0.454	2	1.259		
	15	0.395	3	1.413		
	20	0.358	5	1.780		
	25	0.332	6	1.997		
	30	0.308	7	2.241		
	40	0.282	8	2.515		
	50	0.261	9	2.823		
	60	0.246	10	3.168		
	70	0.233	15	5.638		
	80	0.222	20	10.034		
	90	0.214				
	100	0.206				

The formula for predicted casualty accidents at a crossing is:

$$CA = P(CA|A) \times A \tag{6}$$

where: CA = predicted casualty accidents per year
P(CA|A) = predicted casualty accident probability from equation (4)
A = predicted accidents per year from equation (2)

To illustrate characteristics of the fatal and casualty accident probability formulas, the two functions P(FA|A) and P(CA|A) are plotted as a function of maximum timetable train speed in Figure 3-2. 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 do not have a major influence on fatal accident probability.

The probability of a casualty accident, given an accident, P(CA|A) increases as a nonlinear function of timetable train speed. Injury accident probability generally increases rapidly with low values of timetable train speed and then gradually assumes the upward slope of the fatal accident probability beyond 40 mph. This is initiutively appealing since, as accident severity increases, casualities will increasingly become fatalities and non-fatal injuries should diminish. The number of tracks at the crossing has a significant influence on the casualty function (casualty accident probability decreases with the number of tracks); however, the urban-rural location has only a minor influence.

3.3.3 Combined Casualty Index Formula

The severity of crossing accidents is basically determined by two factors: 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

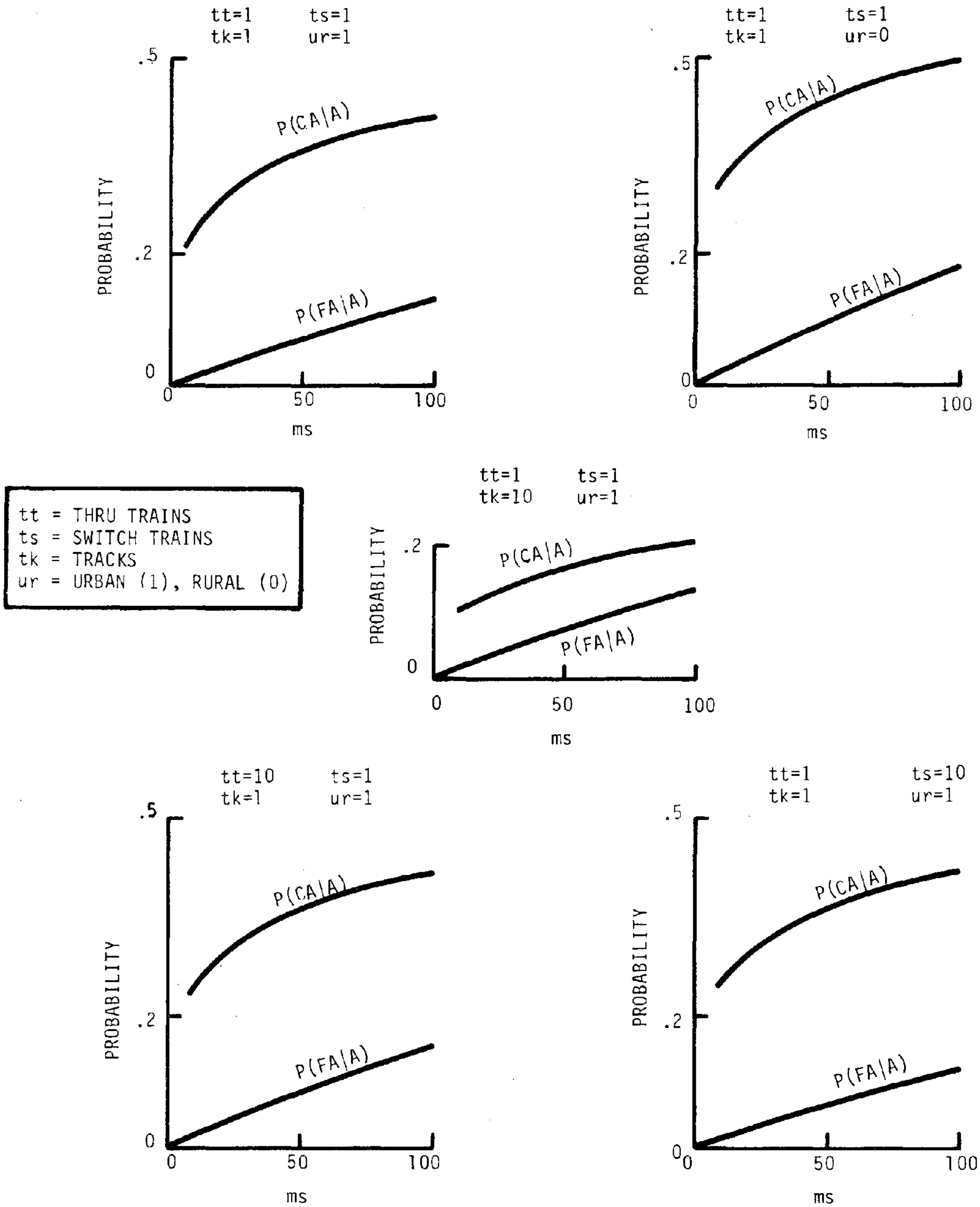

FIGURE 3-2. TYPICAL PLOTS OF PROBABILITY OF FATAL ACCIDENTS P(FA|A) AND PROBABILITY OF CASUALTY ACCIDENTS P(CA|A) AS A FUNCTION OF TIMETABLE TRAIN SPEED ms.

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 accidents per year (FA) and the predicted injury accidents per year (IA). It is expressed as:

$$CCI = k \times FA + IA \qquad (7)$$

This formula can be considered an "equivalent injury" accident function. It converts fatal accidents to equivalent injury accidents using the fatality factor k and adds this value to the number of injury accidents. The units for CCI could be "equivalent injury accidents per year".

The user of the 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[15,16]. Based on results of accident costs[16] a value of 50 for k may be reasonable for users who are unsure as to which value to use.

Making the substitution IA = CA - FA, equation (7) becomes:

$$\begin{aligned} CCI &= k \times FA + CA - FA \\ &= (k - 1) \times FA + CA \qquad (8) \end{aligned}$$

4. RESOURCE ALLOCATION MODEL

4.1 INTRODUCTION

The resource allocation model was developed to assist state and railroad officials in their crossing safety improvement decision process[7]. 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 principally provides safety improvement recommendations for two types of active motorist warning device upgrades; flashing lights and automatic gates. In addition, it identifies crossings that qualify for standard highway stop signs according to the FHWA guidelines[14]. 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 severity prediction formulas 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 for 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 a number between 0 and 1 which determines the 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 devices 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 devices, 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". The resource allocation model only considers improvements for passive and flashing light crossings, since gates are assumed to be the most effective warning device available. Therefore, users of the model may want to obtain a list of gate crossings for the geographical area of interest, possibly ranked by the severity measure used in the resource allocation computation, to complement the resource allocation results. This will enable the user to bring all crossings into the analysis in some way.

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 a passive crossing, and $j = 3$ for gates installed at a crossing with flashing lights. The first parameer (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. It has also been determined that E_j can vary according to the number of tracks and the number of trains per day at the crossing[11]. These results are given in Table 4-8.

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

*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

passive crossing, i, is considered, it could be upgraded with either flashing lights, with an effectiveness E_1, or gates, with an effectiveness E_2. The number of predicted accidents or casualties at crossing i is denoted as AC_i; hence, the reduced accidents or casualties per year is $AC_i x E_1$ for the flashing light option and $AC_i x E_2$ 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 $AC_i x E_1/C_1$ for flashing lights and $AC_i x E_2/C_2$ for gates. The rate of increase in accident or casualty reduction versus cost 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 rato" and is equal to $AC_i(E_2-E_1)/(C_2-C_1)$. The incremental accident or casualty reduction/cost ratio ACR/C 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. 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 $AC_i x E_2/C_2$. 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 $AC_i x E_3/C_3$.

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 cost (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 $AC_i x E_j$.

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 (effectiveness, C_1, C_2, C_3) and the available budget (CMAX). It should be noted that 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 $E_1/C_1 > E_2/C_2$, 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 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: Two accident or casualty reduction/cost ratios are calculated for each single-track passive crossing, $AC_i x E_1/C_1$ and the incremental ratio $AC_i x(E_2-E_1)/(C_2-C_1)$, where AC_i is the number of accidents or casualties predicted per year for the crossing.

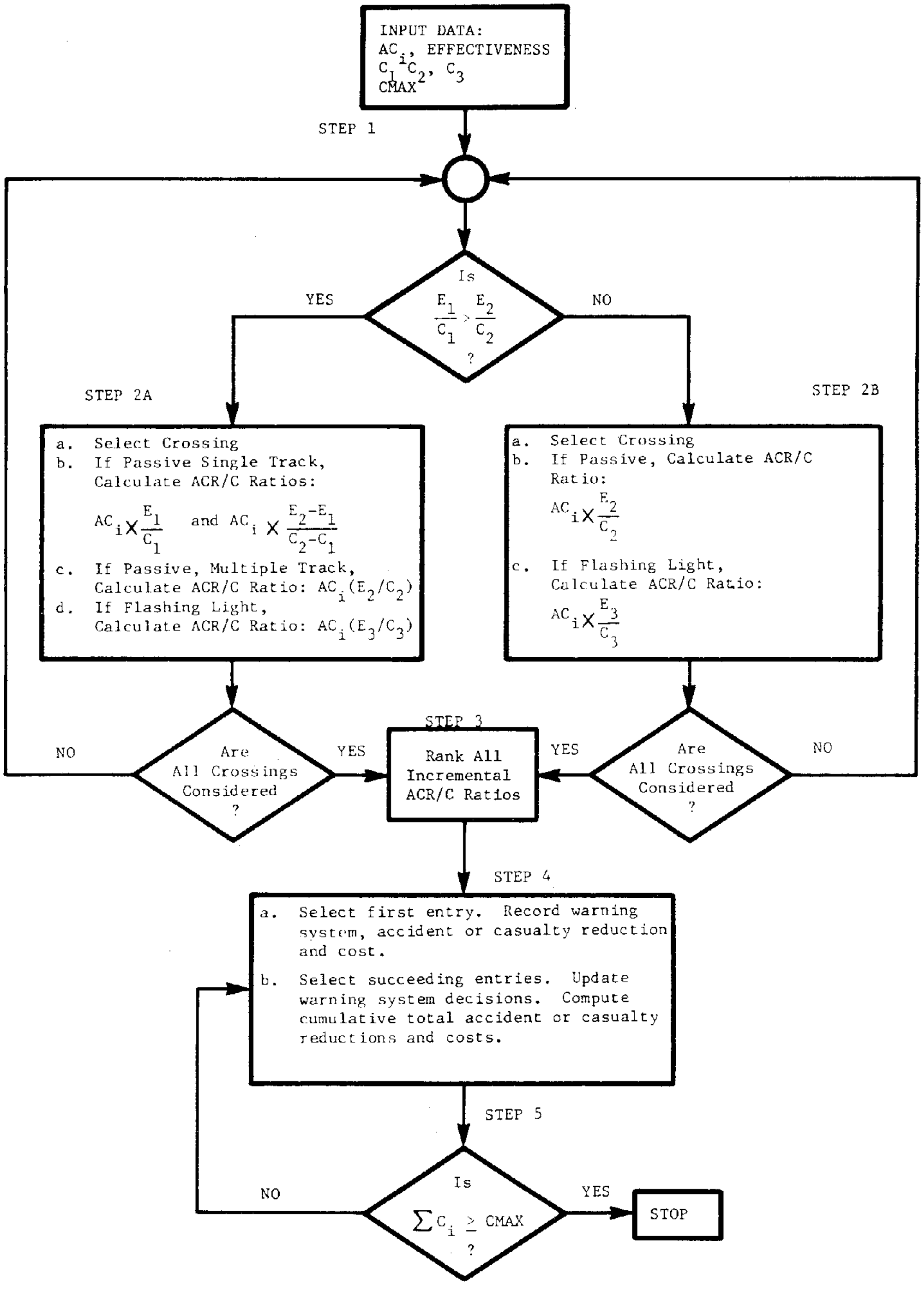

FIGURE 4-1. RESOURCE ALLOCATION ALGORITHM

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_ixE_2/C_2), to conform with Federal regulations. For each crossing equipped with flashing lights, the algorithm computes AC_ixE_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_ixE_2/C_2 for passive crossings and the ratio AC_ixE_3/C_3 for crossings with flashing lights. These accident or casualty reduction/cost ratios are associated with installing only gates at crossings. For this case, these actions are always optimal relative 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/cost ratio at any given step on the list is calculated as AC_ixE_1/C_1, a decision is made to install flashing lights at a passive crossing, with an accident or casualty reduction of AC_ixE_1 and cost of C_1. If the accident or casualty reduction/cost ratio is $AC_ix(E_2-E_1)/(C_2-C_1)$, a previous decision to install flashing lights is changed to install gates at a passive crossing. The incremental accident or casualty reduction of changing the previous decision is $AC_ix(E_2-E_1)$, and the incremental cost is C_2-C_1. If the accident or casualty reduction/cost ratio is AC_ixE_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_ixE_2 at a cost of C_2. If the accident or casualty reduction/cost ratio is AC_ixE_3/C_3, then a decision is made to install gates at a crossing which had flashing lights. The accident or casualty reduction is $AC_i x E_3$ 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 (total benefit) 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/cost 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 for the algorithm. 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. This implies that the most effective first action which can be taken at a passive crossing is the installation of flashing lights.

