IMPLEMENTATION PACKAGE
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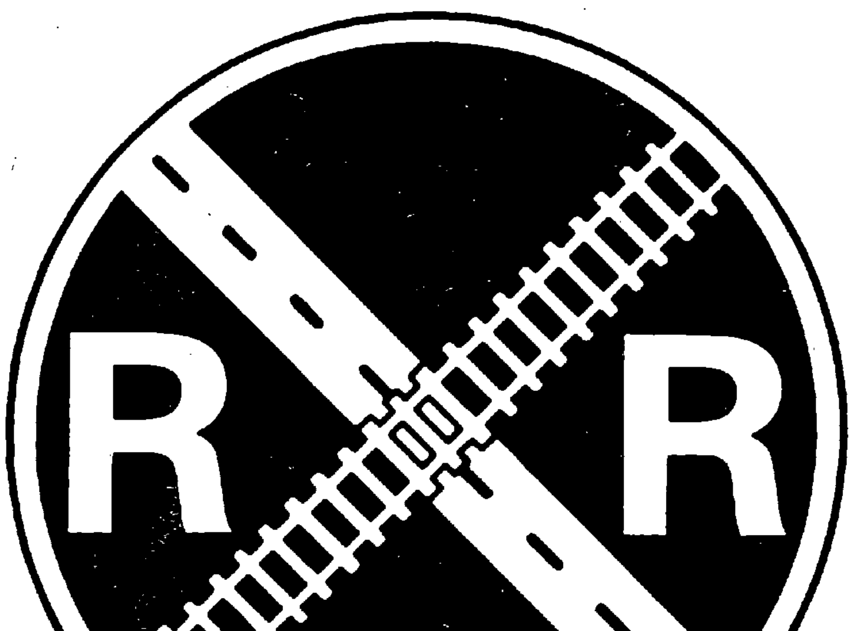
U.S. Department of Transportation

Rail-Highway Crossing Resource Allocation Procedure
User's Guide

Federal Highway Administration
Offices of Research, Development and Technology

Federal Railroad Administration
Office of Safety

December 1982



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16. Abstract

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Act of 1978 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 prediction formula, which predicts the number of accidents at crossings, and the resource allocation model, which nominates crossings for improvement on a cost-effective basis and recommends the type of warning device to be installed. This guide provides interested users with complete information for application of the DOT Rail-Highway Crossing Resource Allocation Procedure.

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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 System Center (TSC) under the sponsorship of the Federal Railroad Administration's (FRA) Office of Safety and the Federal Highway Administration's (FHWA) Offices of Research, Development and Technology. When used together, these procedures provide an automated and systematic means of making a cost-effective but preliminary, allocation of funds among individual crossings and available improvement options.

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

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

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

Approximate Conversions from Metric Measures

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

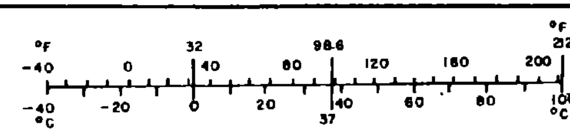


TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont.)

1. INTRODUCTION

1.1 PURPOSE

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

1.2 BACKGROUND

The Highway Safety Acts of 1973 and 1976 and the Surface Transportation Assistance Act of 1978 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. 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 allocations of Federal funds for rail-highway crossing safety improvement. One of these projects concerns development of a resource allocation procedure that determines crossing safety improvements that yield the greatest accident reduction benefits based on consideration of predicted accidents at crossings, the cost and effectiveness of warning device options and the budget limit. Two analytical methods have been developed as part of this procedure. Their development followed completion of a joint U.S. DOT-AAR (Association of American Railroads) National Rail-Highway Crossing Inventory (hereafter referred to as The Inventory), which numbered and collected inventory information for all public and private crossings in the United States. (Ref. 1)

The first analytical method included in the resource allocation procedure is the DOT accident prediction formula, which computes the expected number of accidents at crossings based on information available in The Inventory and crossing accident data files. The second analytical method is a resource allocation model designed to rank 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, which together comprise the DOT Rail-Highway Crossing Resource Allocation Procedure.

1.3 ORGANIZATION OF GUIDE

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

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

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

Chapter 5 discusses procedures for use of the DOT Resource Allocation 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 about 215,000 public at-grade rail-highway crossings in the United States. At an average cost of approximately $50,000 per installation, there are insufficient funds available to install automatic warning systems at each of these crossings. The DOT Resource Allocation 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 accident reduction.

Figure 2-1 illustrates the basic functions of the DOT Resource Allocation 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 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 at each crossing together with information on the safety effectiveness and costs of alternative warning device improvements and the funding level available to determine the most cost-effective set of improvement decisions; i.e., which crossings to improve and the types of warning devices to install at those crossings to result in the greatest accident reduction given the available funding.

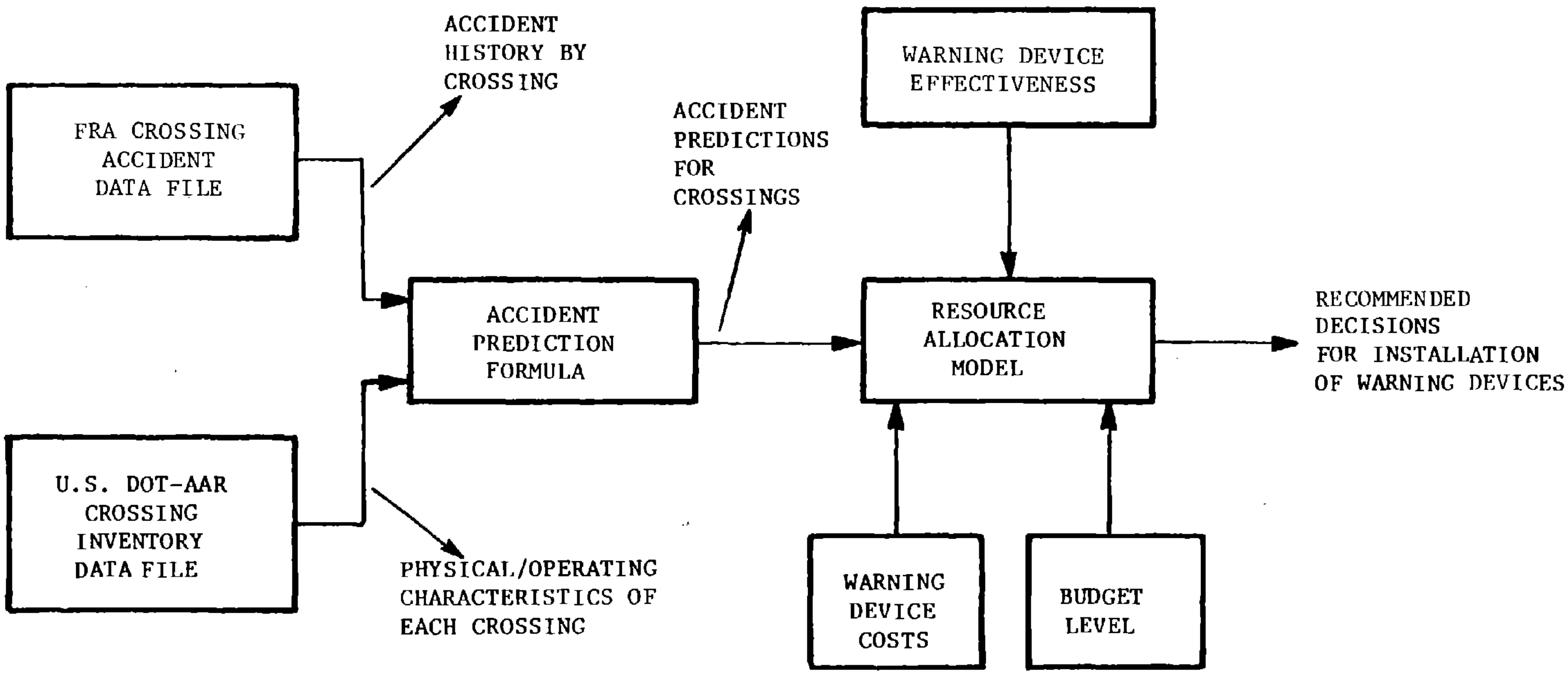


FIGURE 2-1. RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION PROCEDURE

The DOT Resource Allocation Procedure does not dictate final decisions for crossing improvements, but does recommend programs to aid in making informed decisions. As an analytical procedure, its' recommendations are dependent on accurate input data and assumptions. Errors in The Inventory and assumptions regarding warning device cost and effectiveness may cause inappropriate recommendations. To ensure accuracy of the input data, they 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 resource allocation procedure. These considerations include highway congestion, school bus and hazardous materials traffic, restricted sight distance, and other unusually hazardous, costly or mitigating characteristics of individual crossings. A procedure for performing this evaluation is described in Section 4.2.5. Results of the resource allocation 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 resource allocation 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 to identify hazardous crossings potentially needing safety improvements. The resource allocation model can then be used to evaluate alternative programs for improving these crossings. For example, the impacts on program benefits of changes in key program parameters such as budget limits, warning device installation strategies (e.g. flashing lights only, gates only) and warning device cost and effectiveness assumptions can be determined. Analysis of these results will help in deciding upon budget levels for crossing improvements and in determining the effectiveness of implementing state warrants specifying installation strategies. Once key program parameters have been decided upon, the resource allocation model will provide an initial recommended program, based on cost-effectiveness considerations, for review by the state. The procedure is also useful for railroads in providing recommended uniform improvement programs over their entire rail systems that pass through several states.

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

3. DOT ACCIDENT PREDICTION FORMULA

3.1 INTRODUCTION

Many crossing hazard formulas have been developed in the past and used extensively by those concerned with rail-highway crossing safety. (Ref. 2). Examples are the New Hampshire Formula, the Peabody-Dimmick Formula, the Mississippi Formula, and the Ohio Method. Recent availability of The Inventory and accident data by crossing were major considerations which influenced development of the new DOT accident 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 prediction.

The function of the DOT accident prediction formula is described in Figure 3-1. The formula provides a means of calculating the expected annual number of accidents at a crossing on the basis of characteristics of the crossing described in The Inventory and the crossing's historical accident experience described in the FRA Railroad Accident Incident Reporting Systems (RAIRS).

The DOT accident prediction formula is termed an "absolute" formula since it estimates numbers of accidents. Other formulas, such as the New Hampshire Formula, are termed "relative" formulas since they provide an index which is associated with expected accidents only on a relative basis i.e., a larger index means more expected accidents 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 the most cost-effective allocation of improvement funds, as discussed in Section 4. If program effectiveness is to be measured in terms of tangible benefits such as accident reduction benefits, an absolute formula must be used to ensure that the benefits of alternative actions are consistently evaluated. The use of an absolute formula, such as the DOT formula, is therefore recommended to support resource allocation decisions.

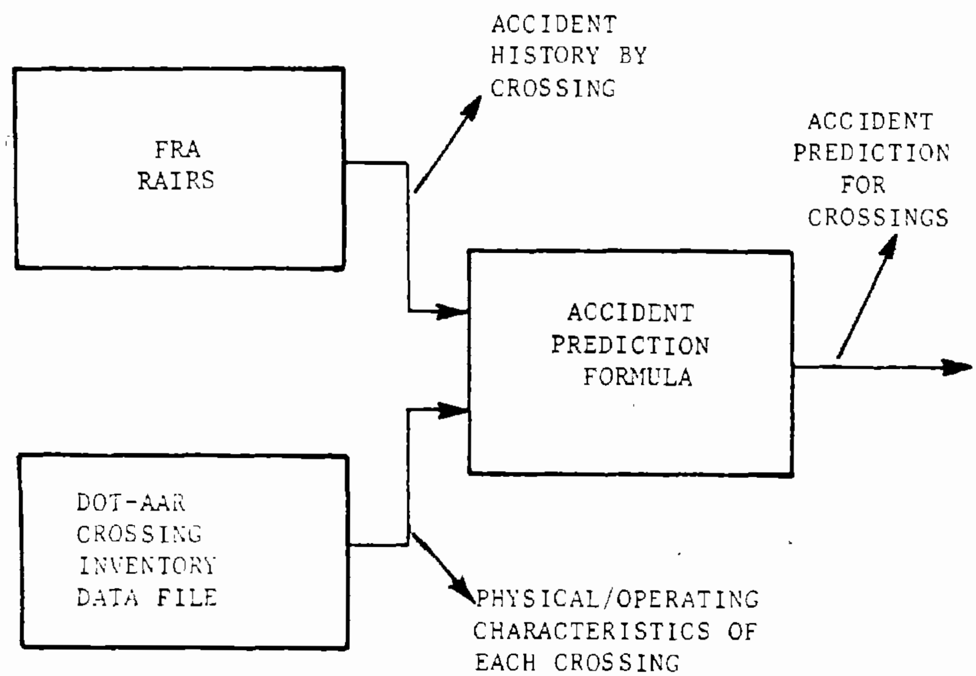


FIGURE 3-1. DOT RAIL-HIGHWAY CROSSING ACCIDENT PREDICTION FORMULA

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 formula with several other well-known formulas (Ref. 3) shows the DOT formula to have significantly improved performance in this regard.

3.2 DESCRIPTION OF DOT FORMULA - DEVELOPMENT AND CHARACTERISTICS

3.2.1 General DOT Formula

The DOT accident prediction formula combines two independent predictions of a crossing's accidents to produce a more accurate resultant prediction. The two independent predictions are obtained from the following two sources:

1. A basic formula (equation 3-2) provides an initial prediction of accidents on the basis of a crossing's characteristics as described in The Inventory. This formula, termed the "basic" formula, is used to predict crossing accidents in a manner similar to other common formulas, such as the Peabody-Dimmick and New Hampshire formulas.

2. The second prediction is equal to the actual observed accident history at a crossing. This prediction assumes that future accidents per year will be the same as the average historical accident rate. It is referred to as a crossing's accident history, and is equal to the total observed accidents divided by the number of years over which the observations were made.

The DOT accident prediction formula can be expressed as follows:

$$A = \frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right) \qquad (3\text{-}1)$$

where

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

a = initial accident prediction from basic formula (equation 3-2), 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_0 = formula weighting factor = 1.0 / (0.05 + a)

The DOT accident prediction formula (equation 3-1) calculates a weighted average of a crossing's predicted accidents from the basic formula (a) (equation 3-2), and accident history (N/T). The two formula weights, $T_0/(T_0+T)$ and $T/(T_0+T)$, add to the value 1.0. Values for the final accident prediction (A), obtained from equation 3-4, for different values of the initial prediction (a), from equation 3-2, and different prior accident rates (N/T) are tabularized in Tables 3-1 to 3-5. Each table represents results for a specific number of years for which accident history data are available. At this time (December 1982), the FRA has 7 years of accident data correlated with The Inventory. If, the number of years of accident data, T, is a fraction, the final accident prediction, A, can be interpolated from the tables or determined directly from the formula. The formula provides the most accurate results if all the accident history available is used; however, the extent of improvement is minimal if data for more than 5 years are used. It is therefore recommended that only data for the most recent 5 years of accident history be used. This ensures both good performance from the formula and use of the most relevant data. Accident history information older than 5 years may be misleading because of changes that occur to crossing characteristics over time. If 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.

