3. DOT ACCIDENT AND CASUALTY PREDICTION FORMULA

3.1 INTRODUCTION

Many crossing hazard formulas have been developed in the past and used extensively by those concerned with rail-highway crossing safety[4]. Examples are the New Hampshire Formula, the Peabody-Dimmick Formula, the Mississippi Formula, and the Ohio Method. Availability of the Inventory and national accident data by crossing were major considerations which influenced development of the DOT accident and severity prediction formula. The Inventory contains information on the physical and operating characteristics of all rail-highway crossings in the United States and, thus, affords an improved basis for rail-highway crossing accident and severity prediction.

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

Both relative and absolute formulas can be used to provide rankings of crossings on the basis of their relative hazards. A comparison of the DOT formulas with several well-known formulas[5,17] shows the DOT formulas to have significantly improved performance in this regard.

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

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

3.2 DESCRIPTION OF FORMULAS FOR ACCIDENT PREDICTION

3.2.1 Overview

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

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

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

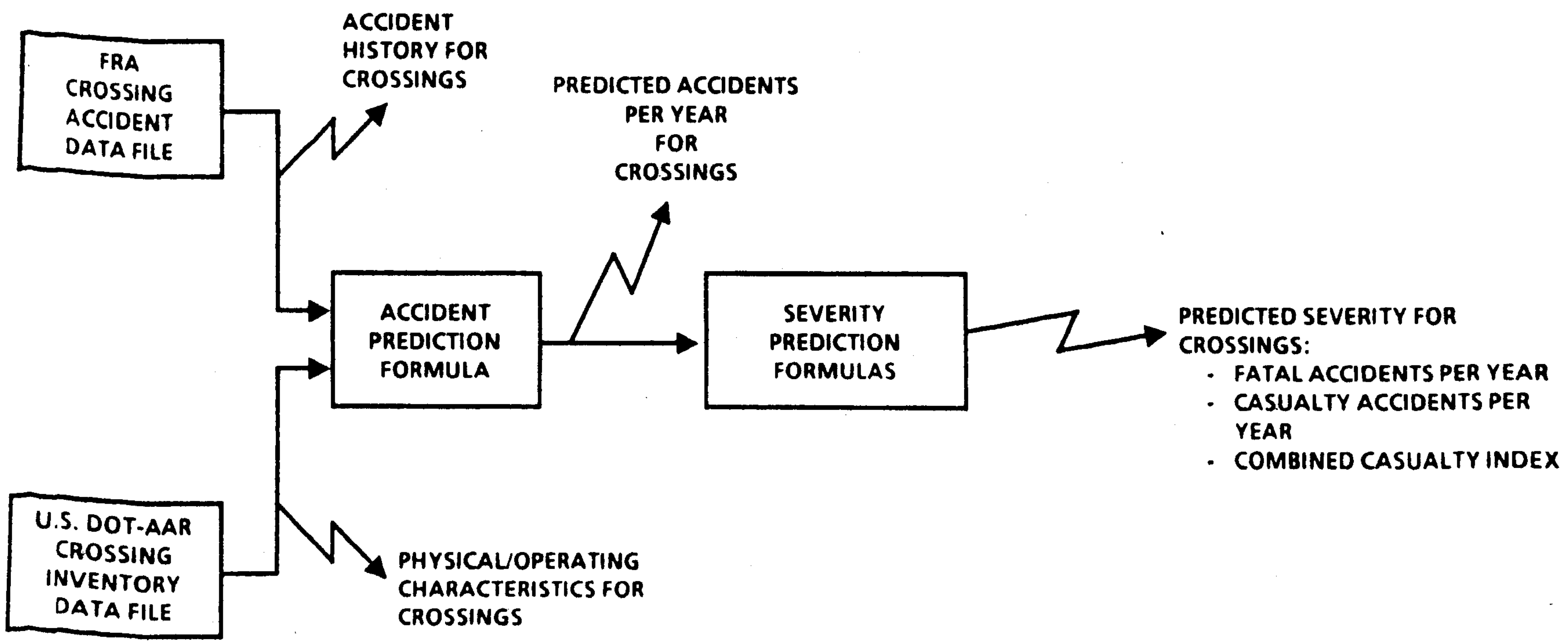

FIGURE 3-1. DOT RAIL-HIGHWAY CROSSING ACCIDENT AND SEVERITY PREDICTION FORMULAS

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

3.2.2 Basic Formula

The unnormalized initial prediction of a crossing's accidents (a) is determined from the basic accident prediction formula given in equation (1) below. The basic formula produces a prediction on the basis of a crossing's characteristics as described in the Inventory. The technique used for developing the basic formula involved applying nonlinear multiple regression techniques to crossing characteristics stored in the Inventory and to accident data contained in the FRA Railroad Accident/Incident Reporting System (RAIRS). The 1981 through 1985 accident file and the April 1986 Inventory were used to develop the formula.