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	—	—	$E_3 = 0.667$	$C_3 = \$35,000$

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

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	$\sum E_jA_i$ CUMULATIVE ACCIDENTS REDUCED PER YEAR	$\sum C_j$ 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	$25,000
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 of these costs[8]. 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[9]. 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[11]. 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[10].

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:

$$MI = \frac{(MS/140 + WR/179)}{2} \tag{9}$$

where:

MI = inflation multiplier for installation costs

MS = materials and supplies index for the subject year

WR = wage rate index for the subject year

The inflation multiplier for maintenance costs (MM) is a weighted average of 95 percent of the installation cost multiplier MI, (determined from equation (9) 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:

$$MM = MI \times 0.95 + (F/232) \times 0.05 \tag{10}$$

where:

MM = inflation multiplier for maintenance costs

F = fuel index for the subject 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 original study to determine these costs[8] 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[11]. 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[12]. A third study was performed in 1974 by the California Public Utilities Commission[13]. 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.

TABLE 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 they used the largest data base of national scope.

The latest DOT study on warning device effectiveness determined that several crossing chracteristics, 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 value 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 DEVICE IMPROVEMENT OPTION	NUMBER OF TRAINS/DAY:	SINGLE TRACK ≤ 10	SINGLE TRACK >10	MULTIPLE TRACK ≤ 10	MULTIPLE TRACK >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.

<u>Instructions for Determining If Recommended Warning Device Should Be Revised</u>

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		3b. Existing Passive Crossing (Classes 1, 2, 3, 4) Multiple Tracks		3c. Existing Flashing Light Crossing (Classes 5, 6, 7)	
Comparison	Decision	Comparison	Decision	Comparison	Decision
$DC_2 \leq R$	Gates	$DC_3 \leq R$	Gates	$DC_4 \leq R$	Gates
$DC_1 \leq R < DC_2$	Flashing Lights	$R < DC_3$	No Installation	$R < DC_4$	No Installation
$R < DC_1$	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 characteristic 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:

$$R = \frac{\text{Revised AC}}{\text{Previous AC}} \times \frac{\text{Revised E}}{\text{Previous E}} \times \frac{\text{Previous C}}{\text{Revised C}} \tag{11}$$

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 5-10) 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:

$$DC_1 = (ACR/C_m)/(A_i(E_1/C_1)) \tag{12}$$

$$DC_2 = (ACR/C_m)/(A_i(E_2-E_1)/(C_2-C_1)) \tag{13}$$

$$DC_3 = (ACR/C_m)/(A_i(E_2/C_2)) \tag{14}$$

$$DC_4 = (ACR/C_m)/(A_i(E_3/(C_3)) \tag{15}$$

where ACR/C_m equals the minimum accident or casualty reduction/cost ratio corresponding to the last (lowest) improvement action selected by the resource allocation model. These 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 hypothetical 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 second crossing (ID# 636R) on the sample standard output report of the resource allocation model shown in Figure 5-10. 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	0.19	0.26
Warning Device Effectiveness, E	0.90	0.87
Warning Device Cost, C	$65,300	$115,000

Using the above data, the R value is calculated using equation (11) (also shown on the worksheet, step 4, part 2):

$$R = (.26/.19)\,(.87/.90)\,(65{,}300/115{,}000)$$

$$= 0.751$$

The decision criteria for this crossing, obtained from the standard output report of the resource allocation model, Figure 5-10, are:

DC_1 = 0.318
DC_2 = 0.780
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[11] 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[11]. The FHWA has established the following guidelines for the selection of candidate crossings for stop signs[4,14]:

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 all of 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 sign 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 two fold: (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 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 hypothetical 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 taffic (c)	350
Total number of train movements per day (t)	15
Total number of thru trains per day (tt)	10
Total number of switch trains per day (ts)	5
Number of main tracks (mt)	2
Total number of tracks (main and other) (tk)	2
Number of thru trains per day during daylight (d)	5
Highway paved? (hp)	yes
Maximum time table speed, mph (ms)	40
Number of highway lanes (hl)	2
Urban - rural location (ur)	Rural
Number of years accident data, T	5
Number of accidents, N, in T years	2

First, the basic formula (1) is used to determine the unnormalized prediction (a):

a = K x EI x DT x MS x MT x HP x HL

where:

a = unnormalized initial accident prediction

K = constant

EI = factor for exposure (product of highway and train traffic)

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

MS = factor for maximum timetable speed

MT = factor for number of main tracks

HP = factor for highway paved (yes or no)

HL = factor for number of highway lanes

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

K = 0.0006938

EI = exposure index factor value for the product of 350 average daily highway vehicle and 15 total train movements per day (c x t = 5250) = 42.39

DT = 1.79

MS = 1.36

MT = 1.00

HP = 1.00

HL = 1.00

Substituting the factor values into the basic formula yields:

a = K x EI x DT x MS x MT x HP x HL
= 0.0006938 x 42.39 x 1.79 x 1.36 x 1.00 x 1.00 x 1.00
= 0.072

The value of (B) is determined by combining the unnormalized prediction (a) with the crossing's accident history using Tables 3-5 through 3-9, which are developed from equation (2a). For the sample crossing, two accidents (N) occurred over the past 5 years (T); therefore, Table 3-9 is used. With an unnormalized accident prediction (a = 0.072) between 0.07 and 0.08, it can be seen from Table 3-9 that the value of B will be between 0.194 and 0.206. A reasonable estimate of (B) can be determined by linear interpolation to be B = 0.196. Thus, from equation (2b), since this is a passive crossing, the final accident prediction (A) is:

A = .8644 x .196
= 0.169 accidents per year

To determine the number of fatal accidents at the sample crossing, the fatal accident probability is first obtained using equation (3):

P(FA|A) = 1/(1 + KF x MS x TT x TS x UR)

where: KF = 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:

KF = 440.9
MS = 0.025
TT = 0.811
TS = 1.169
UR = 1.000

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

$$P(FA|A) = 1/(1 + KF \times MS \times TT \times TS \times UR)$$
$$= 1/(1 + 440.9 \times 0.025 \times 0.811 \times 1.169 \times 1.000)$$
$$= 0.087 \text{ probability of a fatal accident given an accident}$$

The fatal accident probability is then multiplied by the predicted accidents, computed above using equation (2), to obtain the predicted number of fatal accidents from equation (5) for the sample crossing:

$$FA = P(FA|A) \times A$$
$$= 0.087 \times 0.169$$
$$= 0.015 \text{ fatal accidents per year}$$

To determine the number of casualty accidents at the sample crossing, the casualty accident probability is first obtained using equation (4):

$$P(CA|A) = 1/(1 + KC \times MS \times TK \times UR)$$

where: KC = 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 casualty accident probability formula can be determined from Table 3-13 using the sample crossing characteristics from Table 5-1:

KC = 4.481
MS = 0.282
TK = 1.259
UR = 1.000

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

$$P(CIA|A) = 1/(1 + 4.481 \times 0.282 \times 1.259 \times 1.000)$$
$$= 0.386 \text{ probability of a casualty accident given an accident}$$

The casualty accident probability is then multiplied by the predicted accidents, computed above using equation (2), to obtain the predicted number of casualty accidents for the sample crossing from equation (6):

$$CA = P(CA|A) \times A$$
$$= 0.386 \times 0.169$$
$$= 0.065 \text{ casualty accidents per year}$$

The combined casualty index (CCI) is obtained from equation (8) for the sample crossing:

$$CCI = (k-1) \times FA + CA$$

where: k = fatality factor selected by user
FA = fatal accidents per year from equation (5)
CA = casualty accidents per year from equation (6)

Substituting a value of 50 for k and the above values for FA and CA, the combined casualty index formula yields:

$$CCI = 49 \times 0.015 + 0.065$$
$$= 0.80$$

5.1.2 Computer Program for Calculation of Predicted Accidents and Casualties

This section describes procedures for using the DOT accident and severity prediction formula computer program 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 Analysis.

A SAS computer procedure called ACPD.NEW is written to generate accident and severity prediction listings. The program listing for ACPD.NEW is contained in Appendix A-1. The program executes a number of data steps which accomplish the following subtasks:

a. Data Subsetting

From the data set comprising all the grade crossings, select the set of crossings for which accident prediction is to be made and ranked.

b. Accident and Severity Prediction

Compute basic predicted accidents (H) for every selected crossing based on its warning device type. Using the appropriate severity prediction formula, compute the predicted accidents or fatal accidents or combined casuality index.

c. Report Printing

Execute the specific report generating procedure depending on the severity measure selected earlier. This procedure prints the following reports:

(1) Listing of grade crossings sorted by rank,
(2) Listing of grade crossings sorted by crossing IDs.

d. Summary Printing

Execute the summary data step which prints the input data as well as run time summary.

The Accident and Severity Prediction subtask is divided into three sections. The first section, 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 for class 8 the Gates equation is used.

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 5 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 makes an adjustment to the predicted accidents using the appropriate effectiveness factor (see Tables 4-7 and 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 5 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 5 years, the passive (Crossbucks) formula would be used and the result 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.

An algebraic equivalent of equation (2) from Section 3.2.4 is then used 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. The most recent 5 years of accident history data are used. If a crossing has been upgraded or opened during the last 5 years, the value of T is reduced from 5 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 5 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.

Separate data steps are executed to compute predicted fatal accidents and combined casualty index only for the case when the corresponding severity measure has been specified in the input. For the detailed explanation of the fatal, injury and combined casualty index formulas see Section 3.3. The organization of the input file from which an input SAS data set has been created is shown in Appendix A-2.

Examples of the output of ACPD.NEW program are shown in Figures 5-1 through 5-9. This output represents three separate calculations. Figures 5-1, 5-2, and 5-3 are for predicted accidents, Figures 5-4, 5-5, and 5-6 are for predicted fatal accidents. Figures 5-7, 5-8 and 5-9 are for combined casualty index. The first part of each set of the three outputs define the parameters of the crossings listed. The second part is the ranking by predicted accidents computed on the basis of the desired severity measure. All parameter values used in the computation of predicted accidents and severity prediction are included in the output. The third part presents the list of crossings sorted by crossing ID. This third part enables users to find a crossing on the ranked list (second part) when only the crossing ID is known.

5.2 COMPUTER PROGRAM FOR RESOURCE ALLOCATION MODEL

This section describes the computer program for the resource allocation model discussed in Section 4. The model is run by a SAS computer procedure called RESAL.NEW. The program listing for RESAL.NEW is contained in Appendix B. The program executes a number of data steps to accomplish the following subtasks:

a. Data Subsetting

From the dataset comprising all of the rail-highway crossings, select the set of non-gate crossings for which accident prediction is made and for which the available budget is to be allocated.

b. Accident and Severity Prediction

Compute basic predicted accidents (H) for every selected crossing using the passive or flashing lights formula. Using the appropriate severity formula, compute the predicted accidents or fatal accidents or combined casualty index.

c. Identify the Crossings for Stop Signs

Check eligibility of each crossing for stop signs. If it meets the criteria, assign the "yes" attribute to the crossing.

```
************************************************************
*         SUMMARY  OF  INPUT   PARAMETERS                  *
*        FOR ACCIDENT AND SEVERITY PREDICTION              *
************************************************************

         TITLE           :               RR DEMO 1
         STATE           : 99
         COUNTY          : .
         CITY            : .
         RAILROAD        : A
         CROSSING ID     :
          BOTTOM OF RANGE: .
          TOP OF RANGE   : .
         RECORDS TO BE   :
           PRINTED       : 20
         SEVERITY TYPE   : 1    (1) PREDICTED ACCIDENTS
                         :      (2) FATAL ACCIDENT
                         :      (3) COMBIN. CASUALITY INDEX

************************************************************

               SUM OF PREDICTED ACCIDENTS          :1.633867

               TOTAL NUMBER OF CROSSINGS ANALYZED  :120

               INVENTORY DATE: APRIL 1986

************************************************************
```

FIGURE 5-1. EXAMPLE OF INPUT PARAMETERS FOR PREDICTED ACCIDENTS PER YEAR

RR DEMO 1 17:01 THURSDAY, JANUARY 29, 1987

PUBLIC RAIL-HIGHWAY CROSSINGS

RANKED BY PREDICTED ACCIDENTS PER YEAR

RANK	PRED ACCDS	XING ID #	ST	RR	--> 81	NUM 82	OF 83	ACC 84	<-- 85	DATE OF CHG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	URBN RURL	AADT
1	0.264589	734H		A	0	0	1	1	1		7	2	2	2	1	1	25	YES	2	1	8201
2	0.150495	786A		A	0	0	1	1	0		7	2	0	2	1	1	35	YES	2	0	4325
3	0.136474	773Y		A	0	0	1	0	0		7	4	0	0	5	3	35	YES	2	1	11875
4	0.127626	774F		A	0	0	1	0	0		7	6	0	0	3	2	35	YES	2	1	9170
5	0.116265	724C		A	0	1	0	0	0		7	2	2	2	1	1	35	YES	2	1	7305
6	0.086445	881V		A	0	0	0	0	0		7	12	2	16	10	5	40	YES	2	1	1990
7	0.084143	704R		A	1	0	0	0	0		7	2	0	0	3	2	25	YES	2	1	3791
8	0.081564	735P		A	0	0	1	0	0		4	4	2	2	1	1	20	YES	2	1	530
9	0.071269	769J		A	0	0	0	0	0		7	10	0	0	4	2	10	YES	3	1	12055
10	0.062086	794S		A	0	1	0	0	0		4	0	0	2	1	1	49	YES	2	0	535
11	0.059178	725J		A	1	0	0	0	0		4	2	2	2	1	1	25	YES	2	1	100
12	0.054202	858B		A	0	0	0	0	1		7	0	0	2	1	1	49	YES	2	0	455
13	0.049726	814B		A	0	1	0	0	0		8	0	0	2	1	1	49	YES	2	0	2765
14	0.047646	783E		A	0	0	0	0	0		7	4	0	2	1	1	25	YES	2	0	11510
15	0.045226	713P		A	0	0	0	0	0	84-12	8	6	0	0	1	1	25	YES	4	1	31515
16	0.043566	825N		A	0	0	0	1	0		4	0	0	2	1	1	49	NO	2	0	110
17	0.042530	718Y		A	0	0	0	0	0		8	5	2	2	1	1	25	YES	5	1	15865
18	0.038367	736W		A	0	0	0	0	0		8	6	2	6	1	1	25	YES	4	1	9410
19	0.037319	757P		A	0	0	0	0	0		7	0	0	1	1	1	25	YES	4	0	12995
20	0.035142	775M		A	0	0	0	0	0	84-12	8	6	0	0	2	1	25	YES	4	1	16515