Referring to Tables 3-1 to 3-5, the value of the final accident prediction (A) is determined from the intersection of the appropriate column and row for the values of the initial prediction (a) and the observed number of accidents (N). Thus, if a = 0.05 and N = 4, for T = 5 (Table 3-5), the number of predicted accidents (A) is 0.360.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2.2 Basic Formula

The initial prediction of a crossing's accidents (a) is determined from the basic accident prediction formula described in equation 3-2 below. The basic formula produces a prediction on the basis of a crossing's characteristics as described in The Inventory. The technique used for developing the basic formula involved applying nonlinear multiple regression techniques to crossing characteristics stored in The Inventory and to accident data contained in the FRA Railroad Accident/Incident Reporting System (RAIRS). The 1976 accident file and the August 1976 inventory were used to develop the formula. Half of the file was used to determine the formula coefficients, by regression and iteration (data set A), and the other half was used for testing of the formula (data set B). Data sets A and B were disjoint, of equal size and comprised of a random sample of records from The Inventory, including all records for which accident data existed in the RAIRS file. Each data set was categorized into two groups of accident and nonaccident crossings.

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

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL \quad (3\text{-}2)$$

where

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

K = constant for initialization of factor values at 1.00*

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

MT = factor for number of main tracks

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

HP = factor for highway paved (yes or no)

MS = factor for maximum timetable speed*

HT = factor for highway type*

HL = factor for number of highway lanes

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

1. Passive, including the following warning device classes:

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

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

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

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

3. Gates, including the following warning device class:

Class 8 - Automatic gates with flashing lights

The crossing characteristic factor equations for the three warning device categories are shown in Table 3-6. Each set of factor equations should be used only for crossings with the warning device classes for which it was designed. For example, if it is desired to predict the number of accidents at a crossing with crossbucks, then the passive set of equations should be used.

The numerical value of each factor is related to the degree of correlation that a specific crossing characteristic was found to have with crossing accident rates. For those cases in Table 3-6 where the value of the factor is indicated as a constant 1.0, it was found that the characteristic did not have a significant relationship to crossing accidents.

The structure of the basic accident prediction formula makes it possible to construct look-up tables of numerical values for the crossing characteristic factors. To predict the accidents at a particular crossing whose Inventory characteristics are known, the values of the factors are found in the table and multiplied together. The factor values for the three warning device categories (passive, flashing lights and gates) are found in Tables 3-7, 3-8 and 3-9, respectively. Detailed procedures for use of the tables and computer automation of the accident prediction formula are presented in Section 5.1.

An inspection of the factor value tables shows that exposure index (EI), based on the product of annual average daily highway traffic (c) and average daily train traffic (t), has the strongest relationship to predicted accidents. All other factors can be seen as having a secondary relationship to predicted accidents. It is useful in understanding the nature of the basic accident prediction formula to plot the relationship of accidents to the primary crossing characteristics of highway and train traffic, while holding

TABLE 3-6. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS

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

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

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

t = average total train movements per day

mt = number of main tracks

d - average number of thru trains per day during daylight

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

ms = maximum timetable speed, mph

ht = highway type factor value

hl = number of highway lanes

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

9/81

TABLE 3-7. FACTOR VALUES FOR CROSSINGS WITH PASSIVE WARNING DEVICES

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

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

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

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

TABLE 3-8. FACTOR VALUES FOR CROSSINGS WITH FLASHING LIGHT WARNING DEVICES

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

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

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

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

TABLE 3-9. FACTOR VALUES FOR CROSSINGS WITH GATE WARNING DEVICES

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

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

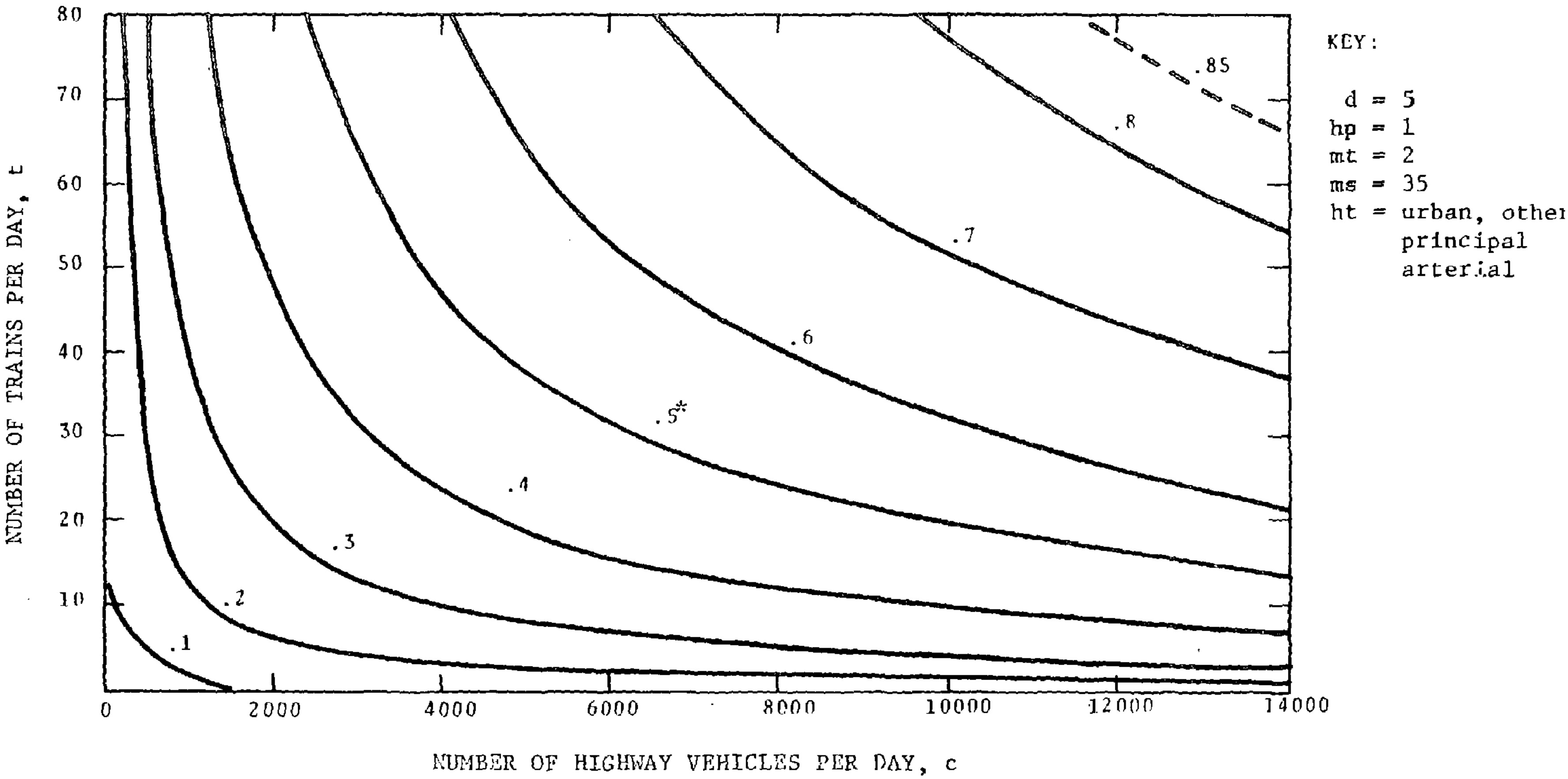
K = formula constant
"c" x "t" = number of highway vehicles per day, "c", multiplied by total train movements per day, "t"
EI = exposure index factor
MT = main tracks factor
DT = day thru trains factor
HP = highway paved factor
MS = maximum timetable speed factor
HT = highway type factor
HL = highway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

* Less than one train per day.
** For definition of highway type codes, see Table 3-6.

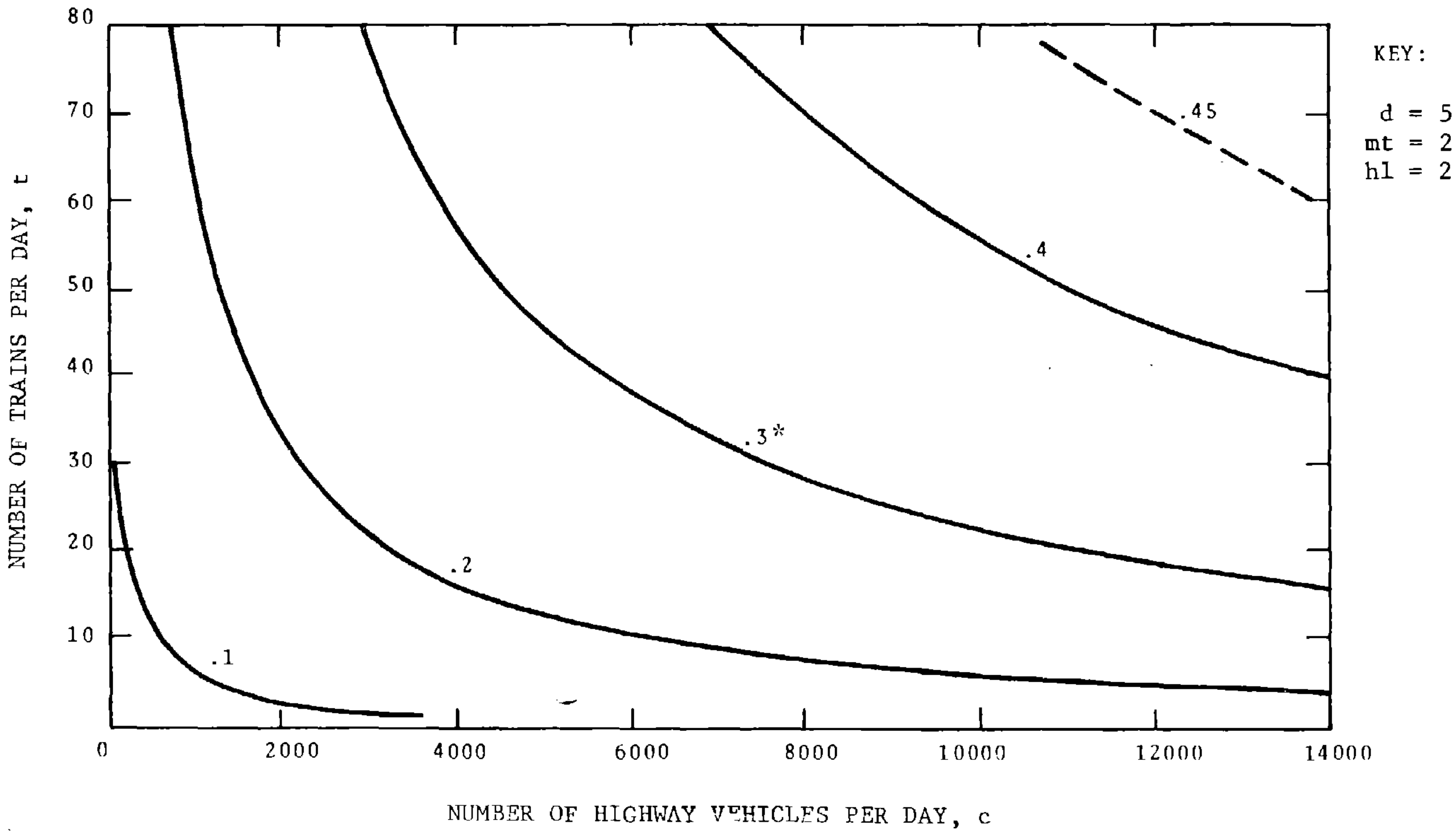
the secondary factors constant at nominal values. When this is done, predicted accidents (a), can be viewed as a surface defined over the c, t plane. The plots are shown in Figures 3-2, 3-3 and 3-4 for the three warning device categories. The predicted accident surface is portrayed by a set of equal-accident-level lines, which are analagous to contour lines on a topographical map. The larger the accident value, the higher above the c, t plane is the accident surface.

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

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

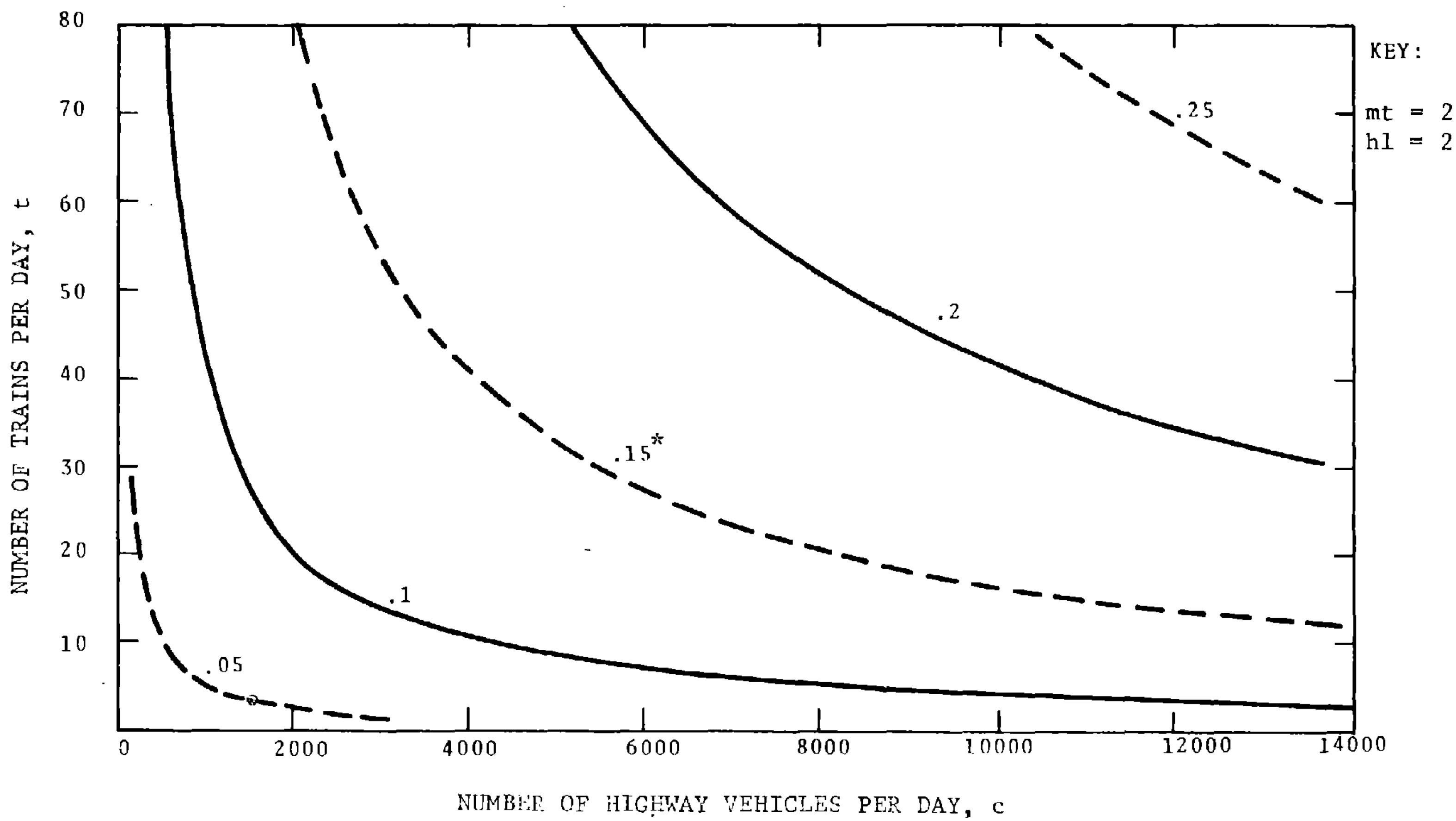


*Numbers on lines denote predicted accidents per year.