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

$$a = K \times EI \times DT \times MS \times MT \times HP \times HL \tag{1}$$

where:

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

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

1. Passive, including the following warning device classes:

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

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

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

3. Gates, including the following warning device class:

   Class 8 - Automatic gates with flashing lights

The crossing characteristic factors for the three warning device categories are shown in Table 3-1. Each set of factor equations should be used only for crossings with the warning device classes for which it was designed. For example, if it is desired to estimate the unnormalized number of accidents at a crossing with crossbucks, then the passive set of equations should be used. If it is desired to estimate the unnormalized number of accidents at a crossing recently upgraded from one warning device category to another, use the formulas for the prior category and apply the effectiveness factor for the upgrade. See Section 5.1.2 for a more detailed discussion.

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

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

TABLE 3-1. EQUATIONS FOR CROSSING CHARACTERISTIC FACTORS

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

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

c = number of highway vehicles per day

t = number of trains per day

mt = number of main tracks

d = number of through trains per day during daylight

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

ms = maximum timetable speed, mph

hl = number of highway lanes

are found in the table and multiplied together. The factor values for the three warning device categories (passive, flashing lights and gates) are found in Tables 3-2, 3-3 and 3-4, respectively. Detailed procedures for use of the tables and computer automation of the accident prediction formula are presented in Section 5.1.

An inspection of the factor value tables shows that exposure index (EI), based on the product of annual average daily highway traffic (c) and average daily train traffic (t), has the strongest relationship to predicted accidents. All other factors can be seen as having a weaker relationship to predicted accidents.

3.2.3 Accident History

The second independent prediction of a crossing's accident rate is derived from the crossing's accident history. This information is obtained from the FRA RAIRS file which contains records of all accidents that occurred at crossings. The required measure of accident history is the ratio N/T, where N is the number of accidents which occurred at a crossing over a period of T years.

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

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

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

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

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

*Less than one train per day.

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

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

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0003351	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	3.12	1	1.22	5	1.00	1	1.21			2	1.20
	6 - 10	4.59	2	1.31	10	1.00	2	1.47	2 (no)	1.00	3	1.44
	11 - 20	5.92	3	1.37	15	1.00	3	1.78			4	1.72
	21 - 30	7.28	4	1.41	20	1.00	4	2.15			5	2.08
	31 - 50	8.82	5	1.45	25	1.00	5	2.61			6	2.49
	51 - 80	10.76	6	1.47	30	1.00	6	3.16			7	2.99
	81 - 120	12.54	7	1.50	35	1.00					8	3.59
	121 - 200	15.57	8	1.52	40	1.00					9	4.31
	201 - 300	18.70	9	1.54	45	1.00						
	301 - 400	21.46	10	1.56	50	1.00						
	401 - 500	23.79	11-20	1.63	55	1.00						
	501 - 600	25.84	21-30	1.73	60	1.00						
	601 - 700	27.67	31-40	1.79	65	1.00						
	701 - 1000	30.89	41-60	1.87	70	1.00						
	1001 - 1300	34.97			75	1.00						
	1301 - 1600	38.47			80	1.00						
	1601 - 2000	42.04			85	1.00						
	2001 - 2500	46.07			90	1.00						
	2501 - 3000	50.03										
	3001 - 4000	55.23										
	4001 - 6000	63.94										
	6001 - 8000	73.42										
	8001 - 10000	81.40										
	10001 - 15000	93.15										
	15001 - 20000	106.95										
	20001 - 25000	118.58										
	25001 - 30000	128.76										
	30001 - 40000	142.17										
	40001 - 50000	157.62										
	50001 - 60000	171.16										
	60001 - 70000	183.31										
	70001 - 90000	199.62										
	90001 - 110000	218.78										
	110001 - 130000	235.78										
	130001 - 180000	261.91										
	180001 - 230000	293.77										
	230001 - 300000	326.42										
	300001 - 370000	359.40										

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

*Less than one train per day.