FIGURE 5-2. EXAMPLE OF RANKED LIST OF CROSSINGS FOR PREDICTED ACCIDENTS PER YEAR

DEMO 1
PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED ACCIDENTS PER YEAR
SORTED BY CROSSING ID

17:01 THURSDAY, JANUARY 29, 1987

OBS	XING ID #	PRED ACCDS	RANK	ST	COUNTY	CITY	RR	ROAD	RRID	MILEPOST
1	704R	0.084143	7		B	P	A	L		000151
2	713P	0.045226	15		B	P	A			000410
3	718Y	0.042530	17		B	P	A	1		000101
4	724C	0.116265	5		B	P	A	E		000213
5	725J	0.059178	11		B	P	A	E		000214
6	734H	0.264589	1		B	S	A	W		000308
7	735P	0.081564	8		B	S	A	S		000330
8	736W	0.038367	18		B	S	A			000343
9	757P	0.037319	19		B	H	A			000008
10	769J	0.071269	9		B	P	A	6		000020
11	773Y	0.136474	3		B	P	A	1		000103
12	774F	0.127626	4		B	P	A	J		000152
13	775M	0.035142	20		B	P	A	1		000167
14	783E	0.047646	14		B	H	A	E		000440
15	786A	0.150495	2		B	H	A	T		000576
16	794S	0.062086	10		B	P	A	P		001036
17	814B	0.049726	13		B	P	A			002578
18	925N	0.043566	16		B	C	A	S		003303
19	858B	0.054202	12		J	C	A	J		005836
20	881V	0.086445	6		B	S	A	C		000358

FIGURE 5-3. EXAMPLE OF CROSSINGS SORTED BY ID FOR PREDICTED ACCIDENTS PER YEAR

```
**********************************************************
*        SUMMARY  OF  INPUT   PARAMETERS                 *
*       FOR ACCIDENT AND SEVERITY PREDICTION             *
**********************************************************

         TITLE          :                RR DEMO 2
         STATE          : 99
         COUNTY         : .
         CITY           : .
         RAILROAD       : A
         CROSSING ID    :
          BOTTOM OF RANGE: .
          TOP OF RANGE   : .
         RECORDS TO BE  :
           PRINTED      : 20
         SEVERITY TYPE  : 2    (1) PREDICTED ACCIDENTS
                        :      (2) FATAL ACCIDENT
                        :      (3) COMBIN. CASUALITY INDEX

**********************************************************

               SUM OF PREDICTED ACCIDENTS          :0.08848205

               TOTAL NUMBER OF CROSSINGS ANALYZED  :120

               INVENTORY DATE: APRIL 1986

**********************************************************
```

FIGURE 5-4. EXAMPLE OF INPUT PARAMETERS FOR PREDICTED FATAL ACCIDENTS PER YEAR

RR DEMO 2
PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED FATAL ACCIDENTS PER YEAR

17:02 THURSDAY, JANUARY 29, 1987

RANK	PRED ACCDS	XING ST ID #	RR	--> 81	NUM 82	OF 83	ACC 84	<-- 85	DATE OF CHG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	URBN RURL	AADT
1	0.010999	786A	A	0	0	1	1	0		7	2	0	2	1	1	35	YES	2	0	4325
2	0.010037	734H	A	0	0	1	1	1		7	2	2	2	1	1	25	YES	2	1	8201
3	0.006721	794S	A	0	1	0	0	0		4	0	0	2	1	1	49	YES	2	0	535
4	0.006244	773Y	A	0	0	1	0	0		7	4	0	0	5	3	35	YES	2	1	11875
5	0.006079	724C	A	0	1	0	0	0		7	2	2	2	1	1	35	YES	2	1	7305
6	0.005868	858B	A	0	0	0	0	1		7	0	0	2	1	1	49	YES	2	0	455
7	0.005677	774F	A	0	0	1	0	0		7	6	0	0	3	2	35	YES	2	1	9170
8	0.005383	814B	A	0	1	0	0	0		8	0	0	2	1	1	49	YES	2	0	2765
9	0.005240	881V	A	0	0	0	0	0		7	12	2	16	10	5	40	YES	2	1	1990
10	0.004716	825N	A	0	0	0	1	0		4	0	0	2	1	1	49	NO	2	0	110
11	0.002910	704R	A	1	0	0	0	0		7	2	0	0	3	2	25	YES	2	1	3791
12	0.002436	783E	A	0	0	0	0	0		7	4	0	2	1	1	25	YES	2	0	11510
13	0.002389	735P	A	0	0	1	0	0		4	4	2	2	1	1	20	YES	2	1	530
14	0.002245	725J	A	1	0	0	0	0		4	2	2	2	1	1	25	YES	2	1	100
15	0.002108	757P	A	0	0	0	0	0		7	0	0	1	1	1	25	YES	4	0	12995
16	0.001963	758W	A	0	0	0	0	0		7	0	0	1	1	1	55	YES	2	0	3295
17	0.001888	720A	A	0	0	0	0	0		8	2	2	2	1	1	40	YES	2	1	33045
18	0.001876	760X	A	0	0	0	0	0		7	0	0	1	1	1	25	YES	4	0	9120
19	0.001863	793K	A	0	0	0	0	0		7	2	0	0	1	1	49	YES	2	0	2775
20	0.001832	836B	A	0	0	0	0	0		4	0	0	2	1	1	49	YES	2	0	725

FIGURE 5-5. EXAMPLE OF RANKED LIST OF CROSSINGS FOR PREDICTED FATAL ACCIDENTS PER YEAR

RR DEMO 2 17:02 THURSDAY, JANUARY 29, 1987

PUBLIC RAIL-HIGHWAY CROSSINGS

RANKED BY PREDICTED FATAL ACCIDENTS PER YEAR

SORTED BY CROSSING ID

OBS	XING ID #	PRED ACCDS	RANK	ST	COUNTY	CITY	RR	ROAD	RRID	MILEPOST
1	704R	0.002910	11		B	P	A	L		000151
2	720A	0.001888	17		B	P	A	C		000150
3	724C	0.006079	5		B	P	A	E		000213
4	725J	0.002245	14		B	P	A	E		000214
5	734H	0.010037	2		B	S	A	W		000308
6	735P	0.002389	13		B	S	A	S		000330
7	757P	0.002108	15		B	H	A			000008
8	758W	0.001963	16		B	H	A	C		000067
9	760X	0.001876	18		B	L	A	O		000243
10	773Y	0.006244	4		B	P	A	1		000103
11	774F	0.005677	7		B	P	A	J		000152
12	783E	0.002436	12		B	H	A	E		000440
13	786A	0.010999	1		B	H	A	T		000576
14	793K	0.001863	19		B	P	A	C		000967
15	794S	0.006721	3		B	P	A	P		001036
16	814B	0.005383	8		B	P	A			002578
17	825N	0.004716	10		B	C	A	S		003303
18	836B	0.001832	20		J	A	A	3		004418
19	858B	0.005868	6		J	C	A	J		005836
20	881V	0.005240	9		B	S	A	C		000358

FIGURE 5-6. EXAMPLE OF CROSSINGS SORTED BY ID FOR PREDICTED FATAL ACCIDENTS PER YEAR

```
**********************************************************
*        SUMMARY  OF  INPUT   PARAMETERS                  *
*        FOR ACCIDENT AND SEVERITY PREDICTION             *
**********************************************************

         TITLE             :              RR DEMO 3
         STATE             : 99
         COUNTY            : .
         CITY              : .
         RAILROAD          : A
         CROSSING ID       :
          BOTTOM OF RANGE: .
          TOP OF RANGE     : .
         RECORDS TO BE     :
           PRINTED         : 20
         SEVERITY TYPE     : 3   (1) PREDICTED ACCIDENTS
                           :     (2) FATAL ACCIDENT
                           :     (3) COMBIN. CASUALITY INDEX
         FATALITY FACTOR : 50

**********************************************************

               SUM OF PREDICTED ACCIDENTS          :4.832302

               TOTAL NUMBER OF CROSSINGS ANALYZED  :120

               INVENTORY DATE: APRIL 1986

**********************************************************
```

FIGURE 5-7. EXAMPLE OF INPUT PARAMETERS FOR COMBINED CASUALTY INDEX

RR DEMO 3
PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED COMBINED CASUALTY INDEX (CCI)

17:02 THURSDAY, JANUARY 29, 1987

RANK	PRED ACCDS	XING ST ID #	RR	--> 81	NUM 82	OF 83	ACC 84	<-- 85	DATE OF CHG	WD CL	TOTL SWIT TRNS	DAY THRU TRNS	TOTL THRU TRNS	TOTL TRKS	MAIN TRKS	TTBL SPD	HWY PVD	HWY LNS	URBN RURL	AADT
1	0.599508	786A	A	0	0	1	1	0		7	2	0	2	1	1	35	YES	2	0	4325
2	0.573475	734H	A	0	0	1	1	1		7	2	2	2	1	1	25	YES	2	1	8201
3	0.356085	794S	A	0	1	0	0	0		4	0	0	2	1	1	49	YES	2	0	535
4	0.338709	773Y	A	0	0	1	0	0		7	4	0	0	5	3	35	YES	2	1	11875
5	0.336666	724C	A	0	1	0	0	0		7	2	2	2	1	1	35	YES	2	1	7305
6	0.314528	774F	A	0	0	1	0	0		7	6	0	0	3	2	35	YES	2	1	9170
7	0.310868	858B	A	0	0	0	0	1		7	0	0	2	1	1	49	YES	2	0	455
8	0.285196	814B	A	0	1	0	0	0		8	0	0	2	1	1	49	YES	2	0	2765
9	0.270301	881V	A	0	0	0	0	0		7	12	2	16	10	5	40	YES	2	1	1990
10	0.249870	825N	A	0	0	0	1	0		4	0	0	2	1	1	49	NO	2	0	110
11	0.164631	704R	A	1	0	0	0	0		7	2	0	0	3	2	25	YES	2	1	3791
12	0.140955	735P	A	0	0	1	0	0		4	4	2	2	1	1	20	YES	2	1	530
13	0.137270	783E	A	0	0	0	0	0		7	4	0	2	1	1	25	YES	2	0	11510
14	0.128263	725J	A	1	0	0	0	0		4	2	2	2	1	1	25	YES	2	1	100
15	0.117287	757P	A	0	0	0	0	0		7	0	0	1	1	1	25	YES	4	0	12995
16	0.104382	760X	A	0	0	0	0	0		7	0	0	1	1	1	25	YES	4	0	9120
17	0.103628	758W	A	0	0	0	0	0		7	0	0	1	1	1	55	YES	2	0	3295
18	0.103467	720A	A	0	0	0	0	0		8	2	2	2	1	1	40	YES	2	1	33045
19	0.100138	793K	A	0	0	0	0	0		7	2	0	0	1	1	49	YES	2	0	2775
20	0.097065	836B	A	0	0	0	0	0		4	0	0	2	1	1	49	YES	2	0	725

FIGURE 5-8. EXAMPLE OF RANKED LIST OF CROSSINGS FOR COMBINED CASUALTY INDEX

RR DEMO 3 17:02 THURSDAY, JANUARY 29, 1987

PUBLIC RAIL-HIGHWAY CROSSINGS

RANKED BY PREDICTED COMBINED CASUALTY INDEX (CCI)

SORTED BY CROSSING ID

OBS	XING ID #	PRED ACCDS	RANK	ST	COUNTY	CITY	RR	ROAD	RRID	MILEPOST
1	704R	0.164631	11		B	P	A	L		000151
2	720A	0.103467	18		B	P	A	C		000150
3	724C	0.336666	5		B	P	A	E		000213
4	725J	0.128263	14		B	P	A	E		000214
5	734H	0.573475	2		B	S	A	W		000308
6	735P	0.140955	12		B	S	A	S		000330
7	757P	0.117287	15		B	H	A			000008
8	758W	0.103628	17		B	H	A	C		000067
9	760X	0.104382	16		B	L	A	O		000243
10	773Y	0.338709	4		B	P	A	1		000103
11	774F	0.314528	6		B	P	A	J		000152
12	783E	0.137270	13		B	H	A	E		000440
13	786A	0.599508	1		B	H	A	T		000576
14	793K	0.100138	19		B	P	A	C		000967
15	794S	0.356085	3		B	P	A	P		001036
16	814B	0.285196	8		B	P	A			002578
17	825N	0.249870	10		B	C	A	S		003303
18	836B	0.097065	20		J	A	A	3		004418
19	858B	0.310868	7		J	C	A	J		005836
20	881V	0.270301	9		B	S	A	C		000358

FIGURE 5-9. EXAMPLE OF CROSSINGS SORTED BY ID FOR COMBINED CASUALTY INDEX

d. Accident Reduction to Cost Ratio

Compute accident or severity reduction to cost ratio and, using this as the key value, sort the set in descending order.

e. Resource Allocation

Execute the resource allocation data step, and allocate the new class to all candidate crossings. Compute benefit/cost ratio, cumulative cost, cumulative accident benefit, and decision criteria.

f. Report Writing

Execute one of the three report writing procedures to print a report, depending on the selected severity measure. Each procedure prints the following report in three or four parts:

1. List of crossings and associated data items sorted by accident reduction to cost ratio. (See Figure 5-10).

2. Set of crossings as listed above along with subset parameters sorted by crossing IDs. (See Figure 5-11).

3. List of crossings eligible for stop signs. (See Figure 5-12).

4. Summary Report (See Figure 5-13).

g. Summary Printing

Execute the summary data step which prints the input data as well as number of crossings analyzed. (See Figure 5-13).