*Numbers on lines denote predicted accidents per year.

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



*Numbers on lines denote predicted accidents per year.

FIGURE 3-4. LINES OF EQUAL ACCIDENT PREDICTION LEVEL FOR WARNING DEVICE CLASS 8.

4. RESOURCE ALLOCATION MODEL

4.1 INTRODUCTION

The resource allocation model is designed to provide an initial recommended list of crossing improvements, that result in the greatest accident reduction benefits on the basis of cost-effectiveness considerations for a given budget limit (Ref. 4). This initial recommendation may then be used by states to guide the on-site inspection of crossings by diagnostic teams. Updated results obtained by the diagnostic teams then form a useful set of recommendations upon which state and local officials can finalize their crossing safety improvement plans. Input to the resource allocation model includes predicted accidents 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 predictions for crossings can come from any accident prediction formula which computes number of accidents per year. The DOT accident prediction formula described in the previous section was developed for this purpose.

Cost data for the warning device options can be of several different types. They may be life cycle costs (the sum of procurement, installation, and maintenance), the costs associated with a particular phase of a project (e.g., procurement or installation or maintenance) or some fraction of these costs. In any case, comparable figures are needed for the following categories of improvement actions currently considered by the model: flashing lights for a previously passive crossing, gates for a previously passive crossing, and gates at a crossing previously equipped with flashing lights. Cost data on warning device improvements which can be used for the resource allocation model are presented in Section 4.2.3.

Warning device effectiveness required by the resource allocation model is defined as the decimal fraction by which accidents are expected to be reduced by installation of a warning device. Effectiveness is a relative measure involving both existing and proposed warning systems at a crossing to be upgraded. If automatic gates have an effectiveness of 0.84, when installed at a crossing with a passive warning device, the accident rate at the crossing will be reduced by 84 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; it is 100 percent effective. Values of effectiveness for different warning device improvement combinations are presented in Section 4.2.4.

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 local 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, 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 4.2.5.

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 DESCRIPTION OF RESOURCE ALLOCATION MODEL

4.2.1 Model Algorithm

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

Table 4-1 is a matrix showing the effectiveness and cost symbols for the three warning device groupings used in describing the resource allocation algorithm. The matrix reflects the possible combinations of crossing 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, such as grade separations and closures. It is also necessary to determine the costs and effectiveness of any additional options that are considered.

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

For any given crossing and/or 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 parameter (E_j) is the effectiveness of installing a proposed warning device at a crossing with a lower class warning device. The second parameter (C_j) is the corresponding cost of the proposed warning device. Table 4-1 shows the six warning device parameters (E_1, C_1, E_2, C_2, E_3, C_3) that are needed to use the resource allocation algorithm.

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

The resource allocation model considers all crossings with either passive or flashing light warning devices for improvements. If, for example, a single-track passive crossing, i, is considered, it could be upgraded with either flashing lights, with an effectiveness E_1, or gates, with an effectiveness of E_2. The number of predicted accidents at crossing i is A_i; hence, the reduced accidents per year is A_iE_1 for the flashing light option and A_iE_2 for the gate option. The corresponding costs for these two improvements are C_1 and C_2. The accident reduction/cost ratios for these improvements are A_iE_1/C_1 for flashing lights and A_iE_2/C_2 for gates. The rate of increase in accident reduction versus costs that results from changing an initial decision to install flashing lights with a decision to install gates, at crossing i, is referred to as the incremental accident reduction/cost ratio and is equal to $A_i(E_2-E_1)/(C_2-C_1)$. The incremental accident reduction/cost ratio is used by the algorithm to compare the cost-effectiveness of a decision to further upgrade a passive crossing from flashing lights to gates with an alternative decision to upgrade another crossing instead. If a passive multiple-track crossing, i, is considered, the only improvement option allowable would be installation of gates, with an effectiveness of E_2, a cost of C_2 and an accident reduction/cost ratio of $A_i\ E_2/C_2$. If crossing i was originally a flashing light crossing, the only improvement option available would be installation of gates, with an effectiveness of E_3, a cost of C_3 and an accident reduction/cost ratio of A_iE_3/C_3.

The resource allocation algorithm systematically computes the accident reduction/cost ratios, including incrementals, of all allowable improvement options for all crossings under consideration. The individual accident reduction/cost ratios which are associated with these improvements are selected by the algorithm in an efficient manner to produce the maximum accident reduction which can be obtained for a predetermined total cost. This total cost is the sum of an integral number of equipment costs (C_1, C_2 and C_3). The total, maximum accident reduction is the sum of the individual accident reductions of the form A_iE_j.

A flow diagram describing the logic of the resource allocation algorithm is shown in Figure 4-1. The input to this program consists of the set of crossings for which the model is to apply, the accidents predicted per year for these crossings, the six warning device parameters (E_1, E_2, E_3, C_1, C_2, C_3), and the funding level (CMAX) which determines where the calculation is to stop.

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 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 reduction/cost ratios. Step 2B assumes that gates will always be installed at passive crossings.

Step 2A: In step 2A, two accident reduction/cost ratios are calculated for each single-track passive crossing, $A_i E_1/C_1$ and the incremental ratio $A_i (E_2-E_1)/(C_2-C_1)$, where A_i is the number of accidents predicted per year for the crossing. These two ratios correspond to the two actions available for single-track passive crossings, either to install flashing lights or a revised decision to install gates. For multiple-track passive crossings, only the accident reduction/cost ratio for installation of gates is calculated ($A_i E_2/C_2$), to conform with Federal regulations. For each crossing equipped with flashing lights, the algorithm computes $A_i E_3/C_3$, corresponding to an upgrading from flashing lights to gates. The accident reduction/cost ratio is represented in units of accidents prevented per year per dollar.

Step 2B: The algorithm computes the accident reduction/cost ratio $A_i E_2/C_2$ for passive crossings and the ratio $A_i E_3/C_3$ for crossings with flashing lights. These accident reduction/cost ratios are associated with installing only gates at crossings. For the step 2B case, these actions are always

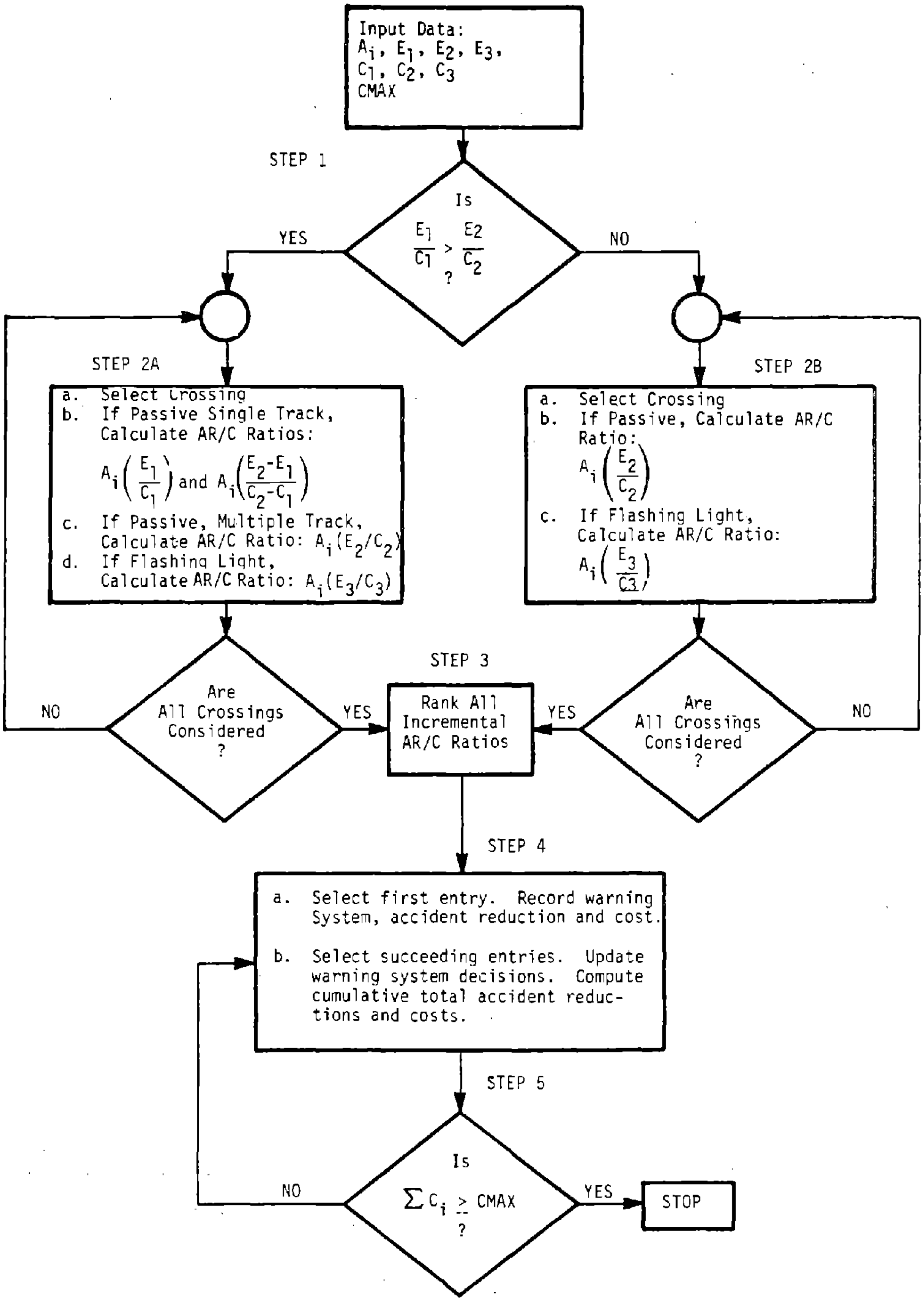


FIGURE 4-1. RESOURCE ALLOCATION ALGORITHM

optimal to the alternative of installing flashing lights, since the accident 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 reduction/cost ratios calculated by the algorithm are ranked with the largest first. The list of accident 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 reduction/cost ratios. This process is equivalent to making the optimum decision of achieving the maximum accident reduction for each additional increment in cost incurred. If the accident reduction/cost ratio at any given step on the list is calculated as $A_i E_1/C_1$, a decision is made to install flashing lights at a passive crossing, with an accident reduction of $A_i E_1$ and cost of C_1. If the accident reduction/cost ratio is $A_i (E_2-E_1)/(C_2-C_1)$, a previous decision to install flashing lights is changed to installation of gates at a passive crossing. The incremental accident reduction of changing the previous decision is $A_i(E_2-E_1)$, and the incremental cost is C_2-C_1. If the accident reduction/cost ratio is $A_i E_2/C_2$, then a decision is made to install gates at a passive crossing without prior consideration of flashing lights. The accident reduction is $A_i E_2$ at a cost of C_2. If the accident reduction/cost ratio is $A_i E_3/C_3$, then a decision is made to install gates at a crossing which had flashing lights. The accident reduction is $A_i E_3$ at a cost of C_3. The total accident reduction at each step is the sum of the previous accident reductions, and the total cost is the sum of the previous costs.

In addition to determining the total accident reduction and cost at each step, the algorithm also determines the particular warning systems which are to be installed at particular crossings. Since the crossings which were affected are known, the accident prediction, accidents, 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 reduction/cost ratios, is compared with the total funding limit specified as input to the algorithm. When the total cost equals or exceeds this limit, the program ends. Otherwise, the sequential procedure described in step 4 continues.

4.2.2 Demonstration of Algorithm

To demonstrate operation of the algorithm, an example which considers the three crossings described in Table 4-2 follows. The predicted accidents per year and current warning device information for the crossings together with assumed warning device cost and effectiveness parameters, presented in Table 4-3, constitute the input data for the algorithm.

TABLE 4-2. SAMPLE CROSSINGS FOR ALGORITHM DEMONSTRATION

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

TABLE 4-3. EFFECTIVENESS/COST INPUT DATA

EXISTING WARNING DEVICE	PROPOSED WARNING DEVICE: FLASHING LIGHTS		AUTOMATIC GATES	
	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	---	---	E_3 = 0.667	C_3=\$35,000

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

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

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

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

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

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

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

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

Step 4: From the ranked list in Table 4-5, the first action selected by the algorithm corresponds to the first ranked accident reduction/cost ratio: installation of flashing lights at crossing X_1 with a cost of $25,000. The next action selected by the algorithm corresponds to the next ranked accident reduction/cost ratio: installation of gates at crossing X_2, resulting in a cumulative cost of $60,000 for the first two projects. The algorithm proceeds in this manner until the cumulative total cost of all improvement actions equals the available funding (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.

4.2.3 Warning Device Cost Data

As described above, the resource allocation model requires data on the costs of the warning device improvement options. A study has been performed to determine average national values for these costs. (Ref. 5) The costs determined include the initial installation costs 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 in 1977 dollars are shown in Table 4-6 below.

TABLE 4-6. WARNING DEVICE IMPROVEMENT COSTS, 1977

IMPROVEMENT OPTION	INSTALLATION COST	NPV MAINTENANCE COST	NPV LIFE CYCLE COST
Passive to Flashing Lights, C_1	$27,400	$15,400	$42,800
Passive to Gates, C_2	$40,800	$24,300	$65,100
Flashing Lights to Gates, C_3	$36,700	$24,500	$61,200

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

The inflation multiplier for installation costs (MI) is determined from the average increase in the "Other Material" index, (OM) and the "Wage Rate" index (WR) from their 1977 values of 217 and 227, respectively:

$$MI = \frac{(OM/217 + WR/227)}{2} \qquad (4\text{-}1)$$

where

MI = inflation multiplier for installation costs
OM = other material index for the current year
WR = wage rate index for the current year

The 1980 annual values for the indexes (published January 30, 1981) were OM= 291.4 and WR= 301.6; hence, MI for 1980 is:

$$MI_{1980} = \frac{(291.4/217 + 301.6/227)}{2}$$

$$= 1.34$$

The inflation multiplier for maintenance costs (MM) is a weighted average of 95 percent of the installation cost multiplier (MI) and 5 percent of the increase in the "Fuel" index (F) from its 1977 value of 390:

$$MM = MI \times 0.95 + (F/390) \times 0.05 \qquad (4\text{-}2)$$

where

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

The 1980 annual value for the fuel index (F) is 908.8; hence, MM for 1980 is:

$$MM_{1980} = 1.34 \times 0.95 + (908.8/390) \times 0.05$$

$$= 1.39$$

Applying the 1980 multiplier values to the 1977 costs shown in Table 4-6 yields the 1980 warning device improvement costs shown in Table 4-7 below. At any future time, the 1977 costs can be increased to reflect current values using the procedure described above.