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

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

K	"c" x "t"	EI	Day Through Trains	DT	Maximum Timetable Speed	MS	Main Tracks	MT	Highway Paved	HP	Highway Lanes	HL
0.0005745	0*-	1.00	0	1.00	0	1.00	0	1.00	1 (yes)	1.00	1	1.00
	1 - 5	2.26	1	1.38	5	1.00	1	1.16			2	1.15
	6 - 10	2.98	2	1.53	10	1.00	2	1.35	2 (no)	1.00	3	1.32
	11 - 20	3.57	3	1.64	15	1.00	3	1.57			4	1.53
	21 - 30	4.15	4	1.72	20	1.00	4	1.83			5	1.76
	31 - 50	4.76	5	1.79	25	1.00	5	2.13			6	2.03
	51 - 80	5.99	6	1.84	30	1.00	6	2.48			7	2.34
	81 - 120	6.23	7	1.89	35	1.00					8	2.70
	121 - 200	7.15	8	1.94	40	1.00					9	3.11
	201 - 300	8.15	9	1.98	45	1.00						
	301 - 400	9.00	10	2.01	50	1.00						
	401 - 500	9.69	11-20	2.16	55	1.00						
	501 - 600	10.28	21-30	2.37	60	1.00						
	601 - 700	10.79	31-40	2.51	65	1.00						
	701 - 1000	11.68	41-60	2.68	70	1.00						
	1001 - 1300	12.77			75	1.00						
	1301 - 1600	13.67			80	1.00						
	1601 - 2000	14.57			85	1.00						
	2001 - 2500	15.55			90	1.00						
	2501 - 3000	16.20										
	3001 - 4000	17.71										
	4001 - 6000	19.67										
	6001 - 8000	21.72										
	8001 - 10000	23.39										
	10001 - 15000	25.76										
	15001 - 20000	28.44										
	20001 - 25000	30.67										
	25001 - 30000	32.49										
	30001 - 40000	34.87										
	40001 - 50000	37.55										
	50001 - 60000	39.83										
	60001 - 70000	41.84										
	70001 - 90000	44.48										
	90001 - 110000	47.49										
	110001 - 130000	50.11										
	130001 - 180000	54.03										
	180001 - 230000	58.24										
	230001 - 300000	63.26										
	300001 - 370000	67.78										

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

*Less than one train per day.

3.2.4 General Accident Prediction Formula

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

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

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

where:

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

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

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

T_o = formula weighting factor = 1.0 / (0.05 + a).

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

TABLE 3-5. VALUES OF B, GIVEN THE INITIAL PREDICTION AND ACCIDENT HISTORY, 1 YEAR OF ACCIDENT DATA (T=1)

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

TABLE 3-6. VALUES OF B, GIVEN THE INITIAL PREDICTION AND ACCIDENT HISTORY, 2 YEARS OF ACCIDENT DATA (T=2)

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

TABLE 3-7. VALUES OF B, GIVEN THE INITIAL PREDICTION AND ACCIDENT HISTORY, 3 YEARS OF ACCIDENT DATA (T=3)

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

TABLE 3-8. VALUES OF B, GIVEN THE INITIAL PREDICTION AND ACCIDENT HISTORY, 4 YEARS OF ACCIDENT DATA (T=4)

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

TABLE 3-9. VALUES OF B, GIVEN THE INITIAL PREDICTION AND ACCIDENT HISTORY, 5 YEARS OF ACCIDENT DATA (T=5)

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

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

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

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

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

2. If a = N/T, then the final prediction (A) will equal a normalizing constant times (a) or N/T.

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

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

3.3 DESCRIPTION OF FORMULAS FOR ACCIDENT SEVERITY PREDICTION

3.3.1 Overview

The effort to develop accident severity prediction formulas was motiviated by the recognition that rail-highway crossing accidents are not equally severe. In recent years about 67 percent of crossing accidents resulted in no casualties while all fatalities resulted from only 6.6 percent of all accidents. Clearly, crossings that exhibit a tendency toward more severe accidents, should be given priority for safety improvements. A formula which can help in identifying these crossings will improve the safety benefits obtained from crossing improvements. The severity prediction formulas described here represent the results of an effort to achieve that objective[6].