The calculation of the accident or severity reduction/cost ratio for each crossing depends on the crossing's current warning device and the number of tracks at the crossing. If the crossing already has gates (warning device class 8), it is deleted from consideration.

DEMO 4 17:04 THURSDAY, JANUARY 29, 1987

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
BASED ON PREDICTED ACCIDENTS PER YEAR

OBS	XING ID #	PREDICTED ACCIDENTS PER YEAR	BEN/COST RATIO	RECOMMD WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL TRACKS	TOTAL TRAINS PER DAY	CUMULATIVE COST	CUMULATIVE REDUCED ACCIDENTS	DC1	DC2	DC3	DC4	STOP SIGN REQMNT
1	284M	0.306321	3.60071	GATE	FLASH	1	18	58700	0.211361	.	.	.	0.294	NO
2	636R	0.194600	2.68208	GATE	PASS	1	10	124000	0.386501	0.318	0.780	.	.	NO
3	369H	0.172432	2.61439	GATE	FLASH	1	4	182700	0.539966	.	.	.	0.405	NO
4	365M	0.172333	2.61289	GATE	FLASH	1	4	241400	0.693342	.	.	.	0.405	NO
5	358C	0.160792	2.43791	GATE	FLASH	1	4	300100	0.836448	.	.	.	0.434	NO
6	639L	0.113824	1.94905	FLASH	PASS	1	10	343900	0.921816	0.543	1.334	.	.	NO
7	249Y	0.110546	1.89293	FLASH	PASS	1	8	387700	1.004726	0.559	1.374	.	.	NO
8	377G	0.095405	1.44653	GATE	FLASH	1	2	446400	1.089638	.	.	.	0.732	NO
9	382D	0.094880	1.43857	GATE	FLASH	1	2	505100	1.174081	.	.	.	0.736	NO
10	175X	0.105484	1.38923	GATE	PASS	2	0	570400	1.264798	.	.	0.762	.	NO
11	337J	0.082409	1.24948	GATE	FLASH	1	4	629100	1.338143	.	.	.	0.848	NO
12	158G	0.070495	1.20711	FLASH	PASS	1	0	672900	1.391014	0.878	2.154	.	.	NO
13	164K	0.070495	1.20711	FLASH	PASS	1	0	716700	1.443885	0.878	2.154	.	.	NO
14	651T	0.086557	1.20548	FLASH	PASS	1	30	760500	1.496686	0.879	1.385	.	.	YES
15	631G	0.086557	1.20548	FLASH	PASS	1	30	804300	1.549486	0.879	1.385	.	.	YES
16	389B	0.068887	1.17959	FLASH	PASS	1	10	848100	1.601152	0.898	2.205	.	.	NO
17	640F	0.065503	1.12163	FLASH	PASS	1	10	891900	1.650279	0.944	2.319	.	.	NO
18	370J	0.069902	1.05985	GATE	FLASH	1	4	950600	1.712492	.	.	.	1.000	NO

FIGURE 5-10. EXAMPLE OF CROSSINGS SELECTED FOR UPGRADE

CTY DEMO 4 17:04 THURSDAY, JANUARY 29, 1987

PUBLIC RAIL-HIGHWAY CROSSINGS RESOURCE ALLOCATION RESULTS

BASED ON PREDICTED ACCIDENTS PER YEAR (SORTED BY CRSSING IDs)

OBS	CROSSING ID	BEN/COST RATIO	STATE	COUNTY	CITY	RAILROAD	ROAD	RRID	MILEPOST
1	249Y	1.89293		SE	W	T	6		020334
2	284M	3.60071		SE	W	T	M		021441
3	337J	1.24948		SE	W	T	T		000049
4	358C	2.43791		SE	W	T	B		000067
5	365M	2.61289		SE	W	T	M		000121
6	368H	2.61439		SE	W	T	S		000167
7	370J	1.05985		SE	W	T	M		000280
8	377G	1.44653		SE	W	T			000008
9	382D	1.43857		SE	W	T			000005
10	389B	1.17959		SE	D	T			022121
11	631G	1.20548		SE	R	T			021415
12	636R	2.68208		SE	M	T			021631
13	639L	1.94905		SE	M	T			021769
14	640F	1.12163		SE	M	T			021804
15	651T	1.20548		SE	M	T			X21850
16	158G	1.20711		SE	W	T	G		000236
17	164K	1.20711		SE	W	T	H		000291
18	175X	1.38923		SE	W	T	T'		000655

FIGURE 5-11. EXAMPLE OF SELECTED CROSSINGS SORTED BY ID

DEMO 4 17:04 THURSDAY, JANUARY 29, 1987

RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS
POSSIBLE CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS
(SEE NOTE AT THE END OF SUMMARY PAGE)

OBS	XING ID #	PREDICTED ACCIDENTS PER YEAR	PRESENT WARNING DEVICE	TOTAL TRAINS PER DAY	AADT	CROSSING LOCATION URBAN/RURAL
1	651T	0.0865577	4	30	85	RURAL
2	631G	0.0865577	4	30	85	RURAL

FIGURE 5-12. EXAMPLE OF CANDIDATE CROSSINGS FOR STOP SIGNS

```
***********************************************************
*         SUMMARY  OF  INPUT   PARAMETERS                 *
*        FOR RESOURCE ALLOCATION PROCEDURE                *
***********************************************************

 TITLE                      :                 DEMO 4
 STATE                      : 99
 COUNTY                     : 17
 CITY                       : .
 RAILROAD                   : .
 CROSSING ID                :
     -BOTTOM OF RANGE       : .
     -TOP OF RANGE          : .
 SEVERITY TYPE              : 1   (1) PREDICTED ACCIDENTS
                            :     (2) FATAL ACCIDENT
                            :     (3) COMBIN. CASUALITY INDEX
 EFFECTIVENESS              : 2  (1)  STANDARD
 CHOICE                     :    (2)  EXTENDED
                            :
 EXTENDED EFF. VALUES       :
                                 TRAINS <=10        TRAINS >=11
                              SINGLE     MULTI    SINGLE     MULTI
                               TRACK     TRACK     TRACK     TRACK
     PASSIVE TO FLASHING : 0.75        0.65      0.61      0.57
     PASSIVE TO GATES    : 0.9         0.86      0.8       0.78
     FLASHING TO GATES   : 0.89        0.65      0.69      0.63
                            :
 UPGRADE COSTS-             :
    PASSIVE TO FLASHING     :  $43,800.00
    PASSIVE TO GATES        :  $65,300.00
    FLASHING TO GATES       :  $58,700.00
                            :
 AVAILABLE BUDGET           :   $1,000,000.00

***********************************************************

              TOTAL NUMBER OF CROSSINGS ANALYZED  :176

 ALL CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS
 ARE SINGLE TRACK, LOCAL 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.

              INVENTORY DATE: APRIL 1986

***********************************************************
```

FIGURE 5-13. EXAMPLE OF INPUT PARAMETERS FOR RESOURCE ALLOCATON REPORT PROGRAM

If the crossing has flashing lights or other active devices (warning device classes 5, 6 and 7), an accident or severity 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, the number of fatal accidents, or the combined casualty index for the crossing from the accident and severity 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 severity 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 severity reduction/cost ratio equation for installing a gate at the passive crossing is shown below and is calculated in the Resource Allocation Subtask:

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

In the case where $EFFECT_2/COST_2$ is greater than $EFFECT_1/COST_1$, the program calculates a ratio given by the equation:

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

This applies to 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 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 year per million dollars.

In addition to calculating the accident or severity reduction/cost ratio for each crossing, RESAL.NEW also determines if a crossing is a possible candidate for standard stop signs. 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.

The set of crossing for which the incremental values of accident or severity reduction/cost ratios were calculated and stored separately are now appended with all the other crossings being analyzed and are sorted with respect to accident or severity reduction/cost ratio in descending order. From this set, only the top few crossings which can be upgraded within the given budget value are retained.

This new, expanded set may have some duplicate crossings. This is due to the fact that some passive crossings which were initially upgraded to flashing lights have now qualified to be considered for upgrade to gates. For all such crossings, the new values of upgrade cost, accident or severity reduction/cost ratio, and accident benefit are computed by adding the incremental values of the parameters to their earlier values computed as upgrade to flashing lights. These crossings are assigned the new upgrade category of gates. The new set of crossings are once again sorted by accident or severity reduction/cost ratio in descending order.

Finally, the Resource Allocation subtask 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 (12), (13), (14), and (15), 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.

The report generating procedures produce the following four reports for the selected severity measure:

- Resource allocation report sorted by accident and severity reduction/cost ratio.
- Resource allocation report sorted by crossing ID.
- Report for crossings that qualify for standard stop signs.
- Summary report for the run.

An example of the output from the resource allocation procedure is shown in Figures 5-10 through 5-13. The principal results of the program are given in Figure 5-10. This list is sorted by benefit/cost ratio (fourth column from left) and the recommended new warning device is given in the fifth colunm. Figure 5-11 gives the crossings sorted by crossing ID and also shows other Inventory data. Figure 5-12 lists the (two) crossings that meet the criteria for standard stop signs. These two crossings contained "YES" in the right-most column in Figure 5-10. The input parameters to the program are given in Figure 5-13.

APPENDIX A

Appendix A1 contains a listing of the program ACPD.NEW, written in the SAS language, version 82.4, which is used to calculate accident and severity predictions. Appendix A2 shows the variable dictionary for the input SAS data set.

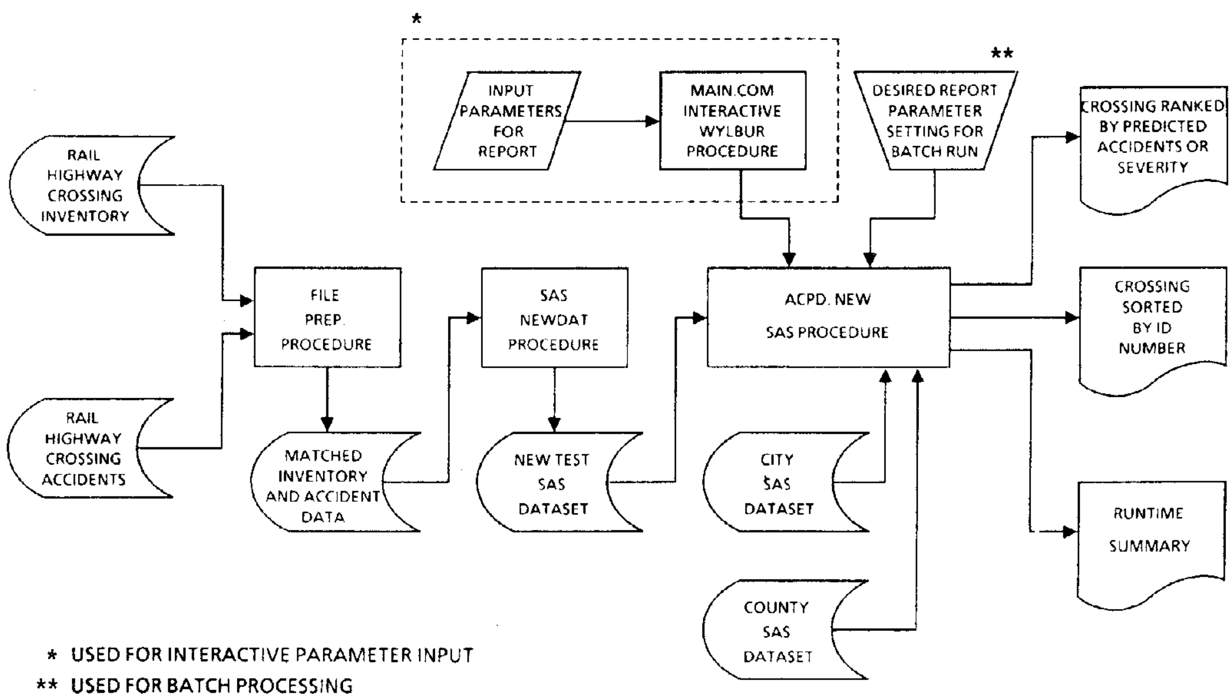

FIGURE A-1. DATA FLOW FOR ACCIDENT OR SEVERITY PREDICTION

NOTE: THE SAS PROCEDURE NEWDAT IS GIVEN IN APPENDIX A2.