TABLE 4-7. WARNING DEVICE IMPROVEMENT COSTS, 1980

IMPROVEMENT OPTION	INSTALLATION COST 1977 COST x 1.34	NPV MAINTENANCE COST 1977 COST x 1.39	NPV LIFE CYCLE COST
Passive to Flashing Lights, C_1	$36,700	$21,400	$58,100
Passive to Gates, C_2	$54,700	$33,800	$88,500
Flashing Lights to Gates, C_3	$49,200	$34,100	$83,300

The cost values shown in Table 4-7 are national averages, and their use will produce a reasonable set of decisions by the resource allocation model, which will be useful in formulating improvement programs. The study to determine these costs did not reveal any significant shifts in costs by region of the country, although some variation by railroad was observed. If other figures for the average costs of improvements are available, and are thought to more accurately reflect the application in question, these figures 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 4.2.5. 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.

4.2.4 Warning Device Effectiveness Data

Two investigations have been performed to determine the effectiveness of warning devices in reducing accidents at rail-highway crossings. The most recent study used information in The Inventory and the FRA accident reporting system. (Ref. 7) 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 1978. An earlier study was performed in 1974 by the California Public Utilities Commission (Ref.8). This study examined accident rates before and after upgrades at 1552 California crossings over the period from 1960 to 1970. The results of these studies are shown in Table 4-8 in terms of the effectiveness values E_1, E_2 and E_3 for the three improvement options considered by the resource allocation model.

TABLE 4-8. EFFECTIVENESS OF WARNING DEVICE IMPROVEMENTS

WARNING DEVICE IMPROVEMENT OPTION	DOT STUDY, 1980	CALIFORNIA STUDY, 1974
Passive to Flashing Lights, E_1	0.65	0.64
Passive to Gates, E_2	0.84	0.88
Flashing Lights to Gates, E_3	0.64	0.66

The effectiveness values resulting from the two studies are quite similar. In fact, the average values from the California study all fall within the 95-percent confidence interval of the DOT study results. 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 DOT study are recommended, since they were most recently developed, and used the largest data base of national scope. The DOT results are currently (summer, 1981) being recalculated, using additional data added to The Inventory and accident files since the previous study was completed. It is expected that the effectiveness values shown in Table 4-8 may change slightly as a result of this work. These values should therefore not be thought of as constants.

4.2.5 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 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.

Steps 1, and 2 of the worksheet involve validating crossing characteristics data, and recalculating the predicted accidents 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 (A);(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. If any of these inputs changed, the parameter (R) is then calculated, using the formula below and described in part 2 of step 4:

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 initial 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 CHARACTERISTIC	INITIAL INFORMATION	REVISED INFORMATION
Crossing Number	________	________
Location	________	________
Existing Warning Device	________	________
Total Trains Per Day (t)	________	________
Annual Average Daily Highway Traffic (c)	________	________
Day Through Trains (d)	________	________
Number Of Main Tracks (mt)	________	________
Is Highway Paved? (hp)	________	________
Maximum Timetable Speed, mph (ms)	________	________
Highway Type (ht)	________	________
Number Of Highway Lanes (hl)	________	________
Number Of Years Of Accident History (T)	________	________
Number Of Accidents In T Years (N)	________	________
Predicted Accident Rate (A)	________	

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

Revised Predicted Accidents (A) = ________

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

	INITIAL INFORMATION	REVISED INFORMATION
Assumed Effectiveness 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 A, E OR C HAS CHANGED.

Instructions For Determining If Recommended Warning Device Should Be Revised

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

DC_1= ____ DC_2= ____ DC_3= ____ DC_4= ____

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

3. Compare R With Appropriate Decision Criteria As Shown Below:

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

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

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

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

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

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

4. Revised Recommended Warning Device Installation: ____________

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

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

Percent trucks ____

Passenger train operations over crossing? ____

High speed trains with limited sight distance?** ____

Combination of high speeds and moderately high volumes of highway and railroad 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'd)

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

The value of R is the ratio of the revised to previous accident 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 (Figure 5-14) 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:

$$DC_1 = AC_m/[A_i(E_1/C_1)] \qquad (4\text{-}4)$$

$$DC_2 = AC_m/[A_i(E_2-E_1)/(C_2-C_1)] \qquad (4\text{-}5)$$

$$DC_3 = AC_m/[A_i\ (E_2/C_2)] \qquad (4\text{-}6)$$

$$DC_4 = AC_m/[A_i(E_3/C_3)] \qquad (4\text{-}7)$$

where

AC_m = the minimum accident reduction/cost ratio corresponding to the last (lowest) improvement action selected by the resource allocation model

The decision criteria represent the amount by which the accident 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 reduction/cost ratio due to revised data is still within the limits permitting selection of the same improvement action.

To demonstrate use of the revision procedure, the following example is provided. A single-track passive crossing was selected by the resource allocation model for upgrading to gates. This crossing is listed as the 14th crossing (ID# 740858L) on the sample standard output report of the resource allocation model, Figure 5-14. 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 cost 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	0.17	0.20
Warning Device Effectiveness, E	0.84	0.95
Warning Device Cost, C	$88,500	$150,000

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

$$R = (.20/.17)\ (.95/.84)(88{,}500/150{,}000)$$

$$= 0.785$$

The decision criteria for this crossing, obtained from the standard output report of the resource allocation model, Figure 5-14, are:

DC_1 = 0.482
DC_2 = 0.809
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.

5. APPLICATION OF DOT RESOURCE ALLOCATION PROCEDURE

5.1 DOT ACCIDENT PREDICTION FORMULA

5.1.1 Manual Calculation of Predicted Accidents

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

TABLE 5-1. CHARACTERISTICS OF SAMPLE CROSSING

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

First, the basic formula (Equation 3-2) is used to determine the initial accident prediction (a). The basic formula is repeated below:

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

where

a = initial accident prediction

K = constant

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

MT = factor for number of main tracks

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

HP = factor for highway paved (yes or no)

MS = factor for maximum timetable speed

HT = factor for highway type

HL = factor for number of highway lanes

The basic formula factor values (K, EI, MT, DT, HP, MS, HT and HL) can be determined from Table 3-7 for passive crossings, using the crossing's characteristics listed in Table 5-1:

K = .002268

EI = exposure index factor value for the product of 350 average daily highway vehicles times 10 total train movements per day ($c \times t = 3500$) = 25.98

MT = 1.52
DT = 1.55
HP = 1.00
MS = 1.36
HT = 0.82
HL = 1.00

Substituting the factor values into the basic formula yields:

$$a = K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$$
$$= 0.002268 \times 25.98 \times 1.52 \times 1.55 \times 1.00 \times 1.36 \times 0.82 \times 1.00$$
$$= 0.15 \text{ accidents per year}$$

The final accident prediction (A) is determined by combining the initial prediction (a) with the crossing's accident history using Tables 3-1 thru 3-5, which are developed from the DOT accident prediction formula (Equation 3-1). For the sample crossing, 2 accidents (N) occurred over the past 4 years (T); therefore, Table 3-4 is used. With an initial accident prediction (a = .15) which is between 0.10 and 0.20, it can be seen from Table 3-4 that the final accident prediction (A) will be between 0.25 and 0.35. A reasonable estimate of A can be determined from linear interpolation:

$$A = 0.25 + [(0.15-0.10) / (0.20-0.10)] [0.35-0.25]$$

$$= 0.30 \text{ accidents per year}$$

5.1.2. Computer Programs for Calculation of Predicted Accidents

This section describes procedures for using the DOT accident prediction formula computer programs to obtain the number of predicted accidents per year for large numbers of crossings, and to list the crossings ranked by number of predicted accidents. 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.

Three separate FORTRAN programs are used to obtain the number of predicted accidents. The first program uses the basic accident prediction formula to calculate the initial accident prediction (a) for input into the second program, which uses the DOT accident prediction formula to calculate the final predicted accidents (A). The third program generates the output in a report format. The three programs are run sequentially according to the following steps.

1. Execute the basic accident prediction formula program.
2. Execute the DOT accident prediction formula program.
3. Sort the output from step 2 in descending order of number of predicted accidents.
4. Execute the accident prediction report program.

The basic accident prediction formula FORTRAN program is shown in Figure 5-1. This program uses the following equations to calculate the basic number of predicted accidents (a). For warning device classes 1 through 4, the equation is:

$$a = 0.00984\ e^{2x}$$

where

$$x = 0.3839 \log_{10} (c \times t + 0.2) + 0.1538 \log_{10} (d + 0.2)$$

$$- 0.3080\ hp + 0.003855\ ms - 0.04991\ ht + 0.1047\ mt$$

For warning device clases 5 through 7 the equation is:

$$a = 0.00551\ e^{2x}$$

where

$$x = 0.3400 \log_{10} (c \times t + 0.2) + 0.05415 \log_{10} (d + 0.2)$$

$$+ 0.05442\ mt + 0.06900\ hl$$

For warning device class 8 the equation is:

$$a = 0.00162\ e^{2x}$$

where

$$x = 0.3588 \log_{10} (c \times t + 0.2) + 0.1456\ mt + 0.05180\ hl$$

```
C               THIS PROGRAM CALCULATES PREDICTED ACCIDENTS USING
C               THE BASIC FORMULA
C               INPUT MUST BE IN THE 50 CHARACTER FORMAT PLUS
C               SIX YEARS OF ACCIDENT HISTORY
C               UNIT 16 - INVENTORY INPUT FILE
C               UNIT 17 - INVENTORY OUTPUT FILE WITH BASIC PREDICTED
C                         ACCIDENTS
C               UNIT  5 - SUMMARY OUTPUT FILE
C
      INTEGER YEAR,OLDCL,CLASS,TRAINS,DT,SPEED,TRACKS,PAVE,FC10,FC1,
     *        HT,AADT
      DIMENSION EFF(6),ITEM1(5),ITEM3(4)
      INTEGER RURAL(9),URBAN(9)
      DATA RURAL/1,2,0,0,0,3,4,5,6/
      DATA URBAN/1,2,0,3,0,4,5,0,6/
      DATA EFF/.35,.16,.36,2.86,6.25,2.78/
      NREC=0
      HTOT=0.0
 100  READ(16,9100,END=900) ITEM1,YEAR,MONTH,OLDCL,NEWCL,TRAINS,DT,
     *        SPEED,TRACKS,ITEM2,PAVE,LANES,FC10,FC1,AADT,ITEM3
 9100 FORMAT(5A4,2I2,2I1,I3,I2,I3,I1,A3,4I1,I6,3A4,A2)
      T=TRAINS
      C=AADT
      D=DT
      CLASS=NEWCL
      IF(YEAR.GT.75) CLASS=OLDCL
      IF(OLDCL.EQ.9) CLASS=NEWCL
      GO TO (200,200,200,200,300,300,300,400),CLASS
      GO TO 100
C               CROSSBUCKS EQUATION
 200  IF(FC1.EQ.0) GO TO 220
      IF(FC10.NE.0) GO TO 210
      HT=RURAL(FC1)
      GO TO 230
 210  IF(FC10.NE.1) GO TO 220
      HT=URBAN(FC1)
      GO TO 230
 220  HT=0
 230  X=0.3839*ALOG10(C*T+0.2)+0.1538*ALOG10(D+0.2)-0.3080*PAVE
     *        +0.003855*SPEED-0.04991*HT+0.1047*TRACKS
      H=0.00984*EXP(2*X)
      GO TO 500
C               FLASHING LIGHTS EQUATION
 300  X=0.3400*ALOG10(C*T+0.2)+0.05415*ALOG10(D+0.2)+0.05442*TRACKS
     *        +0.05900*LANES
      H=0.00551*EXP(2*X)
      GO TO 500
```

FIGURE 5-1. BASIC ACCIDENT PREDICTION FORMULA PROGRAM

```
C              GATES EQUATION
 400    X=0.3588*ALOG10(C*T+0.2)+0.1456*TRACKS+0.05180*LANES
        H=0.00162*EXP(2*X)
C              MODIFY UPGRADES/DOWNGRADES BY EFFECTIVENESS
 500    IF(CLASS.EQ.NEWCL) GO TO 600
        IF(OLDCL.GT.NEWCL) GO TO 550
        K=2
        IF(NEWCL.NE.8) K=1
        IF(OLDCL.GT.4) K=3
        GO TO 555
 550    K=5
        IF(OLDCL.NE.8) K=4
        IF(NEWCL.GT.4) K=6
 555    H=H*EFF(K)
C
 600    HTOT=HTOT+H
        NREC=NREC+1
        WRITE(17,9500) H,ITEM1,YEAR,MONTH,OLDCL,NEWCL,TRAINS,DT,SPEED,
     *         TRACKS,ITEM2,PAVE,LANES,FC10,FC1,AADT,ITEM3
 9500   FORMAT(F10.7,5A4,2I2,2I1,I3,I2,I3,I1,A3,4I1,I6,3A4,A2)
        GO TO 100
 900    WRITE(5,9900) HTOT,NREC
 9900   FORMAT(' TOTAL BASIC PREDICTED ACCIDENTS =  ',F10.3 /
     *         ' TOTAL NUMBER OF CROSSINGS  =  ',I6)
        STOP
        END
```

FIGURE 5-1. BASIC ACCIDENT PREDICTION FORMULA PROGRAM (Cont'd)

The variables used in the above equations are as defined in Section 3.2.2. For warning device classes 1 through 4, the appropriate highway type (ht) value is listed in Table 3-6. The equations in Table 3-6 were algebraically derived from the above equations, so the basic number of predicted accidents could be expressed as a product of factors to be looked up in tables. A variable dictionary for the basic accident prediction formula program is given in Table 5-2.

The basic accident prediction formula computes the initial predicted accident rate for each crossing on the basis of the crossing's current warning device class. If, during the last five years, a change in warning device took place, the formula computes the predicted accidents on the basis of the previous warning device class. An adjustment is then made to the predicted accidents using the appropriate effectiveness factor (see Table 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, the passive formula would be used, the results of which would be multiplied by the effectiveness factor for gates (1.0 - 0.84) to obtain the initial predicted accidents for the crossing with gates. Similarly, the predicted accidents would be divided by the effectiveness of the new warning device if a downgrade took place.

Sample input to the basic accident prediction formula program is shown in Figure 5-2. Each record represents one crossing, and is formatted according to the data field descriptions given in Table 5-3. Those fields marked with two asterisks are the minimum necessary input to the basic accident prediction formula. Fields 20 through 25 are used in the DOT accident prediction formula. Other fields are used for identification and location of crossings, for the field verification worksheets, and for input to the resource allocation model. The source of fields 1 through 19 is the U.S. DOT-AAR National Rail-Highway Crossing Inventory; fields 20 through 25 are from the FRA Railroad Accident/Incident Reporting System. Both data bases are maintained by the Federal Railroad Administration, Office of Safety.