Two casualty prediction formulas have been developed; a fatal accident prediction formula and a casualty accident prediction formula. When used with the accident prediction formulas, described in Section 3.2, these two formulas provide two measures of accident severity; predicted fatal accidents and predicted casualty accidents. A fatal accident is defined as an accident which results in at least one fatality independent of injuries or property damage. A casualty accident is an accident which results in at least one fatality or at least one injury independent of property damage.

The severity prediction formulas are designed to be used with the general accident prediction formula (2) to produce the estimates of fatal and casualty accidents per year at crossings. The severity prediction formulas used without the accident prediction formula produce estimates of the probability of a fatal or casualty accident given that an accident occurred. For example, the fatal accident prediction formula estimates the probability of a fatal accident given that an accident occurred at a crossing; i.e., fatal accidents per accident. When this estimate is multiplied by the crossing's estimated accidents from the accident prediction formula (2) the result is predicted fatal accidents per year at the crossing. As an example, if a crossing has a predicted accident rate of 0.5 accidents per year and a predicted fatal accident probability of 0.2 fatal accidents per accident, the result will be a predicted fatal accident rate of .2 x .5 or 0.1 fatal accidents per year.

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

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

3.3.2 Fatality and Casualty Prediction Formulas

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

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

where:

where:	P(FA|A)	=	probability of a fatal accident, given an accident
	KF	=	formula constant (440.9)
	MS	=	factor for maximum timetable train speed
	TT	=	factor for thru trains per day
	TS	=	factor for switch trains per day
	UR	=	factor for urban or rural crossing

The probability of a casualty accident, given an accident, is expressed as:

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

where: $P(CA|A)$ = probability of a casualty accident, given an accident

KC = formula constant (4.481)

MS = factor for maximum timetable train speed

TK = factor for number of tracks

UR = factor for urban or rural crossing

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

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

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

where: FA = predicted fatal accidents per year

$P(FA|A)$ = predicted fatal accident probability from equation (3)

A = predicted accidents per year from equation (2)

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

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

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

where:

ms = maximum timetable train speed, mph

tt = number of thru trains per day

ts = number of switch trains per day

ur: urban crossing = 1, rural crossing = 0

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

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

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

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

where:

ms = maximum timetable train speed, mph

tk = total number of tracks at crossing

ur: urban crossing = 1, rural crossing = 0

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

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

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

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

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

CASUALTY ACCIDENT PROBABILITY FORMULA: $P(CA|A) = 1/(1 + KC \times MS \times TK \times UR)$

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

The formula for predicted casualty accidents at a crossing is:

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

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

To illustrate characteristics of the fatal and casualty accident probability formulas, the two functions P(FA|A) and P(CA|A) are plotted as a function of maximum timetable train speed in Figure 3-2. The figure contains five individual plots which show how the functions change when one of the other four factors which influence accident severity (thru trains, switch trains, tracks and urban-rural location) is varied. The values of the factors are shown on the individual plots.

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

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

3.3.3 Combined Casualty Index Formula

The severity of crossing accidents is basically determined by two factors: injuries and fatalities. On a casualty severity scale those accidents of lower severity will tend to have more injuries while those of higher severity will tend to have more fatalities. The frequency distribution of accident severity tends to be the opposite; i.e., injury accidents