APPENDIX A1

LISTING OF PROGRAM ACPD.NEW

```
//
//JOBCARD
//
//PROCLIB DD DSN=ZABCRUN.PROCLIB,DISP=SHR
//A EXEC SAS,REGION=900K
//DD1 DD SYSOUT=A
//FINALL DD DSN=WTP1FZU.NEWTEST,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//FILEB DD DSN=WTP1FZU.CITY,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//FILEC DD DSN=WTP1FZU.COUNTY,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//SYSIN DD *
DATA TRIM;
SET FINALL.NEWTEST;
*******************************************************
*    THIS PROGRAM IS CALLED BY THE MAIN.COM PROCEDURE
*    TO GENERATE REPORT FOR ACCIDENT PREDICTION. HOWEVER
*    BY SPECIFYING THE VALUES OF FOLLOWING VARIABLES, IT
*    CAN BE RUN INDEPENDENTLY IN BATCH MODE.

  SATEVAL       = TWO DIGIT STATE CODE
  COUNTVAL      = THREE DIGIT COUNTY CODE
  CITYVAL       = FOUR DIGIT CODE FOR CITY
  RAILVAL       = FOUR CHARACTER CODE FOR RAILROAD
  ID1VAL        = SIX DIGIT NUMERIC CODE FOR THE FIRST
                  CROSSING ID
  ID2VAL        = SIX DIGIT NUMERIC CODE FOR THE FINAL
                  CROSSING ID
  SELVAL        = 1  -FOR ACCIDENT PREDICTION
                  2  -FOR RESOURCE ALLOCATION
  ACCVAL        = 1  -PREDICTED ACCIDENTS
                  2  -FATAL ACCIDENTS
                  3  -COMBINED CASUALTY INDEX
  OPTVAL        = 1  -STANDARD EFFECTIVENESS
                  2  -EXTENDED EFFECTIVENESS
  C1 - C3       = THREE VALUES OF UPGRADE COSTS
  S1 - S3       = THREE VALUES OF STANDARD EFFECTIVENESS
  X1 - X12      = TWELVE VALUES OF EXTENDED EFFECTIVENESS
  KK            = FATALITY FACTOR
  NN            = NUMBER OF RANKED CROSSINGS TO BE PRINTED
  BUDGETX       = AVAILABLE BUDGET IN DOLLARS
  TITVAL        = A CHARACTER STRING OF THE TITLE TO BE PRINTED
                  AT THE TOP OF EACH PAGE IN THE REPORT

     IF ANY OF THE VARIABLE DOES NOT HAVE ANY SPECIFIC VALUE
     IT IS ASSIGNED A MISSING VALUE OF PERIOD (.)
```

```
****************************************************************;
MACRO CROSSBK .8644 %;
MACRO FLASHLK .8887 %;
MACRO GATESK  .8131 %;
ISTATE= STATEVAL;
ICOUNTY= COUNTVAL;
ICITY= CITYVAL;
IRAIL= 'RAILVAL';
ID1= ID1VAL;
ID2= ID2VAL;
IF ISTATE NE . THEN DO  ;
IF STATE NE ISTATE THEN DELETE;          END;
IF ICOUNTY NE . THEN DO;
IF CONTY NE ICOUNTY THEN DELETE;         END;
IF ICITY NE . THEN DO;
IF CITY NE ICITY THEN DELETE;             END;
IF IRAIL NE '.' THEN DO;
IF RAILROAD NE IRAIL THEN DELETE;         END;
IF (ID1 > 0 ) THEN DO;
IF INTID < ID1 THEN DELETE;       END;
IF (ID2 > 0 ) THEN DO;
IF INTID > ID2 THEN DELETE;       END;
*
*                                                            ;
CLASS=NEWCL;
IF CHANGE_Y > 80 THEN CLASS= OLDCL;
IF OLDCL > 8 THEN CLASS = NEWCL;
***********************************************************;
*  GET TOTAL NUMBER OF CROSSINGS BEING ANALYZED
***********************************************************;
TRACKS=MTRKS+OTRKS;
DROP ISTATE ICOUNTY ICITY IRAIL ID1 ID2 INTID FC1;
PROC MEANS NOPRINT;
OUTPUT  OUT=TOTREC N= NUM_CRO;
***********************************************************
*
*  COMPUTE H VALUE FOR DIFFERENT CLASS TYPE
*
************************************************************;
***********************************************************
*
*  BASIC CALCULATION FOR PASSIVE
*
***********************************************************;
DATA ICROSS;
SET TRIM;
*
*  DELETE ALL NON PASSIVE CROSSINGS;
*                                    ;
IF (CLASS > 4) THEN DELETE;
H= .0006938*(((AADT*TRAINS +0.2)/.2)**.37)*
             (((DAYTHRU + 0.2)/0.2)**0.178)*
             (EXP (0.0077*MXTTSP))*
             (EXP (-0.5966*(PAVED-1)));
```

```
************************************************************
*
*   BASIC FLASHING LIGHTS CALCULATION
*
************************************************************;
DATA IFLASH;
SET TRIM;
IF (CLASS < 5 OR CLASS > 7 ) THEN DELETE;
H= .0003351*(((AADT*TRAINS + 0.2)/0.2)** 0.4106)*
             (((DAYTHRU +0.2)/0.2)**0.1131)*
              (EXP (0.1917*MTRKS))*
              (EXP (0.1826*(TRAFLN - 1))) ;
************************************************************
*
*   BASIC GATES CALCULATIONS
*
************************************************************;
DATA IGATE;
SET TRIM;
IF (CLASS NE 8) THEN DELETE;
H= .0005745*(((AADT*TRAINS + 0.2)/0.2)** 0.2942)*
             (((DAYTHRU +0.2)/0.2)**0.1781)*
              (EXP (0.1512*MTRKS))*
              (EXP (0.1420*(TRAFLN - 1))) ;
************************************************************;
*
*  MERGING OF THREE SETS BY CROSSINGS AND USING EFFECTIVENESS
*
************************************************************;
DATA XING;
SET IGATE IFLASH ICROSS;
BY CROSSING;
ARRAY UP UP1-UP3;
ARRAY DN DN1-DN3;
ARRAY UPDN(K) UP1-UP3 DN1-DN3;
UP1= 1-S1;    UP2= 1-S2;    UP3= 1-S3;
DO OVER UP;
DN = 1/UP;
END;
*
*                                                          ;
IF CLASS = NEWCL THEN GO TO LAB1;
IF (OLDCL LT NEWCL) THEN DO;
   K=2;
 IF(NEWCL NE 8) THEN K= 1;
 IF(OLDCL GT 4) THEN K= 3;
END;
IF (OLDCL GT NEWCL) THEN DO;
  K=5;
 IF (OLDCL NE 8) THEN K=4;
 IF(NEWCL > 4)   THEN K=6;
END;
H=H*UPDN;
************************************************************
```

```
*
*   CALCULATIONS FOR PREDICTED ACCIDENTS
*
************************************************************;
LAB1:
CURYEAR= 85;
TA= CURYEAR-CHANGE_Y;
IF TA < 0 THEN TA= 0;
IF TA > 5 THEN TA = 5;
NACC= ACC1+ACC2+ACC3+ACC4+ACC5;
THRU=DAYTHRU+NGTTHRU;
SWITCH=DAYSWT+NGTSWT;
T0=1./(.05+H);
A=(H*T0 + NACC)/(TA + T0);
CLASS = NEWCL;
IF CLASS LE 4 THEN A= CROSSBK*A;
ELSE IF (4 < CLASS < 8) THEN A= FLASHLK*A;
ELSE A= GATESK*A;
DROP NACC TA T0 UP1-UP3 DN1-DN3 K TRAINS ;
************************************************************
*
*   CALCULATIONS FOR FATAL ACCIDENTS
*
************************************************************;
ACCD= ACCVAL;
IF ACCD > 1 THEN DO;
MS= MXTTSP**(-.9981);
TT= (1+THRU)**(-0.0872);
TS= (1+SWITCH)**0.0872;
UR= EXP(0.3571*FC10);
FATPRB=1/(1. + (440.9*MS*TT*TS*UR));
FATAL=FATPRB*A;
DROP MS TT TS FATPRB;
************************************************************
*
*   CALCULATIONS FOR CASUALTY ACCIDENTS
*
************************************************************;
IF ACCD = 3 THEN DO;
MS=MXTTSP**(-0.343);
TRK=0.1153*TRACKS;
TK=EXP(TRK);
URB=0.2960*FC10;
UR=EXP(URB);
CASPRB=1.0/(1+(4.481*MS*TK*UR));
CAS= CASPRB*A;
COMCAS= (KK- 1)*FATAL+ CAS;
DROP TRK TK UR CASPRB CAS;
END;   END;
IF ACCD= 1 THEN ACCIDENT= A;
ELSE IF ACCD= 2 THEN ACCIDENT = FATAL;
ELSE ACCIDENT= COMCAS;
DROP A COMCAS FATAL;
************************************************;
```

```
*      REPORT GENERATION PROGRAM BEGINS                    ;
* DESCRIPTION OF COUNTY AND CITY IS ADDED TO EACH          ;
* RECORD TO BE INCLUDED IN THE RANK LISTING                ;
**********************************************************;
DATA DATA1A;
SET XING;
RENAME CONTY=COUNTY_C  CITY=CITY_C;
PROC SORT;
BY STATE COUNTY_C ;
DATA DATA1B;
MERGE DATA1A(IN=A) FILEC.COUNTY ;
BY STATE COUNTY_C ;
IF A;
PROC SORT;
BY STATE CITY_C;
DATA DATA1C;
MERGE DATA1B(IN=A) FILEB.CITY;
BY STATE CITY_C;
IF A;
DSTATE= 0;   DPAVED= 0;
DSTATE= STATE;   DPAVED= PAVED;
***********************************************************
*  COMBINING CHANGE MONTH & YEAR ATTRIBUTES
**********************************************************;
MONYEAR= 100*CHANGE_Y +CHANGE_M;
DROP STATE;
PROC SORT;
BY DESCENDING ACCIDENT;
DATA DATA2;
SET DATA1C;
IF _N_ > NN THEN STOP;
PROC MEANS NOPRINT;
VAR ACCIDENT;
OUTPUT  OUT=SUMACC SUM=TOTACC;
 MACRO LABELI
LABEL DSTATE=ST          DPAVED= HWY*PVD
      CROSSING=XING*ID*#  RAILROAD=RR
      ACC1=-->*___*81    ACC2=NUM*___*82
      ACC3=OF*___*83      ACC4=ACC*___*84
      ACC5=<--*___*85    MONYEAR=DATE*OF*CHG
      CLASS=WD*CL         SWITCH=TOTL*SWIT*TRNS
      DAYTHRU=DAY*THRU*TRNS
      THRU=TOTL*THRU*TRNS
      TRACKS=TOTL*TRKS    MTRKS=MAIN*TRKS
      MXTTSP=TTBL*SPD     TRAFLN=HWY*LNS
      FC10=URBN*RURL      ACCIDENT=PRED*ACCDS
      COT_NAME=COUNTY     CTY_NAME=CITY          %;
**********************************************************;
*  DEFINE FORMATS TO BE USED FOR PRINTING VALUES           ;
**********************************************************;
PROC FORMAT;
VALUE ESTATE  1='AL'    2='AK'    3=' '    4='AZ'
              5='AR'    6='CA'    7=' '    8='CO'
              9='CT'   10='DE'   11='DC'  12='FL'
```

```
             13='GA'   14='  '   15='HI'  16='ID'
             17='IL'   18='IN'   19='IA'  20='KS'
             21='KY'   22='LA'   23='ME'  24='MD'
             25='MA'   26='MI'   27='MN'  28='MS'
             29='MO'   30='MT'   31='NE'  32='NV'
             33='NH'   34='NJ'   35='NM'  36='NY'
             37='NC'   38='ND'   39='OH'  40='OK'
             41='OR'   42='PA'   43='PR'  44='RI'
             45='SC'   46='SD'   47='TN'  48='TX'
             49='UT'   50='VT'   51='VA'  52='VI'
             53='WA'   54='WV'   55='WI'  56='WY';
VALUE IPAVED 1= YES
             2= NO;
PICTURE PREDACC OTHER='9.999999';
PICTURE ICHANGE 0-8012='     '
                  OTHER='99-99' ;
*********************************************************
*  REPORT PRINTING PROCEDURE FOR                        *
*                 SEVERITY TYPE =  PREDICTED ACCIDENTS  *
*********************************************************;
DATA BASIC;
LABELI ;
SET DATA2;
IF ACCD NE 1 THEN STOP;
RETAIN RANK 0; RANK = RANK +1;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE.  MONYEAR  ICHANGE.;
FORMAT DPAVED IPAVED. ACCIDENT PREDACC.;
ID RANK;
VAR ACCIDENT CROSSING DSTATE RAILROAD ACC1 ACC2 ACC3 ACC4 ACC5
MONYEAR  CLASS SWITCH DAYTHRU THRU TRACKS MTRKS MXTTSP
DPAVED TRAFLN FC10 AADT;
TITLE1  TITVAL;
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS;
TITLE3 RANKED BY PREDICTED ACCIDENTS PER YEAR;
PROC SORT DATA= BASIC;
BY CROSSING;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
VAR CROSSING ACCIDENT RANK DSTATE COT_NAME CTY_NAME RAILROAD
    ROAD RRID MILEPOST;
TITLE4 SORTED BY CROSSING ID;
**********************************************************
*  REPORT PRINTING PROCEDURE FOR
*                   SEVERITY     = FATAL ACCIDENTS
**********************************************************;
DATA FATAL;
LABELI ;
SET DATA2;
IF ACCD NE 2 THEN STOP;
RETAIN RANK 0; RANK=RANK+1;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE.  MONYEAR ICHANGE.;
FORMAT DPAVED IPAVED. ACCIDENT PREDACC.;
```

```
ID RANK;
VAR ACCIDENT CROSSING DSTATE RAILROAD ACC1 ACC2 ACC3 ACC4 ACC5
MONYEAR CLASS SWITCH DAYTHRU THRU TRACKS MTRKS MXTTSP
DPAVED TRAFLN FC10 AADT;
TITLE1  TITVAL;
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS;
TITLE3 RANKED BY PREDICTED FATAL ACCIDENTS PER YEAR;
PROC SORT DATA= FATAL;
BY CROSSING;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
VAR CROSSING ACCIDENT RANK DSTATE COT_NAME CTY_NAME RAILROAD
    ROAD RRID MILEPOST;
TITLE4 SORTED BY CROSSING ID;
*****************************************************
*  REPORT PRINTING PROCEDURE FOR
*                  SEVERITY   = COMBINED CASUALITY
*****************************************************;
DATA CCI;
 LABELI ;
SET DATA2;
IF ACCD NE 3 THEN STOP;
RETAIN RANK 0; RANK=RANK+1;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE.  MONYEAR ICHANGE.;
FORMAT DPAVED IPAVED. ACCIDENT PREDACC.;
ID RANK;
VAR ACCIDENT CROSSING DSTATE RAILROAD ACC1 ACC2 ACC3 ACC4 ACC5
MONYEAR CLASS SWITCH DAYTHRU THRU TRACKS MTRKS MXTTSP
DPAVED TRAFLN FC10 AADT;
TITLE1  TITVAL;
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS;
TITLE3 RANKED BY PREDICTED COMBINED CASUALTY INDEX (CCI);
PROC SORT DATA= CCI;
BY CROSSING;
PROC PRINT SPLIT=*;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
VAR CROSSING ACCIDENT RANK DSTATE COT_NAME CTY_NAME RAILROAD
    ROAD RRID MILEPOST;
TITLE4 SORTED BY CROSSING ID;
***************************************************
*  PROCEDURE FOR PRINTING SUMMARY PAGE
***************************************************;
DATA SUMMRY;
MERGE TOTREC SUMACC;
FILE DD1, PRINT;
N_N = NN;
ACCD= ACCVAL;
ID1= ID1VAL; ID2= ID2VAL;
IF ID1 = 0 THEN DO;
ID1= .;  ID2= .; END;
PUT
///@36'*********************************************************-
*';
```

```
PUT    @36   '*          SUMMARY  OF  INPUT   PARAMETERS
  *';
PUT    @36   '*         FOR ACCIDENT AND SEVERITY PREDICTION
  *';
PUT    @36
'*************************************************************';
PUT  /@36   '           TITLE              : TITVAL ';
PUT    @36   '           STATE              : STATEVAL ';
PUT    @36   '           COUNTY             : COUNTVAL ';
PUT    @36   '           CITY               : CITYVAL ';
PUT    @36   '           RAILROAD           : RAILVAL ';
PUT    @36   '           CROSSING ID        :        ';
PUT    @36   '            BOTTOM OF RANGE: ' ID1;
PUT    @36   '            TOP OF RANGE    : ' ID2;
PUT    @36   '           RECORDS TO BE    : ';
IF N_N < 195000 THEN
PUT    @36   '             PRINTED          : NN ';
ELSE
PUT    @36   '             PRINTED          : ALL ';
PUT    @36   '           SEVERITY TYPE    : ACCVAL   (1) PREDICTED
ACCIDENTS';
PUT    @36   '                              :      (2) FATAL ACCIDENT';
PUT    @36   '                              :      (3) COMBIN. CASUALITY
INDEX';
IF ACCD = 3 THEN
PUT    @36   '           FATALITY FACTOR : KK ';
PUT
//@36'*************************************************************';
PUT  //@36   '                  SUM OF PREDICTED ACCIDENTS          :'
                                                 TOTACC;
PUT  /@36    '                  TOTAL NUMBER OF CROSSINGS ANALYZED  :'
                                                 NUM_CRO;
PUT  /@36    '                  INVENTORY DATE: APRIL 1986';
PUT
//@36'*************************************************************';
TITLE1  TITVAL;
```