TABLE 5-2. VARIABLE DICTIONARY FOR THE BASIC ACCIDENT PREDICTION FORMULA PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINITION
AADT	Integer	Annual average daily vehicular traffic
C	Real	Annual average daily vehicular traffic
CLASS	Integer	Warning device class used to calculate H
D	Real	Number of daylight thru trains
EFF	Real	Effectiveness multipliers
DT	Integer	Number of daylight thru trains
FC1	Integer	Units digit of functional classification of road
FC10	Integer	Tens digit of functional classification of road
H	Real	Basic predicted accidents per year = a
HT	Integer	Highway type
HTOT	Real	Total basic predicted accidents
ITEM1	Alphanumeric	Holds data that is input and output only
ITEM2	Alphanumeric	Holds data that is input and output only
ITEM3	Alphanumeric	Holds data that is input and output only
K	Integer	Category of upgrade/downgrade – 1: Passive to flashing lights 2: Passive to gates 3: Flashing lights to gates 4: Flashing lights to passive 5: Gates to passive 6: Gates to flashing lights
LANES	Integer	Number of highway traffic lanes
MONTH	Integer	Month of change in warning device class
NEWCL	Integer	Present warning device class
NREC	Integer	Total number of crossings processed
OLDCL	Integer	Former warning device class
PAVE	Integer	Is highway paved? – 1: yes, 2: no
RURAL	Integer	Lookup table for rural highway types
SPEED	Integer	Maximum timetable train speed
T	Real	Number of trains per day
TRACKS	Integer	Number of main tracks
TRAINS	Integer	Number of trains per day
URBAN	Integer	Lookup table for urban highway types
X	Real	Intermediate variable in calculation of H
YEAR	Integer	Year of change in warning device class

ID NUMBER / STATE / COUNTY / CITY / RAILROAD	UPGRADE YEAR / UPGRADE MONTH / FORMER CLASS / PRESENT CLASS	TOTAL TRAINS / DAY TRAINS	SPEED / MAIN TRACKS	OTHER TRACKS / AMTRAK / PAVED / LANES / FUNC. CLASS	AADT / % TRUCKS	1975 ACC.	1976 ACC.	1977 ACC.	1978 ACC.	1979 ACC.	1980 ACC.
740703U320310208SP	700107	19 9	452	011209	3000	0	0	0	0	0	0
740705H320310208SP	781248	19 9	452	011209	35003	0	0	0	0	0	0
740715N320310170SP	700104	19 9	451	011109	18006	0	0	0	0	0	0
740716V320310170SP	700104	19 9	450	021109	1500	0	0	0	0	0	0
740719R320310170SP	700108	19 9	452	111209	45007	0	0	0	0	1	0
740722Y320310170SP	800748	19 9	452	011209	10000	0	0	0	0	0	0
740724M320310170SP	700108	23 9	452	211416	1940004	1	0	0	0	0	1
740725U320310170SP	771278	23 9	202	111219	345010	0	1	0	0	0	0
740726B320310170SP	800578	21 9	202	121216	1100	0	0	0	0	0	0
740727H320310170SP	800778	25 9	202	111217	425002	0	0	0	0	0	0
740728P320310170SP	800378	25 9	202	011414	913502	1	0	0	2	0	1
740729W320310170SP	800978	25 9	202	011419	530001	0	0	0	0	0	0
740730R320310170SP	700108	25 9	202	012416	1230002	0	1	0	1	0	0
740731X320310170SP	700108	25 9	202	011414	1940000	1	0	2	0	1	0
740732E320310170SP	700108	25 9	202	011419	1160005	0	0	0	0	0	0
740733L320310170SP	700108	25 9	202	011416	1030000	0	0	1	1	0	1
740734T320310170SP	810147	2 0	00	221414	1650015	0	0	0	0	0	0
740736G320310170SP	700104	25 9	202	111219	70007	0	0	0	0	0	0
740740W320310170SP	761178	27 9	302	011319	550013	0	0	0	1	1	0
740744Y320310190SP	700106	2514	702	011208	80007	0	0	0	0	2	1
740752R320290190SP	700107	3314	701	411209	17520	0	0	0	0	0	0
740756T320310091SP	700104	2514	701	011209	6501	0	0	0	0	0	0
740763D320010091SP	700104	2914	701	012109	1025	0	0	0	1	0	0
740765S320010130SP	750978	2011	701	021202	54015	0	0	0	1	0	0
740768M320270130SP	700104	2011	701	012108	5000	0	0	0	0	0	0
740769U320270130SP	750878	2011	701	011208	16516	0	0	0	0	0	0
740770N320270130SP	700104	2011	702	012109	3514	0	0	0	0	0	0
740771V320270130SP	700104	2011	702	012109	500	0	0	0	0	0	0
740772C320270130SP	700107	2211	402	312209	100	0	0	0	0	0	0
740773J320270130SP	700107	2211	402	111209	20000	0	0	0	0	0	0

FIGURE 5-2. SAMPLE INPUT TO THE BASIC ACCIDENT PREDICTION FORMULA PROGRAM

TABLE 5-3. INPUT DATA FIELD DESCRIPTIONS

DATA FIELD	COLUMN	LENGTH	DATA TYPE*	FIELD DESCRIPTION
1	1	7	A	CROSSING ID NUMBER
2	8	2	I	STATE FIPS CODE
3	10	3	I	COUNTY FIPS CODE
4	13	4	I	CITY FIPS CODE
5	17	4	A	FRA RAILROAD CODE
6	21	4	I	**YEAR AND MONTH OF LAST CHANGE IN WARNING DEVICE
7	25	1	I	**FORMER WARNING DEVICE CLASS
8	26	1	I	**PRESENT WARNING DEVICE CLASS
9	27	3	I	**TOTAL NUMBER OF TRAINS PER DAY
10	30	2	I	**NUMBER OF DAYLIGHT THRU TRAINS
11	32	3	I	**MAXIMUM TIMETABLE SPEED
12	35	1	I	**NUMBER OF MAIN TRACKS
13	36	2	I	NUMBER OF OTHER TRACKS
14	38	1	I	DO PASSENGER TRAINS OPERATE OVER CROSSING? -- 1: YES, 2: NO
15	39	1	I	**IS HIGHWAY PAVED? -- 1: YES, 2: NO
16	40	1	I	**NUMBER OF TRAFFIC LANES
17	41	2	I	**FUNCTIONAL CLASSIFICATION OF ROAD
18	43	6	I	**ESTIMATED ANNUAL AVERAGE DAILY TRAFFIC
19	49	2	I	ESTIMATED PERCENT TRUCK TRAFFIC
20	51	2	I	NUMBER OF ACCIDENTS IN 1975
21	53	2	I	NUMBER OF ACCIDENTS IN 1976
22	55	2	I	NUMBER OF ACCIDENTS IN 1977
23	57	2	I	NUMBER OF ACCIDETNS IN 1978
24	59	2	I	NUMBER OF ACCIDENTS IN 1979
25	61	2	I	NUMBER OF ACCIDENTS IN 1980

* DATA TYPE:

A - Alphanumeric
I - Integer

** Input to basic accident prediction formula

Sample output from the basic accident prediction formula program is shown in Figure 5-3. The field descriptions and the data contained in them are identical to the input (Table 5-3 and Figure 5-2), except that a field of length 10 has been added to the beginning of each record. This field contains the initial predicted accidents (a) and is a real number in F10.7 format. The program also writes a second output file, containing the total number of crossings (records) processed and the total initial numbers of predicted accidents for those crossings.

The output shown in Figure 5-3 is also used as input to the second FORTRAN program, the DOT accident prediction formula program, which is shown in Figure 5-4. This program uses an algebraic equivalent of equation 3-1 from Section 3.2.1 to calculate the final predicted accident rate (A). The equation used is:

$$A = (T_o \times a + N)/(T + T_o)$$

where

$$T_o = 1/(0.05 + a)$$

A value of 5 is used in the formula for the maximum number of years of accident history, even though 6 years are available. The most recent 5 years are used.

If a crossing has been upgraded or opened during the 5-year period, 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. A variable dictionary for the DOT accident prediction formula program is given in Table 5-4.

Sample output from the DOT accident prediction formula program is shown in Figure 5-5. The field descriptions and the data contained in them are identical to the input (Figure 5-3) except that another field of length 10 has been added to the beginning of each record. This field contains the final predicted accidents (A), and is a real number in F10.7 format. The program also writes a second output file, containing the total number of crossings

BASIC PRED. ACC.	ID NUMBER	STATE	COUNTY	CITY	RAILROAD	UPGRADE YEAR	UPGRADE MONTH	FORMER CLASS	PRESENT CLASS	TOTAL TRAINS	DAY TRAINS	SPEED	MAIN TRACKS	OTHER TRACKS	AMTRAK	PAVED	LANES	FUNC. CLASS	AADT / % TRUCKS	1975 ACC.	1976 ACC.	1977 ACC.	1978 ACC.	1979 ACC.	1980 ACC.
0.0652823	740703U	32	031	0208	SP	70	01	0	7	19	9	45	2	0	1	1	2	09	3000	0	0	0	0	0	0
0.0554395	740705H	32	031	0208	SP	78	12	4	8	19	9	45	2	0	1	1	2	09	35003	0	0	0	0	0	0
0.1033159	740715N	32	031	0170	SP	70	01	0	4	19	9	45	1	0	1	1	1	09	18006	0	0	0	0	0	0
0.0365986	740716V	32	031	0170	SP	70	01	0	4	19	9	45	0	0	2	1	1	09	1500	0	0	0	0	0	0
0.0599561	740719R	32	031	0170	SP	70	01	0	8	19	9	45	2	1	1	1	2	09	45007	0	0	0	0	1	0
0.0375207	740722Y	32	031	0170	SP	80	07	4	8	19	9	45	2	0	1	1	2	09	10000	0	0	0	0	0	0
0.2529846	740724M	32	031	0170	SP	70	01	0	8	23	9	45	2	2	1	1	4	16	1940004	1	0	0	0	0	1
0.1200540	740725U	32	031	0170	SP	77	12	7	8	23	9	20	2	1	1	1	2	19	345010	0	1	0	0	0	0
0.0817247	740726B	32	031	0170	SP	80	05	7	8	21	9	20	2	1	2	1	2	16	1100	0	0	0	0	0	0
0.1314886	740727H	32	031	0170	SP	80	07	7	8	25	9	20	2	1	1	1	2	17	425002	0	0	0	0	0	0
0.2053247	740728P	32	031	0170	SP	80	03	7	8	25	9	20	2	0	1	1	4	14	913502	1	0	0	2	0	1
0.1732835	740729W	32	031	0170	SP	80	09	7	8	25	9	20	2	0	1	1	4	19	530001	0	0	0	0	0	0
0.2252710	740730R	32	031	0170	SP	70	01	0	8	25	9	20	2	0	1	2	4	16	1230002	0	1	0	1	0	0
0.2596448	740731X	32	031	0170	SP	70	01	0	8	25	9	20	2	0	1	1	4	14	1940000	1	0	2	0	1	0
0.2211947	740732E	32	031	0170	SP	70	01	0	8	25	9	20	2	0	1	1	4	19	1160005	0	0	0	0	0	0
0.2131509	740733L	32	031	0170	SP	70	01	0	8	25	9	20	2	0	1	1	4	16	1030000	0	0	1	1	0	1
0.1916091	740734T	32	031	0170	SP	81	01	4	7	2	0	0	0	2	2	1	4	14	1650015	0	0	0	0	0	0
0.1810558	740736G	32	031	0170	SP	70	01	0	4	25	9	20	2	1	1	1	2	19	70007	0	0	0	0	0	0
0.1618804	740740W	32	031	0170	SP	76	11	7	8	27	9	30	2	0	1	1	3	19	550013	0	0	0	1	1	0
0.1905169	740744Y	32	031	0190	SP	70	01	0	6	25	14	70	2	0	1	1	2	08	80007	0	0	0	0	2	1
0.1183993	740752R	32	029	0190	SP	70	01	0	7	33	14	70	1	4	1	1	2	09	17520	0	0	0	0	0	0
0.1035872	740756T	32	031	0091	SP	70	01	0	4	25	14	70	1	0	1	1	2	09	6501	0	0	0	0	0	0
0.0314985	740763D	32	001	0091	SP	70	01	0	4	29	14	70	1	0	1	2	1	09	1025	0	0	0	1	0	0
0.0481931	740765S	32	001	0130	SP	75	09	7	8	20	11	70	1	0	2	1	2	02	54015	0	0	0	1	0	0
0.0509407	740768M	32	027	0130	SP	70	01	0	4	20	11	70	1	0	1	2	1	08	5000	0	0	0	0	0	0
0.0333058	740769U	32	027	0130	SP	75	08	7	8	20	11	70	1	0	1	1	2	08	16516	0	0	0	0	0	0
0.0504679	740770N	32	027	0130	SP	70	01	0	4	20	11	70	2	0	1	2	1	09	3514	0	0	0	0	0	0
0.0263915	740771V	32	027	0130	SP	70	01	0	4	20	11	70	2	0	1	2	1	09	500	0	0	0	0	0	0
0.0252644	740772C	32	027	0130	SP	70	01	0	7	22	11	40	2	3	1	2	2	09	100	0	0	0	0	0	0
0.1204743	740773J	32	027	0130	SP	70	01	0	7	22	11	40	2	1	1	1	2	09	20000	0	0	0	0	0	0

FIGURE 5-3. SAMPLE OUTPUT FROM THE BASIC ACCIDENT PREDICTION FORMULA PROGRAM

```
C               THIS PROGRAM CALCULATES PREDICTED ACCIDENTS USING
C               THE ACCIDENT HISTORY FORMULA (T=5; 1976-80)
C               INPUT MUST BE IN THE 60 CHARACTER FORMAT PLUS
C               SIX YEARS OF ACCIDENT HISTORY
C               UNIT 16 - INVENTORY INPUT FILE WITH BASIC PREDICTED
C                         ACCIDENTS
C               UNIT 17 - INVENTORY OUTPUT FILE WITH FINAL PREDICTED
C                         ACCIDENTS
C               UNIT  5 - SUMMARY OUTPUT FILE
C
      INTEGER YEAR,ACC(5) ,TA
      REAL N
      DIMENSION ITEM1(5),ITEM2(8)
      NREC=0
      ATOT=0.0
 100  READ(16,9100,END=999) H,ITEM1,YEAR,ITEM2,ACC
 9100 FORMAT(F10.7,5A4,I2,7A4,A2,5I2)
C               CALCULATE NUMBER OF YEARS
      TA=80-YEAR
      IF(TA.LT.0) TA=0
      IF(TA.GT.5) TA=5
      T=TA
C               CALCULATE NUMBER OF ACCIDENTS
      N=0.
      DO 200 I=6-TA,5
 200  N=N+ACC(I)
C               CALCULATE PREDICTED ACCIDENTS
      T0=1./(.05+H)
      A=(H*T0+N)/(T+T0)
      ATOT=ATOT+A
      NREC=NREC+1
      WRITE(17,9900) A,H,ITEM1,YEAR,ITEM2,ACC
 9900 FORMAT(2F10.7,5A4,I2,7A4,A2,5I2)
      GO TO 100
 999  WRITE(5,9999) ATOT,NREC
 9999 FORMAT(' TOTAL PREDICTED ACCIDENTS =   ',F10.3 /
     *          ' TOTAL NUMBER OF CROSSINGS  =   ',I6)
      STOP
      END
```