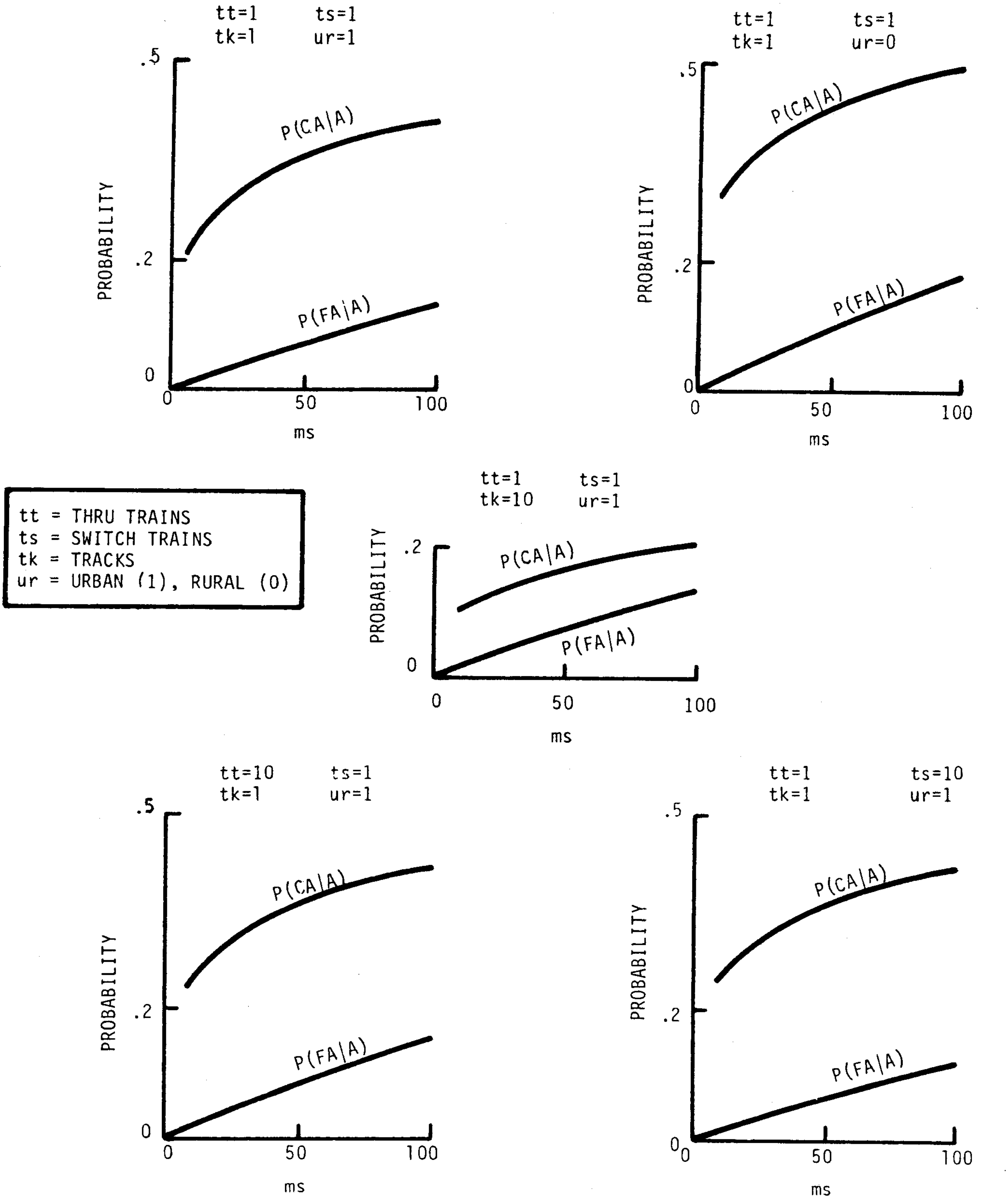

FIGURE 3-2. TYPICAL PLOTS OF PROBABILITY OF FATAL ACCIDENTS P(FA|A) AND PROBABILITY OF CASUALTY ACCIDENTS P(CA|A) AS A FUNCTION OF TIMETABLE TRAIN SPEED ms.

tend to be more frequent than fatal accidents. Thus, a comprehensive indicator of total accident casualty impacts should take into account both the number and nature (i.e., injuries versus fatalities) of accident casualties. Using this approach, a crossing that has, for example, many injury accidents can be considered on the same scale as one with few fatal accidents. The combined casualty index (CCI) formula was developed to achieve this objective.

The CCI formula is a weighted sum of the predicted fatal accidents per year (FA) and the predicted injury accidents per year (IA). It is expressed as:

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

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

The user of the CCI formula must specify a value for the constant k. This value indicates the relative impact of fatal versus injury accidents. The user is best qualified to determine the basis upon which an appropriate value of k is to be selected. A number of studies have been performed that are relevant to this topic[15,16]. Based on results of accident costs[16] a value of 50 for k may be reasonable for users who are unsure as to which value to use.

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

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