APPENDIX A2

LISTING OF NEWDAT PROCEDURE

```
//
//JOBCARD
//
//PROCLIB DD DSN=ZABCRUN.PROCLIB,DISP=SHR
//A EXEC SAS,REGION=900K
//FILEB DD DSN=WTP1FZU.NEWTEST,DISP=(NEW,KEEP),UNIT=FILE,
// VOL=SER=FRASIR,SPACE=(TRK,(150,10),RLSE)
//FILEA DD DSN=WTP1FZZ.SEV.INDEX,DISP=SHR,UNIT=MSS
//SYSIN  DD *
****************************************************************
* THIS PROCEDURE IS USED TO CREATE SAS DATASET NEWTEST FROM
* MATCHED ACCIDENT AND INVENTORY DATA. THE DATA SET IS USED BY
* BOTH ACPD.NEW AND RESAL.NEW PROGRAMS.
****************************************************************;
DATA FILEB.NEWTEST;
INFILE FILEA;
INPUT
CROSSING $  1-7         STATE      $   8-9
INTID       1-6
CONTY    $ 10-12        CITY       $  13-16
RAILROAD $ 17-20        CHANGE_Y      21-22
CHANGE_M   23-24        ROAD       $  25-41
RRID     $ 42-51        MILEPOST   $  52-57
OLDCL         58        NEWCL            59
STOP          60        NGTSWT        64-65
NGTTHRU    66-67        TRAINS        61-63
DAYSWT     68-69        DAYTHRU       70-71
MXTTSP     72-74        MTRKS         75-75
OTRKS      76-77        PASS_TRN   $  78-78
PAVED    $ 79-79        TRAFLN        80-80
FC10       81-81        FC1           82-82
AADT       83-88        PCTTRUK    $  89-90
CHANGE_D   91-92
ACC0       93-94        ACC1          95-96
ACC2       97-98        ACC3          99-100
ACC4     101-102        ACC5         103-104;
```

*   The parameters ACC0 thru ACC5 are taken from accident history file. If the change year of the warning device is within the period of six years, the accidents prior to warning device change are set to zero.

All other parameters are taken from the Rail Highway Crossing Inventory file.

LIST OF PARAMETERS USED IN NEWDAT PROCEDURE

VARIABLE	VARIABLE DESCRIPTION
CROSSING	CROSSING ID NUMBER
INTID	INTEGER VALUE OF CROSSING ID
STATE	LOCATION STATE CODE
CONTY	LOCATION COUNTY CODE
CITY	LOCATION CITY CODE
RAILROAD	RAILROAD CODE
CHANGE_Y	YEAR OF LAST WARNING DEVICE CHANGE
CHANGE_M	MONTH OF LAST WARNING DEVICE CHANGE
ROAD	ROAD OR STREET NAME
RRID	RAILROAD DESIGNATION
MILEPOST	MILEPOST AT CROSSING
OLDCL	OLD CLASSIFICATION OF THE CROSSING
NEWCL	NEW CLASSIFICATION OF THE CROSSING
STOP	STOP SIGNS
TRAINS	NUMBER OF TOTAL TRAINS
NGTSWT	NUMBER OF NIGHT SWITCH TRAINS
NGTTHRU	NUMBER OF NIGHT THRU TRAINS
DAYSWT	NUMBER OF DAY SWITCH TRAINS
DAYTHRU	NUMBER OF DAY THRU TRAINS
MXTTSP	MAXIMUM TIME TABLE SPEED
MTRKS	MAIN TRACKS
OTRKS	OTHER TRACKS
PASS_TRN	NUMBER OF PASSANGER TRAINS
PAVED	IS HIGHWAY PAYED ?
TRAFLN	TRAFFIC LANES
FC10	TENS DIGIT OF FUNCTIONAL CLASSIFICATION
FC1	UNITS DIGIT OF FUNCTIONAL CLASSIFICATION
AADT	ANNUAL AVERAGE DAILY TRAFFIC
PCTTRUK	PERCENTAGE TRUCKS
CHANGE_D	DAY OF LAST WARNING DEVICE CHANGE
ACC0, ACC1 ACC2, ACC3 ACC4, ACC5	"SIX FIELDS OF NUMBER OF ACCIDENTS IN LAST SIX YEARS. EACH FIELD HAS TWO POSITIONS. THE MOST RECENT YEAR IS ACC5."

APPENDIX B

This Appendix contains a listing of the program RESAL.NEW, written in the SAS language, version 82.4, which is used to calculate resource allocation results.

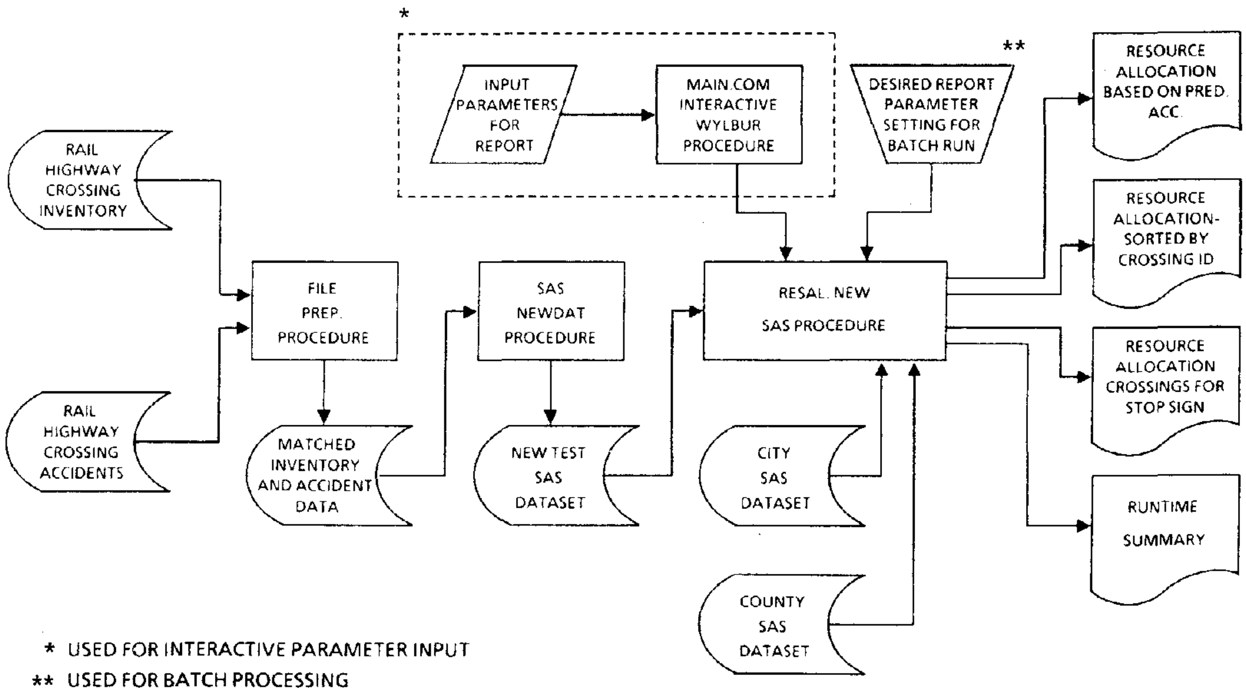

FIGURE B-1. DATA FLOW FOR RESOURCE ALLOCATION

NOTE: THE SAS PROCEDURE NEWDAT IS GIVEN IN APPENDIX A2.