FIGURE 5-4. DOT ACCIDENT PREDICTION FORMULA PROGRAM

TABLE 5-4 VARIABLE DICTIONARY FOR THE DOT ACCIDENT PREDICTION FORMULA PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINITION
A	Real	Final predicted accidents per year
ACC	Integer	Accident history for 1976 through 1980
ATOT	Real	Total predicted accidents
H	Real	Initial predicted accidents per year = a
I	Integer	DO loop index
ITEM1	Integer	Holds data that is input and output only
ITEM2	Integer	Holds data that is input and output only
N	Real	Number of accidents in T years
NREC	Integer	Total number of crossings processed
T	Real	Number of years of accident history
TO	Real	1/ (.05 + H); weighting factor in accident prediction formula
TA	Integer	Number of years of accident history
YEAR	Integer	Year of upgrade or opening of crossing

PRED. ACC.	BASIC PRED. ACC. / ID NUMBER / STATE / COUNTY / CITY / RAILROAD	UPGRADE YEAR / UPGRADE MONTH / FORMER CLASS / PRESENT CLASS	TOTAL TRAINS	DAY TRAINS	SPEED / MAIN TRACKS	OTHER TRACKS / AMTRAK / PAVED / LANES / FUNC. CLASS	AADT / % TRUCKS	1975 ACC.	1976 ACC.	1977 ACC.	1978 ACC.	1979 ACC.	1980 ACC.
0.0414120	0.0652823740703U320310208SP	700107	19	9	452	011209	3000	0	0	0	0	0	0
0.0457845	0.0554395740705H320310208SP	781248	19	9	452	011209	35003	0	0	0	0	0	0
0.0584836	0.1033159740715N320310170SP	700104	19	9	451	011109	18006	0	0	0	0	0	0
0.0255400	0.0365986740716V320310170SP	700104	19	9	450	021109	1500	0	0	0	0	0	0
0.1095363	0.0599561740719R320310170SP	700108	19	9	452	111209	45007	0	0	0	0	1	0
0.0375207	0.0375207740722Y320310170SP	800748	19	9	452	011209	10000	0	0	0	0	0	0
0.2210681	0.2529846740724M320310170SP	700108	23	9	452	211416	1940004	1	0	0	0	0	1
0.0794974	0.1200540740725U320310170SP	771278	23	9	202	111219	345010	0	1	0	0	0	0
0.0817247	0.0817247740726B320310170SP	800578	21	9	202	121216	1100	0	0	0	0	0	0
0.1314886	0.1314886740727H320310170SP	800778	25	9	202	111217	425002	0	0	0	0	0	0
0.2053247	0.2053247740728P320310170SP	800378	25	9	202	011414	913502	1	0	0	2	0	1
0.1732835	0.1732835740729W320310170SP	800978	25	9	202	011419	530001	0	0	0	0	0	0
0.3264718	0.2252710740730R320310170SP	700108	25	9	202	012416	1230002	0	1	0	1	0	0
0.4664343	0.2596448740731X320310170SP	700108	25	9	202	011414	1940000	1	0	2	0	1	0
0.0938863	0.2211947740732E320310170SP	700108	25	9	202	011419	1160005	0	0	0	0	0	0
0.4329490	0.2131509740733L320310170SP	700108	25	9	202	011416	1030000	0	0	1	1	0	1
0.1916091	0.1916091740734T320310170SP	810147	2	0	00	221414	1650015	0	0	0	0	0	0
0.0840057	0.1810558740736G320310170SP	700104	25	9	202	111219	70007	0	0	0	0	0	0
0.3169875	0.1618804740740W320310170SP	761178	27	9	302	011319	550013	0	0	0	1	1	0
0.4140897	0.1905169740744Y320310190SP	700106	25	14	702	011208	80007	0	0	0	0	2	1
0.0642777	0.1183993740752R320290190SP	700107	33	14	701	411209	17520	0	0	0	0	0	0
0.0585922	0.1035872740756T320310091SP	700104	25	14	701	011209	6501	0	0	0	0	0	0
0.0802825	0.0314985740763D320010091SP	700104	29	14	701	012109	1025	0	0	0	1	0	0
0.0981822	0.0481931740765S320010130SP	750978	20	11	701	021202	54015	0	0	0	1	0	0
0.0338543	0.0509407740768M320270130SP	700104	20	11	701	012108	5000	0	0	0	0	0	0
0.0235123	0.0333058740769U320270130SP	750878	20	11	701	011208	16516	0	0	0	0	0	0
0.0335929	0.0504679740770N320270130SP	700104	20	11	702	012109	3514	0	0	0	0	0	0
0.0190972	0.0263915740771V320270130SP	700104	20	11	702	012109	500	0	0	0	0	0	0
0.0183565	0.0252644740772C320270130SP	700107	22	11	402	312209	100	0	0	0	0	0	0
0.0650379	0.1204743740773J320270130SP	700107	22	11	402	111209	20000	0	0	0	0	0	0

FIGURE 5-5. SAMPLE OUTPUT FROM THE DOT ACCIDENT PREDICTION FORMULA PROGRAM

(records) processed and the total final predicted accidents for those crossings.

The output shown in Figure 5-5 is used as input to the accident prediction report program and also to the resource allocation program (see Section 5.2). The accident prediction report program generates the output in a report format. The data must first be sorted in descending order of number of predicted accidents (the first 10 columns), and then used as input to the accident prediction report program shown in Figure 5-6. Sample output from the accident prediction report program is shown in Figure 5-7.

The basic formula and the DOT accident prediction formula programs and their inputs and outputs are currently designed for use with the 1980 data file which has six years of accident history appended to each crossing record. At a future time, if accident data beyond 1980 is to be added, appropriate modifications to the programs and data files will be required to accomodate the additional data.

5.2 COMPUTER PROGRAMS FOR RESOURCE ALLOCATION MODEL

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

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

1. Execute the accident reduction/cost ratio program.
2. Sort the output from step 1 in descending order of accident reduction/cost ratio.
3. Execute the resource allocation algorithm program.

```
C                 THIS PROGRAM PRINTS THE OUTPUT OF THE ACCIDENT
C                 PREDICTION FORMULA IN A REPORT FORMAT
C                 UNIT 20 - INVENTORY INPUT FILE WITH FINAL PREDICTED
C                           ACCIDENTS SORTED IN DESCENDING ORDER OF
C                           PREDICTED ACCIDENTS
C                 UNIT 21 - REPORT OUTPUT FILE
C
      INTEGER ID(2),STATE,ISTATE(56),COUNTY,CITY,YEAR,OLDCL,TRAINS,DT,
     * SPEED,OTRKS,AMTRAK,PAVED,AADT,TRUCKS,PAVE(2),PAGE,RANK,DAY(2)
      DATA PAVE/'YES','NO '/
      DATA ISTATE/'AL','AK','  ','AZ','AR','CA','  ','CO','CT','DE',
     1           'DC','FL','GA','  ','HI','ID','IL','IN','IA','KS',
     2           'KY','LA','ME','MD','MA','MI','MN','MS','MO','MT',
     3           'NE','NV','NH','NJ','NM','NY','NC','ND','OH','OK',
     4           'OR','PA','PR','RI','SC','SD','TN','TX','UT','VT',
     5           'VA','VI','WA','WV','WI','WY'/
      PAGE=0
      RANK=0
      CALL DATE(DAY)
100   PAGE=PAGE+1
      WRITE(21,110) DAY,PAGE
110   FORMAT('1',T3,2A5,T54,'PUBLIC RAIL-HIGHWAY CROSSINGS',
     *           T126,'PAGE ',I3)
      WRITE(21,120)
120   FORMAT(T49,'RANKED BY PREDICTED ACCIDENTS PER YEAR'/
     *           T56,'INVENTORY DATE: JUNE 1981'/)
      WRITE(21,140)
140   FORMAT(T9,'PREDICTED',T20,'CROSSING',T37,'RAIL',
     *           T43,'  OF ACCIDENTS',T60,'DATE',T68,'WARNING',
     *           T77,'TRAINS',T85,'DAY',T93,'  OF',T100,'TIME',
     *           T108,'IS',T115,'  OF',T123,'FUNC.'/
     *           T3,'RANK',T9,'ACCIDENTS',T22,'ID  ',T30,'STATE',
     *           T37,'ROAD',T43,'-- -- -- -- --',T61,'OF',T68,'DEVICE',
     *           T78,'PER',T85,'THRU',T93,'MAIN',T100,'TABLE',
     *           T108,'HWY.',T114,'TRAFFIC',T123,'CLASS',T130,'AADT'/
     *           T43,'76 77 78 79 80',T59,'CHANGE',T69,'CLASS',T78,'DAY',
     *           T84,'TRAINS',T92,'TRACKS',T100,'SPEED',T107,'PAVED',
     *           T115,'LANES'//)
      LINE=10
200   READ(20,210,END=900) A,H,ID,STATE,COUNTY,CITY,RROAD,YEAR,
     *           MONTH,OLDCL,NEWCL,TRAINS,DT,SPEED,MTRKS,OTRKS,AMTRAK,
     *           PAVED,LANES,FC,AADT,TRUCKS,N75,N76,N77,N78,N79,N80
210   FORMAT(2F10.7,A4,A3,I2,I3,I4,A4,2I2,2I1,I3,I2,I3,I1,I2,3I1,
     *           A2,I6,I2,6I2)
      K=PAVED
      RANK=RANK+1
      IF(YEAR.LT.76) GO TO 230
      WRITE(21,220) RANK,A,ID,ISTATE(STATE),RROAD,N76,N77,N78,N79,
     *           N80,MONTH,YEAR,NEWCL,TRAINS,DT,MTRKS,SPEED,PAVE(K),
     *           LANES,FC,AADT
220   FORMAT(T2,I5,T9,F7.4,T20,A4,A3,T32,A2,T37,A4,T42,
     *           5I3,T60,I2,'/',I2,T71,I1,T78,I3,T86,I2,T95,I1,T101,I3,
     *           T108,A3,T116,I2,T124,A2,T128,I6)
      GO TO 250
230   WRITE(21,240) RANK,A,ID,ISTATE(STATE),RROAD,N76,N77,N78,N79,
     *           N80,NEWCL,TRAINS,DT,MTRKS,SPEED,PAVE(K),
     *           LANES,FC,AADT
240   FORMAT(T2,I5,T9,F7.4,T20,A4,A3,T32,A2,T37,A4,T42,
     *           5I3,T71,I1,T78,I3,T86,I2,T95,I1,T101,I3,
     *           T108,A3,T116,I2,T124,A2,T128,I6)
250   LINE=LINE+1
      IF(LINE.LT.60) GO TO 200
      GO TO 100
900   STOP
      END
```

FIGURE 5-6. ACCIDENT PREDICTION REPORT PROGRAM

PUBLIC RAIL-HIGHWAY CROSSINGS
RANKED BY PREDICTED ACCIDENTS PER YEAR
INVENTORY DATE: JUNE 1981

RANK	PREDICTED ACCIDENTS	CROSSING ID #	STATE	RAIL ROAD	# OF ACCIDENTS 76	77	78	79	80	DATE OF CHANGE	WARNING DEVICE CLASS	TRAINS PER DAY	DAY THRU TRAINS	# OF MAIN TRACKS	TIME TABLE SPEED	IS HWY. PAVED	# OF TRAFFIC LANES	FUNC. CLASS	AADT
1	0.7507	740854J			0	0	0	2	3		7	24	10	1	30	YES	2	07	6350
2	0.5389	804207E			1	0	1	1	1		8	23	14	1	79	YES	4	14	25300
3	0.4688	740852V			0	0	0	1	2		7	29	10	1	30	YES	2	08	4400
4	0.4725	833473E			0	2	1	1	0		7	26	10	1	15	YES	2	17	500
5	0.4664	740731X			0	2	0	1	0		8	25	9	2	20	YES	4	14	19400
6	0.4325	740733L			0	1	1	0	1		8	25	9	2	20	YES	4	16	10300
7	0.4141	740744Y			0	0	0	2	1		6	25	14	2	70	YES	2	08	800
8	0.4113	740855R			0	1	0	0	2		7	24	10	1	30	YES	2	19	1200
9	0.3664	833475T			1	0	0	0	1		7	26	10	1	15	YES	2	16	5870
10	0.3424	804244G			1	0	1	0	0		7	2	0	0	40	YES	6	14	17000
11	0.3291	740856X			0	2	0	0	0		7	24	10	1	30	YES	2	17	2400
12	0.3289	833479V			1	0	0	1	0		7	26	10	1	15	YES	2	16	2200
13	0.3265	740730R			1	0	1	0	0		8	25	9	2	20	NO	4	16	12300
14	0.3170	740740W			0	0	1	1	0	11/76	8	27	9	2	30	YES	3	19	5500
15	0.3066	740857E			0	0	1	0	1		7	24	10	1	30	YES	2	19	1400
16	0.2852	804206X			0	0	0	1	1		8	22	14	1	79	YES	4	14	12600
17	0.2844	833481W			0	1	0	1	0		7	26	10	1	15	YES	2	17	675
18	0.2211	740724M			0	0	0	0	1		8	23	9	2	45	YES	4	16	19400
19	0.2058	740842P			0	0	1	0	0		7	38	14	1	25	YES	2	09	1300
20	0.2053	740728P			0	0	2	0	1	3/80	8	25	9	2	20	YES	4	14	9135
21	0.1516	740734T			0	0	0	0	0	1/81	7	2	0	0	0	YES	4	14	16500
22	0.1888	833476A			0	0	1	0	0		7	26	10	1	15	YES	2	19	900
23	0.1857	804209T			0	0	0	0	1		8	23	14	1	79	YES	4	16	13800
24	0.1733	740729W			0	0	0	0	0	9/80	8	25	9	2	20	YES	4	19	5300
25	0.1724	740901P			1	0	0	1	1		4	4	0	0	0	NO	2	19	1100
26	0.1681	740858L			0	0	0	1	0		4	22	10	1	70	YES	2	19	200
27	0.1453	740775X			0	0	1	0	0		8	22	11	2	40	YES	2	08	2230
28	0.1355	740841H			0	0	0	1	0		4	38	14	1	25	YES	2	09	80
29	0.1315	740727H			0	0	0	0	0	7/80	8	25	9	2	20	YES	2	17	4250
30	0.1234	804193Y			0	0	0	0	0		7	24	14	1	60	YES	4	17	5975
31	0.1227	804003T			1	0	0	0	0		8	14	7	2	79	YES	2	16	1230
32	0.1096	740719R			0	0	0	1	0		8	19	9	2	45	YES	2	09	450
33	0.1089	833592N			0	0	0	0	0		7	4	1	1	0	YES	4	16	19260
34	0.1051	833601K			0	0	0	0	0		7	4	0	1	0	YES	4	07	19900
35	0.1037	740853C			0	0	0	0	0		7	29	10	1	30	YES	2	09	3400
36	0.1024	833425P			0	0	1	0	0		4	20	10	1	55	NO	1	08	80
37	0.0987	740876J			0	0	0	1	0		7	20	10	1	70	NO	2	08	15
38	0.0982	740765S			0	0	1	0	0		8	20	11	1	70	YES	2	02	540
39	0.0939	740732C			0	0	0	0	0		8	25	9	2	20	YES	4	19	11600
40	0.0932	740914R			0	0	1	0	0		4	2	1	1	49	YES	2	09	260
41	0.0922	740882M			0	0	1	0	0	6/80	8	34	14	2	50	YES	2	08	1000
42	0.0905	833574R			0	0	0	0	0		7	2	1	1	25	YES	4	06	11100
43	0.0855	833599L			0	0	0	0	0		7	2	0	0	0	YES	4	16	19900
44	0.0851	804135D			0	0	0	1	0		5	2	0	0	0	YES	2	19	200
45	0.0875	740843W			0	0	0	0	0		4	38	14	1	25	YES	2	09	800
46	0.0840	740736S			0	0	0	0	0		4	25	9	2	20	YES	2	19	700
47	0.0825	834521V			0	0	0	0	0	11/79	8	26	10	1	15	YES	2	16	3600
48	0.0817	740726B			0	0	0	0	0	5/80	8	21	9	2	20	YES	2	16	1100
49	0.0811	804238D			0	0	0	1	0		4	2	0	0	40	YES	2	17	375
50	0.0807	753625C			0	0	0	0	0	11/79	8	24	10	1	30	YES	2	16	3600

FIGURE 5-7. SAMPLE OUTPUT FROM THE ACCIDENT PREDICTION REPORT PROGRAM

4. Sort the output from step 3 in descending order of accident reduction/cost ratio.
5. Execute the resource allocation report program.

The accident reduction/cost ratio program is shown in Figure 5-8. This program reads two input files. One input file is the output of the accident prediction formula program (see Figure 5-5). The second input file contains cost, effectiveness and funding data. This file is to be generated by the user. Suggested values for cost and effectiveness data are given in Section 4.2.3 and 4.2.4. A sample input file of this type is shown in Figure 5-9. The first line of input contains the cost data in 3 fields, each of length 10. The first entry on the line is the cost of upgrading a passive crossing to a flashing light; the second entry is the cost of upgrading a passive crossing to a gate; and the third entry is the cost of upgrading a flashing light to a gate. The second line of input contains the effectiveness data in 3 fields, each of length 10. The order is the same as for the cost data on the first line. The third and last line consists of 1 field of length 10 containing the maximum amount of available funding in dollars. This value is to be established by the user.

The program in Figure 5-8 calculates an accident reduction/cost ratio for each crossing, depending on the present 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. If the crossing has flashing lights or other active devices (warning device classes 5,6 and 7), an accident reduction/cost ratio for upgrading to gates is calculated according to the equation:

$$AR/C = A\ (E_3/C_3)$$

where A is the number of predicted accidents for the crossing from the accident prediction formula and C_3 and E_3 are the cost and effectiveness of the upgrade, as discussed in Section 4. If the crossing is passive (warning device classes 1-4) but has multiple tracks, an accident reduction/cost ratio for upgrading to gates is calculated according to the equation:

```
C               THIS PROGRAM CALCULATES AN INITIAL BENEFIT/COST RATIO
C               FOR EACH CROSSING WHICH DOES NOT CURRENTLY HAVE GATES
C               INPUT MUST BE IN THE 70 CHARACTER FORMAT PLUS SIX
C               YEARS OF ACCIDENT HISTORY
C               UNIT 20 - INVENTORY INPUT FILE WITH FINAL PREDICTED
C                         ACCIDENTS
C               UNIT 21 - INITIAL BENEFIT/COST RATIO OUTPUT FILE
C               UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL INPUT FILE
C
        INTEGER ID(2),CLASS,CTRKS,TRACKS
C               READ IN COST AND EFFECTIVENESS DATA
        READ(22,50) C1,C2,C3
 50     FORMAT(3F10.0)
        READ(22,55) E1,E2,E3
 55     FORMAT(3F10.2)
        R1=E1/C1
        R2=E2/C2
        R3=E3/C3
C               IF GATES ARE ALWAYS MORE COST-EFFECTIVE THAN
C               FLASHING LIGHTS, USE A GATES ONLY POLICY
        IF(R2.GT.R1) R1=R2
 100    READ(20,1000,END=500) A,ID,CLASS,MTRKS,OTRKS
 1000   FORMAT(F10.7,10X,A4,A3,18X,I1,8X,I1,I2)
C               DELETE CROSSINGS WHICH CURRENTLY HAVE GATES
        IF(CLASS.EQ.8) GO TO 100
        TRACKS=MTRKS+OTRKS
        IF(CLASS.GT.4) GO TO 300
        IF(TRACKS.GT.1) GO TO 200
C               SINGLE TRACK PASSIVE CROSSINGS
        BENCOS=A*R1*10.**6
        GO TO 400
C               MULTIPLE TRACK PASSIVE CROSSINGS - GATES ONLY
 200    BENCOS=A*R2*10.**6
        GO TO 400
C               CROSSINGS WITH FLASHING LIGHTS
 300    BENCOS=A*R3*10.**6
 400    WRITE(21,4000) BENCOS,A,ID,CLASS,TRACKS
 4000   FORMAT(F10.6,F10.7,A4,A3,I1,I2)
        GO TO 100
 500    STOP
        END
```

FIGURE 5-8 ACCIDENT REDUCTION/COST RATIO PROGRAM

	P→FL	P→G	FL→G
COST	36700.	54700.	49200.
EFFECTIVENESS	.65	.84	.64
TOTAL BUDGET	1000000.		

FIGURE 5-9. SAMPLE INPUT TO THE ACCIDENT REDUCTION/COST RATIO PROGRAM

$$AR/C = A\ (E_2/C_2)$$

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 reduction/cost ratio is calculated for upgrading to flashing lights according to the equation:

$$AR/C = A\ (E_1/C_1)$$

The incremental accident reduction/cost ratio of installing a gate at the passive crossing,

$$AR/C = A\ (E_2 - E_1)/(C_2 - C_1),$$

is not calculated by the accident reduction/cost ratio program, but is calculated later by the resource allocation algorithm program. However in the case where E_2/C_2 is greater than E_1/C_1, the accident reduction/cost ratio program calculates a ratio given by:

$$AR/C = A\ (E_2/C_2)$$

for all passive crossings, regardless of the number of tracks. In this case, the installation of gates is always more cost-effective than installation of flashing lights. The resource allocation algorithm program does not calculate the incremental accident reduction/cost ratio in this case.

For convenience of storage, all accident reduction/cost ratios are multiplied by 10^6, i.e., they are expressed in accidents per million dollars. A variable dictionary for the accident reduction/cost ratio program is given in Table 5-5.

Sample output from the accident reduction/cost ratio program is shown in Figure 5-10. Field descriptions for this output are given in Table 5-6. This output must be sorted in descending order of accident reduction/cost ratio (the first 10 columns), and then used as input to the resource allocation program.

TABLE 5-5. VARIABLE DICTIONARY FOR THE ACCIDENT REDUCTION/COST RATIO PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINTION
A	Real	Predicted accidents per year
BENCOS	Real	Accident reduction/cost ratio in accidents per million dollars
C1	Real	Cost of upgrading from passive to flashing lights
C2	Real	Cost of upgrading from passive to gates
C3	Real	Cost of upgrading from flashing lights to gates
CLASS	Integer	Present warning device class
E1	Real	Effectiveness of upgrading from passive to flashing lights
E2	Real	Effectiveness of upgrading from passive to gates
E3	Real	Effectiveness of upgrading from flashing lights to gates
ID	Integer	Crossing identification number
MTRKS	Integer	Number of main tracks
OTRKS	Integer	Number of other tracks
R1	Real	Ratio of E1 and C1
R2	Real	Ratio of E2 and C2
R3	Real	Ratio of E3 and C3
TRACKS	Integer	Total number of tracks

INITIAL AR/C RATIO	PREDICTED ACCIDENTS	ID NUMBER	PRESENT CLASS	TOTAL TRACKS
9.765544	0.7507262	740854J	7	2
6.317363	0.4856473	740852V	7	3
6.145866	0.4725403	833473E	7	2
5.386533	0.4140897	740744Y	6	2
5.350283	0.4113030	740855R	7	2
4.766600	0.3664324	833475T	7	2
4.454577	0.3424456	804244G	7	1
4.281244	0.3291206	740856X	7	2
4.277769	0.3288535	833479V	7	2
4.013993	0.3085757	740857E	7	3
3.699002	0.2843606	833481W	7	3
3.053000	0.1723771	740901P	4	1
2.977793	0.1681308	740858L	4	1
2.729020	0.2097934	740842P	7	7
2.492476	0.1916091	740734T	7	2
2.456442	0.1888390	833476A	7	3
2.080327	0.1354689	740841H	4	3
1.813569	0.1023969	833425P	4	1
1.650067	0.0931653	740914R	4	1
1.605422	0.1234168	804193Y	7	3
1.435197	0.0810899	804238D	4	1
1.421897	0.0802825	740763D	4	1
1.415949	0.1088511	833592N	7	2
1.367659	0.1051368	833601K	7	1
1.349578	0.1037488	740853C	7	2
1.343644	0.0874968	740843W	4	6
1.290033	0.0840057	740736G	4	3
1.283571	0.0986745	740876J	7	2
1.181554	0.0769417	740787S	4	2
1.177633	0.0905305	833574R	7	1

FIGURE 5-10. SAMPLE OUTPUT FROM THE ACCIDENT REDUCTION/COST RATIO PROGRAM

TABLE 5-6. FIELD DESCRIPTIONS FOR THE OUTPUT FROM THE ACCIDENT REDUCTION/COST RATIO PROGRAM

FIELD	COLUMN	LENGTH	DATA TYPE*	FIELD DESCRIPTION
1	1	10	F	Accident reduction/cost ratio in accidents per million dollars
2	11	10	F	Predicted accidents per year
3	21	7	A	Crossing identification number
4	28	1	I	Present warning device class
5	29	2	I	Total number of tracks

* DATA TYPE:
I - integer
A - alphanumeric
F - fixed decimal

The resource allocation program (Figure 5-11) performs the algorithm described in Section 4, recommending the crossings to be improved and the warning device to be installed. A variable dictionary for the program is given in Table 5-7. The program reads each crossing in order, starting with the highest accident reduction/cost ratio.

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

$$AR/C = A\ (E_2 - E_1)/(C_2 - C_1).$$

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

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

```
C                 THIS PROGRAM RUNS THE RESORCE ALLOCATICN ALGORITHM
C                 AFTER THE INITIAL BENEFIT/COST RATIO HAS BEEN CALCULATED
C                 UNIT 20 - INITIAL BENEFIT/COST RATIO INPUT FILE SORTED
C                                IN DESCENDING ORDER OF BENEFIT/COST RATIO
C                 UNIT 21 - FINAL BENEFIT/COST RATIO OUTPUT FILE
C                 UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL INPUT FILE
C                 UNIT 23 - OUTPUT FILE FOR LOWEST COST/BENEFIT RATIO
C
      INTEGER ID(2),XID,CLASS,PC,TRACKS,TRKS
      REAL MAXAMT
      DIMENSION BCGATE(500),BC(500)
      COMMON /AA/ XID(2,500),PA(500),PC(500),TRKS(500)
      COMMON /BB/ MAX,E2,C2,C1,GATE,COST,MAXAMT,BCMIN
      DATA GATE/'GATE '/,LIGHT/'LIGHT'/
      MAX=1
      MIN=1
      COST=0.
      BCGATE(1)= -9999.
C                 READ IN COST AND EFFECTIVNESS DATA
      READ(22,10) C1,C2,C3
 10   FORMAT(3F10.0)
      READ(22,20) E1,E2,E3
 20   FORMAT(3F10.2)
C                 READ IN TOTAL BUDGET AMOUNT
      READ(22,30) MAXAMT
 30   FORMAT(F10.0)
      R1=E1/C1
      R2=E2/C2
C                 SELECT A CROSSING
 100  READ(20,101,END=400) BENCOS,A,ID,CLASS,TRACKS
 101  FORMAT(F10.6,F10.7,A4,A3,I1,I2)
      IF(CLASS.GT.4) GO TO 200
      IF(TRACKS.GT.1) GO TO 300
C                 IF GATES ARE ALWAYS MORE COST-EFFECTIVE THAN
C                 FLASHING LIGHTS, USE A GATES ONLY POLICY
      IF(R2.GT.R1) GO TO 300
C                 SINGLE TRACK PASSIVE CROSSINGS
      BCGATE(MIN)=A*(E2-E1)/(C2-C1)*10.**6
C                 CHECK THE TEMPORARY DECISION LIST
 110  IFLAG=0
      IF(BENCOS.LT.BCGATE(MAX)) CALL GATES(IFLAG)
      IF(IFLAG.EQ.1) GO TO 110
      IF(IFLAG.EQ.2) GO TO 400
C                 ADD THE SELECTED CROSSING TO THE BOTTOM OF THE
C                 TEMPORARY DECISION LIST
      BC(MIN)=BENCOS
      XID(1,MIN)=ID(1)
      XID(2,MIN)=ID(2)
      PA(MIN)=A
      PC(MIN)=CLASS
      TRKS(MIN)=TRACKS
      MIN=MIN+1
      BCMIN=BENCOS
```

FIGURE 5-11. RESOURCE ALLOCATION ALGORITHM PROGRAM

```
C             CHECK TO SEE IF THE BUDGET IS EXPENDED
      COST=COST+C1
      IF(COST.GE.MAXAMT) GO TO 400
      GO TO 100
C             FLASHING LIGHT CROSSINGS
C             CHECK THE TEMPORARY DECISION LIST
 200  IFLAG=0
      IF(BENCOS.LT.BCGATE(MAX)) CALL GATES(IFLAG)
      IF(IFLAG.EQ.1) GO TO 200
      IF(IFLAG.EQ.2) GO TO 400
      BENFIT=A*E3
C             RECOMMEND GATES AT SELECTED CROSSING
      WRITE(21,201) BENCOS,A,ID,CLASS,TRACKS,GATE,C3,BENFIT
 201  FORMAT(F8.4,F7.4,A4,A3,I1,I2,A5,F7.0,F7.4)
      BCMIN=BENCOS
C             CHECK TO SEE IF THE BUDGET IS EXPENDED
      COST=COST+C3
      IF(COST.GE.MAXAMT) GO TO 400
      GO TO 100
C             MULTIPLE TRACK PASSIVE CROSSINGS
C             CHECK THE TEMPORARY DECISION LIST
 300  IFLAG=0
      IF(BENCOS.LT.BCGATE(MAX)) CALL GATES(IFLAG)
      IF(IFLAG.EQ.1) GO TO 300
      IF(IFLAG.EQ.2) GO TO 400
      BENFIT=A*E2
C             RECOMMEND GATES AT SELECTED CROSSING
      WRITE(21,201) BENCOS,A,ID,CLASS,TRACKS,GATE,C2,BENFIT
      BCMIN=BENCOS
C             CHECK TO SEE IF THE BUDGET IS EXPENDED
      COST=COST+C2
      IF(COST.LT.MAXAMT) GO TO 100
C             BUDGET EXPENDED: RECOMMEND FLASHING LIGHTS AT THOSE
C             CROSSINGS STILL ON THE TEMPORARY DECISION LIST
 400  IF(MAX.GE.MIN) GO TO 500
      DO 410 K=MAX,MIN-1
      BENFIT=PA(K)*E1
 410  WRITE(21,201) BC(K),PA(K),XID(1,K),XID(2,K),PC(K),TRKS(K),LIGHT,
     *        C1,BENFIT
 500  WRITE(23,501) BCMIN
 501  FORMAT(F8.4)
      STOP
      END
```