APPENDIX B1

LISTING OF PROGRAM RESAL.NEW

```
//
//JOBCARD
//
//PROCLIB DD DSN=ZABCRUN.PROCLIB,DISP=SHR
//A EXEC SAS,REGION=900K
//DD1 DD SYSOUT=A
//FINALL DD DSN=WTP1FZU.NEWTEST,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//FILEB DD DSN=WTP1FZU.CITY,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//FILEC DD DSN=WTP1FZU.COUNTY,DISP=(OLD,KEEP),UNIT=FILE,
// VOL=SER=FRASIR
//SYSIN DD *
DATA TRIM;
SET FINALL.NEWTEST;
********************************************************
*    THIS PROGRAM IS CALLED BY THE MAIN.COM PROCEDURE
*    TO GENERATE REPORT FOR RESOURCE ALOCATION.  HOWEVER
*    BY SPECIFYING THE VALUES OF FOLLOWING VARIABLES, IT
*    CAN BE RUN INDEPENDENTLY IN BATCH MODE.

  SATEVAL        = TWO DIGIT STATE CODE
  COUNTVAL       = THREE DIGIT COUNTY CODE
  CITYVAL        = FOUR DIGIT CODE FOR CITY
  RAILVAL        = FOUR CHARACTER CODE FOR RAILROAD
  ID1VAL         = SIX DIGIT NUMERIC CODE FOR THE FIRST
                   CROSSING ID
  ID2VAL         = SIX DIGIT NUMERIC CODE FOR THE FINAL
                   CROSSING ID
  SELVAL         = 1  -FOR ACCIDENT PREDICTION
                   2  -FOR RESOURCE ALLOCATION
  ACCVAL         = 1  -PREDICTED ACCIDENTS
                   2  -FATAL ACCIDENTS
                   3  -COMBINED CASUALTY INDEX
  OPTVAL         = 1  -STANDARD EFFECTIVENESS
                   2  -EXTENDED EFFECTIVENESS
  C1 - C3        = THREE VALUES OF UPGRADE COSTS
  S1 - S3        = THREE VALUES OF STANDARD EFFECTIVENESS
  X1 - X12       = TWELVE VALUES OF EXTENDED EFFECTIVENESS
  KK             = FATALITY FACTOR
  BUDGETX        = AVAILABLE BUDGET IN DOLLARS
  TITVAL         = A CHARACTER STRING OF THE TITLE TO BE PRINTED
                   AT THE TOP OF EACH PAGE IN THE REPORT

     IF ANY OF THE VARIABLE DOES NOT HAVE ANY SPECIFIC VALUE
     IT IS ASSIGNED A MISSING VALUE OF PERIOD (.)

*************************************************************;
```

```
MACRO CROSSBK .8644 %;
MACRO FLASHLK .8887 %;
MACRO GATESK  .8131 %;
ISTATE= STATEVAL;
ICOUNTY= COUNTVAL;
ICITY= CITYVAL;
IRAIL= 'RAILVAL';
ID1= ID1VAL;
ID2= ID2VAL;
IF ISTATE NE . THEN DO  ;
IF STATE NE ISTATE THEN DELETE;          END;
IF ICOUNTY NE . THEN DO;
IF CONTY NE ICOUNTY THEN DELETE;         END;
IF ICITY NE . THEN DO;
IF CITY NE ICITY THEN DELETE;             END;
IF IRAIL NE '.' THEN DO;
IF (RAILROAD NE IRAIL ) THEN DELETE;     END;
IF (ID1 > 0 ) THEN DO;
IF INTID < ID1 THEN DELETE;       END;
IF (ID2 > 0 ) THEN DO;
IF INTID > ID2 THEN DELETE;       END;
*
*                                                           ;
CLASS=NEWCL;
IF CHANGE_Y > 80 THEN CLASS= OLDCL;
IF OLDCL > 8 THEN CLASS = NEWCL;
***********************************************************;
*     DELETE ALL RECORDS FOR GATES IF RESOUCE ALLOCATION
*     IS TO BE PERFORMED AND GET THE TOTAL NUMBER OF
*     CROSSINGS BEING ANALYZED.
***********************************************************;
SELECT= SELVAL;
IF (SELECT = 2 AND NEWCL = 8 ) THEN DELETE;
TRACKS=MTRKS+OTRKS;
DROP ISTATE ICOUNTY ICITY IRAIL ID1 ID2 INTID ;
PROC MEANS NOPRINT;
OUTPUT OUT=TOTREC N= NUM_CRO;
***********************************************************
*
*  COMPUTE H VALUE FOR DIFFERENT CLASS TYPE
*
************************************************************;
***********************************************************
*
*  CALCULATION FOR PASSIVE
*
***********************************************************;
DATA ICROSS;
SET TRIM;
*
*  DELETE ALL NON PASSIVE CROSSINGS;
*                                ;
IF (CLASS > 4) THEN DELETE;
H= .0006938*(((AADT*TRAINS +0.2)/.2)**.37)*
```

```
            (((DAYTHRU + 0.2)/0.2)**0.178)*
            (EXP (0.0077*MXTTSP))*
            (EXP (-0.5966*(PAVED-1)));
************************************************************
*
*   FLASHING LIGHTS CALCULATION
*
************************************************************;
DATA IFLASH;
SET TRIM;
IF (CLASS < 5 OR CLASS > 7 ) THEN DELETE;
H= .0003351*(((AADT*TRAINS + 0.2)/0.2)** 0.4106)*
            (((DAYTHRU +0.2)/0.2)**0.1131)*
             (EXP (0.1917*MTRKS))*
             (EXP (0.1826*(TRAFLN - 1))) ;
************************************************************;
*
*  MERGING OF TWO SETS BY CROSSINGS AND USING EFFECTIVENESS
*
************************************************************;
DATA XING;
SET IFLASH ICROSS;
BY CROSSING;
ARRAY UP UP1-UP3;
ARRAY DN DN1-DN3;
ARRAY UPDN(K) UP1-UP3 DN1-DN3;
OPTION= OPTVAL;
IF OPTION NE 1 THEN DO;
*   ---*  USE EXTENDED EFFECTIVENESS VALUS  *---          ;
IF TRACKS > 1 AND TRAINS > 10 THEN DO;
UP1= 1-X10;     UP2= 1-X11;  UP3= 1-X12; END;
ELSE IF TRACKS > 1 AND TRAINS < 11 THEN DO;
UP1= 1-X7;      UP2= 1-X8;   UP3= 1-X9;  END;
ELSE IF TRACKS=1 AND TRAINS > 10 THEN DO;
UP1= 1-X4;      UP2= 1-X5;    UP3= 1-X6;  END;
ELSE IF TRACKS=1 AND TRAINS LT 11 THEN DO;
UP1= 1-X1;     UP2= 1-X2;     UP3= 1-X3;  END;
END;
ELSE DO;
*   ---*  USE STANDARD EFFECTIVENESS VALUES  *---          ;
UP1= 1-S1;     UP2= 1-S2;     UP3= 1-S3;   END;
DO OVER UP;
DN = 1/UP;
END;
*
*   ---* GENERATE INDEX VALUE TO BE USED WITH ARRAY  *---
*   ---* OF EFFECTIVENESS VALUES                     *---
*                                                    ;
IF CLASS = NEWCL THEN GO TO LAB1;
IF (OLDCL LT NEWCL) THEN DO;
   K=2;
 IF(NEWCL NE 8) THEN K= 1;
 IF(OLDCL GT 4) THEN K= 3;
END;
```

```
IF (OLDCL GT NEWCL) THEN DO;
  K=5;
 IF (OLDCL NE 8) THEN K=4;
 IF(NEWCL > 4)   THEN K=6;
END;
H=H*UPDN;
***********************************************************
*
*  CALCULATIONS FOR PREDICTED ACCIDENTS
*
***********************************************************;
LAB1:
CURYEAR= 85;
TA= CURYEAR-CHANGE_Y;
IF TA < 0 THEN TA= 0;
IF TA > 5 THEN TA = 5;
NACC= ACC1+ACC2+ACC3+ACC4+ACC5;
T0=1./(.05+H);
A=(H*T0 + NACC)/(TA + T0);
IF CLASS LE 4 THEN A= CROSSBK*A;
ELSE IF (4 < CLASS < 8) THEN A= FLASHLK*A;
ELSE A= GATESK*A;
DROP NACC TA T0 UP1-UP3 DN1-DN3 K TRAINS ;
************************************************************
*
*   CALCULATIONS FOR FATAL ACCIDENTS
*
************************************************************;
ACCD= ACCVAL;
IF ACCD > 1 THEN DO;
THRU=DAYTHRU+NGTTHRU;
SWITCH=DAYSWT+NGTSWT;
MS= MXTTSP**(-.9981);
TT= (1+THRU)**(-0.0872);
TS= (1+SWITCH)**0.0872;
UR= EXP(0.3571*FC10);
FATPRB=1/(1. + (440.9*MS*TT*TS*UR));
FATAL=FATPRB*A;
DROP MS TT TS FATPRB;
*************************************************************
*
*   CALCULATIONS FOR CASUALTY ACCIDENTS
*
************************************************************;
IF ACCD = 3 THEN DO;
MS=MXTTSP**(-0.343);
TRK=0.1153*TRACKS;
TK=EXP(TRK);
URB=0.2960*FC10;
UR=EXP(URB);
CASPRB=1.0/(1+(4.481*MS*TK*UR));
CAS= CASPRB*A;
COMCAS= (KK- 1)*FATAL+ CAS;
DROP TRK TK UR CASPRB CAS;
```

```
END;   END;
IF ACCD= 1 THEN ACCIDENT= A;
ELSE IF ACCD= 2 THEN ACCIDENT = FATAL;
ELSE ACCIDENT= COMCAS;
DROP A COMCAS FATAL;
****************************************************;
*
*   RESOURCE ALLOCATION PROGRAM BEGINS
*
****************************************************************;
DATA RES;
SET XING;
CLASS= NEWCL;
*   ---* DELETE CROSSINGS DOWNGRADED IN LAST FIVE YEARS *--- ;
IF CLASS > 7 THEN DELETE;
EFFLAG = OPTVAL;  *1- STANDARD EFFECTIVENESS  2- EXTENDED EFFECT.;
COST1= CS1;   COST2= CS2;    COST3= CS3;
TRAINS=NGTSWT +DAYSWT + DAYTHRU +NGTTHRU;
TRACKS = MTRKS +OTRKS;
****************************************************************
* IDENTIFY THE CROSSINGS WHICH QUALIFY FOR THE STOP SIGNS
****************************************************************;
STPFLG = 0;
IF (STOP > 0 OR CLASS >  4  OR FC1 NE 9 OR TRAINS < 10 OR
   TRACKS NE 1) THEN GO TO LAB3;
IF ((FC10 NE 1 AND AADT < 400) OR
    (FC10 EQ 1 AND AADT < 1500)) THEN STPFLG = 1;
****************************************************************
* SELECT EFFECTIVENESS VALUES
****************************************************************;
LAB3:
    IF EFFLAG = 1 THEN DO;
   EF1= S1;   EF2= S2;   EF3= S3;
    GO TO LAB4;
END;
IF TRACKS > 1 AND TRAINS > 10 THEN DO;
   EF1= X10;  EF2= X11;  EF3= X12; END;
IF TRACKS > 1 AND TRAINS < 11 THEN DO;
   EF1= X7;   EF2= X8;   EF3= X9;  END;
IF TRACKS = 1 AND TRAINS > 10 THEN DO;
   EF1= X4;   EF2= X5;   EF3= X6;  END;
IF TRACKS = 1 AND TRAINS < 11 THEN DO;
   EF1= X1;   EF2= X2;   EF3= X3;  END;
****************************************************************
* COMPUTE BENEFIT RATIOS ACCIDENT AND COST BENEFITS
****************************************************************;
LAB4:
RAT1 = EF1/COST1;
RAT2 = EF2/COST2;
RAT3 = EF3/COST3;
*                                                              ;
IF NEWCL < 5 AND TRACKS > 1 THEN DO;
   RAT= RAT2;   COST= COST2;  EFFECT= EF2; RECCAT= 'GATE '; END;
ELSE IF NEWCL > 4 THEN DO          ;
```

```
   RAT= RAT3;    COST= COST3;   EFFECT= EF3; RECCAT= 'GATE '; END;
ELSE                             DO;
   RAT= RAT1;    COST= COST1;   EFFECT= EF1; RECCAT= 'FLASH'; END;
*                                                                  ;
BENCOS= ACCIDENT*RAT*10.**6;
ACCBEN= ACCIDENT*EFFECT;
*                                                                  ;
KEEP BENCOS ACCBEN ACCIDENT ACCD RECCAT CROSSING NEWCL TRAINS
     TRACKS FC10 FC1 AADT COST1 COST2 COST3 EF1 EF2 EF3 STPFLG
     COST EFFECT STATE CONTY CITY RAILROAD ROAD RRID MILEPOST;

DATA INCREM;
SET RES;
*  ---* CALCULATE INCREMENTAL BENEFIT AND COST VALUES *---   ;
IF NEWCL > 4 OR TRACKS > 1 THEN DELETE;
BENCOS= ACCIDENT*(EF2-EF1)/(COST2- COST1)*10**6;
RECCAT= 'S     ';
ACCBEN= (EF2- EF1)*ACCIDENT;
COST= COST2- COST1;

DATA CONC;
***********************************************************
* APPEND THE CROSSINGS WITH INCREMENTAL BENEFIT TO THE
* THE CROSSINGS SELECTED EARLIER AND SORT THEM BY
* ACCIDENT COST BENEFIT VALUES.
**********************************************************;

SET RES INCREM;
PROC SORT;
BY DESCENDING BENCOS;

DATA CUMCOST;
SET CONC;
*  ---* CALCULATE TOTAL COST AND LIMIT THE NUMBER OF *---
*  ---* CROSSINGS WHICH CAN BE COVERED WITHIN BUDGET *---    ;
BCOST= BUDGETX ;
RETAIN TCOST 0;
TCOST= TCOST+ COST;
IF TCOST > BCOST THEN STOP;
DATA;
SET _LAST_;
PROC MEANS NOPRINT;
VAR BENCOS;
OUTPUT OUT=OUTMIN MIN=MINBEN;

DATA CUMCOST1 INC1;
SET CUMCOST;
DROP BCOST TCOST;
IF RECCAT = 'S     ' THEN OUTPUT INC1;
ELSE OUTPUT CUMCOST1;
PROC SORT DATA=CUMCOST1;
BY CROSSING;
DATA INC2;
SET INC1;
```

```
RENAME BENCOS=IBEN RECCAT=IREC ACCBEN=IABEN COST=ICOST;
KEEP CROSSING BENCOS RECCAT ACCBEN COST;
PROC SORT;
BY CROSSING;

DATA REP1;