FIGURE 5-11. RESOURCE ALLOCATION ALGORITHM PROGRAM (cont'd)

```
      SUBROUTINE GATES(IFLAG)
C               THIS SUBROUTINE RECOMMENDS GATES AT SINGLE TRACK
C               PASSIVE CROSSINGS
      INTEGER XID,PC,TRKS
      REAL MAXAMT
      COMMON /AA/ XID(2,500),PA(500),PC(500),TRKS(500)
      COMMON /BB/ MAX,E2,C2,C1,GATE,COST,MAXAMT,BCMIN
C               TURN ON FLAG TO INDICATE SUBROUTINE GATES HAS
C               BEEN CALLED
      IFLAG=1
      BENFIT=PA(MAX)*E2
      BENCOS=BENFIT/C2*10.**6
C               FINALIZE THE RECOMMENDATION OF GATES AND REMOVE
C               CROSSING FROM THE TEMPORARY DECISION LIST
      WRITE(21,201) BENCOS,PA(MAX),XID(1,MAX),XID(2,MAX),PC(MAX),
     *          TRKS(MAX),GATE,C2,BENFIT
  201 FORMAT(F8.4,F7.4,A4,A3,I1,I2,A5,F7.0,F7.4)
      MAX=MAX+1
      BCMIN=BENCOS
C               CHECK TO SEE IF THE BUDGET IS EXPENDED
      COST=COST+C2-C1
      IF(COST.GE.MAXAMT) IFLAG=2
      RETURN
      END
```

FIGURE 5-11. RESOURCE ALLOCATION ALGORITHM PROGRAM (cont'd)

TABLE 5-7. VARIABLE DICTIONARY FOR THE RESOURCE ALLOCATION PROGRAM

VARIABLE NAME	VARIABLE TYPE	DEFINITION
A	Real	Predicted accidents
BC	Real	Accident reduction/cost ratio stored for passive crosssings with single track
BCGATE	Real	Incremental accident reduction/cost ratio stored for passive crossings with single track
BCMIN	Real	Minimum accident reduction/cost ratio for the run
BENCOS	Real	Accident reduction/cost ratio
BENFIT	Real	Accidents prevented
C1	Real	Cost of upgrading a passive crossing to flashing lights
C2	Real	Cost of upgrading a passive crossing to gates
C3	Real	Cost of upgrading a flashing-lights crossing to gates
CLASS	Integer	Present warning device class
COST	Real	Cumulative cost of upgrades
E1	Real	Effectiveness of upgrading a passive crossing to flashing lights
E2	Real	Effectiveness of upgrading a passive crossing to gates
E3	Real	Effectiveness of upgrading a flashing-lights crossing to gates
GATE	Character	The word "GATE"
ID	Character	Crossing identification number
IFLAG	Integer	Flag to tell if subroutine GATES has been called 0 - no, 1 - yes, 2 - yes, money ran out
K	Integer	Do loop index
LIGHT	Character	The word "LIGHT"
MAX	Integer	Index of the largest accident reduction/cost ratio being stored in BCGATE
MAXAMT	Real	Total amount of money available
MIN	Integer	Index of the smallest accident reduction/cost ratio being stored in BCGATE
PA	Character	Predicted accidents stored for passive crossing with single track
PC	Integer	Present warning device class stored for passive crossings with single track
TRACKS	Integer	Total number of tracks
TRKS	Integer	Total number of tracks stored for passive crossings with single track
XID	Character	Crossing identification number stored for passive crossings with single track

Sample output from the resource allocation algorithm program is shown in Figure 5-12. This output is then sorted in descending order of accident reduction/cost ratio (columns 1-8) for input into the resource allocation report program.

The resource allocation report program (Figure 5-13) calculates the decision criteria and generates the output in a report format. The decision criteria, DC_1, DC_2, DC_3 and DC_4, are calculated from equations 4-4, 4-5, 4-6 and 4-7, respectively, described in Section 4.2.5. If the crossing being considered is passive, single-track, the program calculates DC_1 and DC_2. If the crossing is passive, multiple-track, DC_3 is calculated. If the crossing has flashing lights, DC_4 is calculated. Sample output from the resource allocation model is shown in Figure 5-14.

AR/C RATIO	PREDICTED ACCIDENTS	ID NUMBER	PRESENT CLASS	TOTAL TRACKS	RECOMMENDED DEVICE	COST	ACCIDENT REDUCTION
9.7655	0.7507	740854J	7	2	GATE	49200.	0.4805
6.3174	0.4856	740852V	7	3	GATE	49200.	0.3108
6.1469	0.4725	833473E	7	2	GATE	49200.	0.3024
5.3865	0.4141	740744Y	6	2	GATE	49200.	0.2650
5.3503	0.4113	740855R	7	2	GATE	49200.	0.2632
4.7666	0.3664	833475T	7	2	GATE	49200.	0.2345
4.4546	0.3424	804244G	7	1	GATE	49200.	0.2192
4.2812	0.3291	740856X	7	2	GATE	49200.	0.2106
4.2778	0.3289	833479V	7	2	GATE	49200.	0.2105
4.0140	0.3086	740857E	7	3	GATE	49200.	0.1975
3.6990	0.2844	833481W	7	3	GATE	49200.	0.1820
2.7290	0.2098	740842P	7	7	GATE	49200.	0.1343
2.6471	0.1724	740901P	4	1	GATE	54700.	0.1448
2.5819	0.1681	740858L	4	1	GATE	54700.	0.1412
2.4925	0.1916	740734T	7	2	GATE	49200.	0.1226
2.4564	0.1888	833476A	7	3	GATE	49200.	0.1209
2.0803	0.1355	740841H	4	3	GATE	54700.	0.1138
1.8136	0.1024	833425P	4	1	LIGHT	36700.	0.0666
1.6501	0.0932	740914R	4	1	LIGHT	36700.	0.0606
1.6054	0.1234	804193Y	7	3	GATE	49200.	0.0790
1.4362	0.0811	804238D	4	1	LIGHT	36700.	0.0527

FIGURE 5-12. SAMPLE OUTPUT FROM THE RESOURCE ALLOCATION PROGRAM

```
C               THIS PROGRAM COMPUTES THE DECISION CRITERIA AND PRINTS
C               THE OUTPUT OF THE RESOURCE ALLOCATION ALGORITHM IN A
C               REPORT FORMAT
C               UNIT 20 - FINAL BENEFIT/COST RATIO INPUT FILE SORTED
C                         IN DESCENDING ORDER OF BENEFIT/COST RATIO
C               UNIT 21 - REPORT OUTPUT FILE
C               UNIT 22 - COST/EFFECTIVENESS/BUDGET LEVEL INPUT FILE
C               UNIT 23 - INPUT FILE FOR LOWEST COST/BENEFIT RATIO
C               UNIT  5 - INTERACTIVE INPUT FILE FOR RUN TITLE
C
      INTEGER ID(2),CLASS,TRACKS,WARN,TITLE(3),C1,C2,C3,DEVICE(2,7),
     *        DAY(2),PAGE
      DATA DEVICE/'NONE ','     ',
     *            'OTHER',' SIGN',
     *            'STOP ','SIGN ',
     *            'CROSS','BUCK ',
     *            'SPECI','AL   ',
     *            'HWY S','GNL  ',
     *            'LIGHT','     '/
      TCOST=0
      TBEN=0.
      WRITE(5,10)
 10   FORMAT(' ENTER TITLE OF RUN:')
      READ(5,20) TITLE
 20   FORMAT(3A5)
      READ(22,30) C1,C2,C3
 30   FORMAT(3(I9,1X))
      READ(22,40) E1,E2,E3
 40   FORMAT(3F10.2)
      READ(22,50) MAXAMT
 50   FORMAT(I9)
      READ(23,60) BCMIN
 60   FORMAT(F8.4)
      R1=E1/C1
      R2=(E2-E1)/(C2-C1)
      R3=E2/C2
      R4=E3/C3
      CALL DATE(DAY)
      PAGE=1
 100  WRITE(21,101) DAY,TITLE,MAXAMT,C1,C2,C3,E1,E2,E3
 101  FORMAT('1',T8,2A5,T44,
     *        'RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS',
     *        T120,'PAGE  1'/T45,'FOR ',3A5,'  TOTAL BUDGET:  $',I9/
     *        T47,'WARNING DEVICE     P--FL     P--G     FL--G'/
     *        '+',T67,'>',T76,'>',T86,'>'/T49,'COST:',
     *        7X,3(2X,'$',I6)/T49,'EFFECTIVENESS:  '3(F3.2,6X)/)
      LINE=7
      GO TO 110
 105  PAGE=PAGE+1
      WRITE(21,106) DAY,PAGE
 106  FORMAT('1',T8,2A5,T120,'PAGE',I3/)
      LINE=3
```

FIGURE 5-13. RESOURCE ALLOCATION REPORT PROGRAM

```
110     WRITE(21,111)
111     FORMAT(T31,'BENEFIT/',T90,'CUMULATIVE'/T8,'CROSSING  ',
   *          'PREDICTED   COST RATIO    RECOMMENDED   PRESENT    ',
   *          'TOTAL   CUMULATIVE    BENEFIT   DECISION ',
   *          'CRITERIA VALUES'/T10,'ID      ACCIDENTS  ',
   *          '(REDUCED ACC/    WARNING     WARNING      OF         ',
   *          'COST        (REDUCED'/T18,'(ACC/YR)     $ MILLION)',
   *          '       DEVICE       DEVICE      TRACKS  ($ THOUSAND)    ',
   *          'ACC/YR)     DC1     DC2     DC3     DC4'/T8,'--------  ',
   *          '---------  ----------        -------      -------    ',
   *          '------  ----------    --------     ---     ---      ',
   *          '---    ---'/)
        LINE=LINE+6
200     READ(20,201,END=999) BENCOS,A,ID,CLASS,TRACKS,WARN,COST,BEN
201     FORMAT(F8.4,F7.4,A4,A3,I1,I2,A5,F7.0,F7.4)
        TCOST=TCOST+COST
        TBEN=TBEN+BEN
        KCOST=TCOST/1000. +0.5
        IF(CLASS.GT.4) GO TO 230
        IF(TRACKS.GT.1) GO TO 220
        IF(R2.GT.R1) GO TO 220
        DC1=BCMIN/(A*R1*10**6)
        DC2=BCMIN/(A*R2*10**6)
        WRITE(21,205) ID,A,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
   *          KCOST,TBEN,DC1,DC2
205     FORMAT(T8,A4,A3,T20,F5.2,T32,F5.2,T47,A5,T57,2A5,
   *          T70,I2,T79,I5,T92,F5.1,T100,2F7.3)
        GO TO 250
220     DC3=BCMIN/(A*R3*10**6)
        WRITE(21,211) ID,A,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
   *          KCOST,TBEN,DC3
211     FORMAT(T8,A4,A3,T20,F5.2,T32,F5.2,T47,A5,T57,2A5,
   *          T70,I2,T79,I5,T92,F5.1,T114,F7.3)
        GO TO 250
230     DC4=BCMIN/(A*R4*10**6)
        WRITE(21,221) ID,A,BENCOS,WARN,(DEVICE(J,CLASS),J=1,2),TRACKS,
   *          KCOST,TBEN,DC4
221     FORMAT(T8,A4,A3,T20,F5.2,T32,F5.2,T47,A5,T57,2A5,
   *          T70,I2,T79,I5,T92,F5.1,T121,F7.3)
250     LINE=LINE+1
        IF(LINE.GT.60) GO TO 105
        GO TO 200
999     STOP
        END
```

FIGURE 5-13. RESOURCE ALLOCATION REPORT PROGRAM (cont'd)

2-OCT-81 RAIL-HIGHWAY CROSSING RESOURCE ALLOCATION RESULTS PAGE 1

TOTAL BUDGET: $ 1000000

WARNING DEVICE	P->FL	P->G	FL->G
COST:	$ 36700	$ 54700	$ 49200
EFFECTIVENESS:	.65	.84	.64

CROSSING ID #	PREDICTED ACCIDENTS (ACC/YR)	ACC REDUCTION/ COST RATIO (REDUCED ACC/ $ MILLION)	RECOMMENDED WARNING DEVICE	PRESENT WARNING DEVICE	TOTAL # OF TRACKS	CUMULATIVE COST ($ THOUSAND)	CUMULATIVE ACC REDUCTION (REDUCED ACC/YR)	DECISION CRITERIA VALUES DC1	DC2	DC3	DC4
740854J	0.75	9.77	GATE	LIGHT	2	49	0.5				0.147
740852V	0.49	6.32	GATE	LIGHT	3	98	0.8				0.227
833473E	0.47	6.15	GATE	LIGHT	2	148	1.1				0.234
740744Y	0.41	5.39	GATE	HWY SGNL	2	197	1.4				0.267
740855R	0.41	5.35	GATE	LIGHT	2	246	1.6				0.268
833475T	0.37	4.77	GATE	LIGHT	2	295	1.9				0.301
804244G	0.34	4.45	GATE	LIGHT	1	344	2.1				0.322
740856X	0.33	4.28	GATE	LIGHT	2	394	2.3				0.335
833479V	0.33	4.28	GATE	LIGHT	2	443	2.5				0.336
740857E	0.31	4.01	GATE	LIGHT	3	492	2.7				0.358
833481W	0.28	3.70	GATE	LIGHT	3	541	2.9				0.388
740842P	0.21	2.73	GATE	LIGHT	7	590	3.0				0.526
740901P	0.17	2.65	GATE	CROSSBUCK	1	645	3.2	0.470	0.789		
740858L	0.17	2.58	GATE	CROSSBUCK	1	700	3.3	0.482	0.809		
740734T	0.19	2.49	GATE	LIGHT	2	749	3.4				0.576
833476A	0.19	2.46	GATE	LIGHT	3	798	3.5				0.585
740841H	0.14	2.08	GATE	CROSSBUCK	3	653	3.7			0.690	
833425P	0.10	1.81	LIGHT	CROSSBUCK	1	890	3.7	0.792	1.329		
740914R	0.09	1.65	LIGHT	CROSSBUCK	1	926	3.8	0.870	1.460		
804193Y	0.12	1.61	GATE	LIGHT	3	976	3.9				0.855
804238D	0.08	1.44	LIGHT	CROSSBUCK	1	1012	3.9	1.003	1.678		

FIGURE 5-14. SAMPLE OUTPUT FROM THE RESOURCE ALLOCATION REPORT PROGRAM

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