MERGE CUMCOST1(IN=A) INC2;
BY CROSSING;
IF A;
PROC SORT;
BY DESCENDING BENCOS;
DATA REP2;
*  ---* COMPUTE DECISION CRITERIA VALUES          *---          ;
MERGE REP1 OUTMIN;
RETAIN MINTBEN 0;
IF MINBEN = . THEN MINBEN= 0;
MINTBEN= MINTBEN+ MINBEN;
IF EFFECT = EF1 THEN
DC2=MINTBEN/(ACCIDENT*(EF2-EF1)/(COST2-COST1)*10.**6);
IF IREC= 'S    ' THEN DO;
DC1=MINTBEN/BENCOS;
  BENCOS=ACCIDENT*EF2/COST2*10**6;
  ACCBEN=ACCBEN+IABEN;
  COST  =COST + ICOST;
  RECCAT= 'GATE ';
END;
KEEP CROSSING ACCBEN BENCOS RECCAT NEWCL TRACKS TRAINS DC2
 DC1 ACCIDENT COST MINTBEN EFFECT EF1 EF2 EF3 STPFLG
STATE AADT FC10 ACCD CONTY CITY RAILROAD ROAD RRID MILEPOST;
PROC FORMAT;
VALUE CLASS 1-4='PASS '
            5-7='FLASH';
VALUE YES_NO 0=NO
             1=YES;
VALUE URBR 0=RURAL
           1=URBAN;
PICTURE ACCBNF OTHER='9.999999';
PICTURE DECIS OTHER='9.999';

DATA DATA1A;
*  ---* ADD STATE, CITY AND COUNTY DESCRIPTION TO EACH  *---
*  ---* RECORD IN THE SELECTED SET                      *---  ;
SET REP2;
RENAME CONTY=COUNTY_C  CITY=CITY_C;
PROC SORT;
BY STATE COUNTY_C ;
DATA DATA1B;
MERGE DATA1A(IN=A) FILEC.COUNTY ;
BY STATE COUNTY_C ;
IF A;
PROC SORT;
BY STATE CITY_C;
DATA DATA1C;
MERGE DATA1B(IN=A) FILEB.CITY;
```

```
BY STATE CITY_C;
IF A;
DSTATE= 0;
DSTATE= STATE;
PROC FORMAT;
VALUE ESTATE  1='AL'    2='AK'    3=' '     4='AZ'
              5='AR'    6='CA'    7=' '     8='CO'
              9='CT'   10='DE'   11='DC'   12='FL'
             13='GA'   14=' '    15='HI'   16='ID'
             17='IL'   18='IN'   19='IA'   20='KS'
             21='KY'   22='LA'   23='ME'   24='MD'
             25='MA'   26='MI'   27='MN'   28='MS'
             29='MO'   30='MT'   31='NE'   32='NV'
             33='NH'   34='NJ'   35='NM'   36='NY'
             37='NC'   38='ND'   39='OH'   40='OK'
             41='OR'   42='PA'   43='PR'   44='RI'
             45='SC'   46='SD'   47='TN'   48='TX'
             49='UT'   50='VT'   51='VA'   52='VI'
             53='WA'   54='WV'   55='WI'   56='WY';
PICTURE PREDACC OTHER='9.999999';
DATA FINAL1;
SET DATA1C;
PROC SORT;
BY DESCENDING BENCOS;
DATA FINAL;
SET FINAL1;
RETAIN CUMCOST CUMARED 0;
CUMCOST=CUMCOST + COST;
CUMARED=CUMARED+ACCBEN;
IF EFFECT = EF1 AND DC1=. THEN DC1=MINTBEN/BENCOS;
ELSE IF EFFECT = EF2 THEN DC3=MINTBEN/BENCOS;
ELSE IF EFFECT= EF3 THEN DC4= MINTBEN/BENCOS;
MACRO LAB0 CROSSING=XING*ID*#        BENCOS=BEN/COST*RATIO
           RECCAT=RECOMMD*WARNING*DEVICE
           NEWCL=PRESENT*WARNING*DEVICE
           TRACKS=TOTAL*TRACKS        TRAINS=TOTAL*TRAINS*PER" "DAY
           CUMCOST=CUMULATIVE*COST
           CUMARED=CUMULATIVE*REDUCED*ACCIDENTS
           STPFLG=STOP*SIGN*REQMNT
           FC10=CROSSING*LOCATION*URBAN/RURAL  % ;
MACRO LABB ACCIDENT=PREDICTED*ACCIDENTS*PER' 'YEAR %;
MACRO LABF ACCIDENT=PREDICTED*FATAL' 'ACC*PER' 'YEAR %;
MACRO LABC ACCIDENT=PREDICTED*CCI*INDEX        %;
MACRO LABP CROSSING=CROSSING*ID   BENCOS=BEN/COST*RATIO
              DSTATE= STATE   COT_NAME=COUNTY  CTY_NAME=CITY %;

DATA BASIC;
**************************************************************
*  PRINT REPORT FOR SEVERITY MEASURE = PREDICTED ACCIDENTS
**************************************************************;

LABEL LAB0 LABB;
SET FINAL;
IF ACCD NE 1 THEN STOP;
```

```
PROC PRINT SPLIT=*;
VAR CROSSING ACCIDENT BENCOS RECCAT NEWCL TRACKS TRAINS CUMCOST
CUMARED DC1 DC2 DC3 DC4 STPFLG;
FORMAT NEWCL CLASS. STPFLG YES_NO.
       ACCIDENT CUMARED ACCBNF.
       DC1 DC2 DC3 DC4 DECIS.;
TITLE TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON PREDICTED ACCIDENTS PER YEAR;

DATA;
*  ---* PRINT REPORT SORTED BY CROSSING ID        *---       ;
LABEL LAB0 LABB LABP;
SET BASIC;
PROC SORT;
BY CROSSING;
PROC PRINT SPLIT=*;
VAR CROSSING BENCOS DSTATE COT_NAME CTY_NAME RAILROAD ROAD RRID
MILEPOST;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
TITLE1 TITVAL;
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS  RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON PREDICTED ACCIDENTS PER YEAR (SORTED BY CROSSING IDs);

DATA;
*  ---* PRINT REPORT FOR CROSSINGS ELIGIBLE FOR STOP SIGNS *--- ;
LABEL LAB0 LABB ;
SET BASIC;
IF STPFLG  = 0 THEN DELETE;
PROC PRINT SPLIT= *;
VAR CROSSING ACCIDENT NEWCL TRAINS AADT FC10;
FORMAT FC10 URBR.;
TITLE1 TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 POSSIBLE CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS;
TITLE4 (SEE NOTE AT THE END OF SUMMARY PAGE);

DATA FATAL;
*****************************************************************
* PRINT REPORT FOR SEVERITY MEASURE = FATAL ACCIDENTS
*****************************************************************;
LABEL LAB0 LABF;
SET FINAL;
IF ACCD NE 2 THEN STOP;
PROC PRINT SPLIT=*;
VAR CROSSING ACCIDENT BENCOS RECCAT NEWCL TRACKS TRAINS CUMCOST
CUMARED DC1 DC2 DC3 DC4 STPFLG;
FORMAT NEWCL CLASS. STPFLG YES_NO.
       ACCIDENT CUMARED ACCBNF.
       DC1 DC2 DC3 DC4 DECIS.;
TITLE TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON PREDICTED FATAL ACCIDENTS PER YEAR;
```

```
DATA;
LABEL LABO LABB LABP;
*  ---* PRINT REPORT SORTED BY CROSSING IDS          *---       ;
SET FATAL;
PROC SORT;
BY CROSSING;
PROC PRINT SPLIT=*;
VAR CROSSING BENCOS DSTATE COT_NAME CTY_NAME RAILROAD ROAD RRID
MILEPOST;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
TITLE1 TITVAL;
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS  RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON PREDICTED FATAL ACCIDENTS PER YEAR (SORTED BY CROSSING
IDs);
DATA;
*  ---* PRINT REPORT FOR CROSSINGS ELIGIBLE FOR STOP SIGNS *--- ;
LABEL LABO LABF;
SET FATAL;
IF STPFLG  = 0 THEN DELETE;
PROC PRINT SPLIT= *;
VAR CROSSING ACCIDENT NEWCL TRAINS AADT FC10;
FORMAT FC10 URBR.;
TITLE1 TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 POSSIBLE CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS;
TITLE4 (SEE NOTE AT THE END OF SUMMARY PAGE);
DATA CCI;
*****************************************************************
* PRINT REPORT FOR SEVERITY MEASURE= COMBINED CASUALTY INDEX
****************************************************************;
LABEL LABO LABC;
SET FINAL;
IF ACCD NE 3 THEN STOP;
PROC PRINT SPLIT=*;
VAR CROSSING ACCIDENT BENCOS RECCAT NEWCL TRACKS TRAINS CUMCOST
CUMARED DC1 DC2 DC3 DC4 STPFLG;
FORMAT NEWCL CLASS. STPFLG YES_NO.
       ACCIDENT CUMARED ACCBNF.
       DC1 DC2 DC3 DC4 DECIS.;
TITLE TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON COMBINED CASUALTY INDEX (CCI);

DATA;
*  ---* PRINT THE REPORT SORTED BY CROSSING IDS          *--- ;
LABEL LABO LABC LABP;
SET CCI;
PROC SORT;
BY CROSSING;
PROC PRINT SPLIT=*;
VAR CROSSING BENCOS DSTATE COT_NAME CTY_NAME RAILROAD ROAD RRID
MILEPOST;
FORMAT DSTATE ESTATE. ACCIDENT PREDACC.;
TITLE1 TITVAL;
```

```
TITLE2 PUBLIC RAIL-HIGHWAY CROSSINGS  RESOURCE ALLOCATION RESULTS;
TITLE3 BASED ON PREDICTED COMBINED CASUALTY INDEX (SORTED BY CROSSING
IDs);
DATA;
*  ---* PRINT REPORT FOR CROSSINGS ELIGIBLE FOR STOP SIGNS *---  ;
LABEL LAB0 LABC;
SET CCI;
IF STPFLG  = 0 THEN DELETE;
PROC PRINT SPLIT= *;
VAR CROSSING ACCIDENT NEWCL TRAINS AADT FC10;
FORMAT FC10 URBR.;
TITLE1 TITVAL;
TITLE2 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS;
TITLE3 POSSIBLE CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS;
TITLE4 (SEE NOTE AT THE END OF SUMMARY PAGE);

DATA SUMMRY;
*  ---* PRINT SUMMMARY FOR INPUT PARAMETERS AND THE RUN *---  ;
SET TOTREC;
FILE DD1, PRINT;
ACCD= ACCVAL;
OPTION= OPTVAL;
Y1= X1; Y2= X2; Y3= X3; Y4= X4; Y5= X5; Y6= X6;
Y7= X7; Y8=X8; Y9=X9;  A1= X11; A2= X12; A0= X10;
ID1= ID1VAL; ID2= ID2VAL;
IF ID1= 0 THEN DO;
ID1= .;  ID2= .;  END;
COST1= CS1; COST2= CS2; COST3= CS3; BCOST= BUDGETX;
PUT  ///@36'*********************************************************-
*';
PUT   @36  '*          SUMMARY  OF  INPUT   PARAMETERS
*';
PUT   @36  '*         FOR RESOURCE ALLOCATION PROCEDURE
*';
PUT   @36
'************************************************************';
PUT  /@36  ' TITLE                     : TITVAL ';
PUT   @36  ' STATE                     : STATEVAL ';
PUT   @36  ' COUNTY                    : COUNTVAL ';
PUT   @36  ' CITY                      : CITYVAL ';
PUT   @36  ' RAILROAD                  : RAILVAL ';
PUT   @36  ' CROSSING ID               :        ';
PUT   @36  '     -BOTTOM OF RANGE      : ' ID1;
PUT   @36  '     -TOP OF RANGE         : ' ID2;
PUT   @36  ' SEVERITY TYPE             : ACCVAL   (1) PREDICTED
ACCIDENTS';
PUT   @36  '                           :      (2) FATAL ACCIDENT';
PUT   @36  '                           :      (3) COMBIN. CASUALTY INDEX'
IF ACCD = 3 THEN
PUT   @36  ' FATALITY FACTOR           : KK ';
PUT   @36  ' EFFECTIVENESS             : ' OPTION  ' (1)  STANDARD   ';
PUT   @36  ' CHOICE                    :    (2)  EXTENDED ';
PUT   @36  '                           : ' ;
IF OPTION = 1 THEN DO;
```

```
PUT    @36  ' STANDARD EFF. VALUES     : S1      S2      S3';
END;
ELSE DO;
PUT    @36  ' EXTENDED EFF. VALUES     : ';
PUT @36 ' '
PUT @36 '                           TRAINS <=10       TRAINS >=11'
PUT @36 '                         SINGLE      MULTI    SINGLE
MULTI';
PUT @36 '                          TRACK      TRACK     TRACK
TRACK';
PUT @36 ' '
PUT @36 '     PASSIVE TO FLASHING : ' Y1 @74 Y7 @84 Y4 @95 A0;
PUT @36 '     PASSIVE TO GATES    : ' Y2 @74 Y8 @84 Y5 @95 A1;
PUT @36 '     FLASHING TO GATES   : ' Y3 @74 Y9 @84 Y6 @95 A2;
END;
PUT    @36  '                          : ';
PUT    @36  ' UPGRADE COSTS-           :';
PUT    @36  '    PASSIVE TO FLASHING   : ' COST1 DOLLAR11.2;
PUT    @36  '    PASSIVE TO GATES      : ' COST2 DOLLAR11.2;
PUT    @36  '    FLASHING TO GATES     : ' COST3 DOLLAR11.2;
PUT    @36  '                          : ';
PUT    @36  ' AVAILABLE BUDGET         : ' BCOST DOLLAR15.2;
PUT
//@36'*******************************************************';
PUT   /@36   '              TOTAL NUMBER OF CROSSINGS ANALYZED  :'
                                              NUM_CRO;
PUT   /@36  ' ALL CANDIDATE CROSSINGS FOR STANDARD HIGHWAY STOP SIGNS';
PUT    @36  ' ARE SINGLE TRACK, LOCAL CROSSINGS. REFER TO PARAGRAPH';
PUT    @36  ' 8B-9 OF THE MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES';
PUT    @36  ' FOR FACTORS TO BE CONSIDERED PRIOR TO MAKING STOP ';
PUT    @36  ' SIGN INSTALLATION DECISIONS.';
PUT   /@36   '              INVENTORY DATE: APRIL 1986';
PUT
//@36'*******************************************************';
TITLE1  TITVAL;
```

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