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Rail-Highway Crossing Accident Prediction Analysis

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Approved for Distribution

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PREFACE

The Department of Transportation's (DOT) rail-highway crossing accident prediction formula and resource allocation procedure were developed at the Transportation Systems Center (TSC) under the sponsorship of the Federal Railroad Administration's (FRA) Office of Safety and the Federal Highway Administration's (FHWA) Office of Research.

When used together, these formulas and procedures provide a systematic means of making preliminary decisions on the allocation of funds among individual crossings as well as the available improvement options. These procedures provide a ranked listing of crossings which can then be used as a guide for selecting crossings for on-site visits by diagnostic teams.

This report presents technical results of a study sponsored by the FRA's Office of Safety Analysis. Section 2 was primarily written by Edwin H. Farr of TSC. Section 3 was primarily written by Peter H. Mengert of TSC. Section 4 was primarily written by Randhir Chhatwal of Bedford Research Inc. under contract to TSC.

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1. INTRODUCTION

This report contains technical results that have been produced in a study to revise and update the DOT rail-highway crossing resource allocation procedure. This work has resulted in new accident prediction and severity formulas, a modified and extended resource allocation model, and more flexible and more complete software. The new accident and severity prediction formulas are based on recent inventory and recent accident experience. This report complements two other reports which have been produced from the study and which are due to be published in 1987[1,2].

Most of the results presented here are of a specialized nature. They are either too technical or too detailed to be included in the other two reports, which are intended for a wider audience. However, these results are important and may be useful to rail-highway crossing analysts, both inside the Government and outside. The report is presented with the following objectives:

1. To assure technical accuracy and soundness;
2. To provide a general sketch of the technique used;
3. To provide only the most significants results; and
4. To encourage individuals interested in more detail to contact the authors.

The techniques used in developing the formulas and the associated results are presented in Section 2. Some theoretical considerations are presented in Section 3. Software results of the project, including user-operating instructions for the "user-friendly" resource allocation procedure, are presented in Section 4. It is expected that the material in Section 4 may be useful only to programming specialists.

2. FORMULA DEVELOPMENT PROCEDURE

To recalibrate and revise the accident and severity prediction formulas the PLR and PAR regression procedures available in the BMDP software system were used. These employ the maximum likelihood and least squares criteria, respectively, and both methods are accessed from SAS using the National Institute of Health (NIH) computer. In addition to the standard statistical results from BMDP, power factors and prediction factors were used to select the "best" formula.

Power factors and prediction factors are a way of measuring the accident prediction capability of a given formula. To do these calculations a set of crossings must be specified along with the accident experience for these crossings for a given period of time. Next, the accident prediction for each crossing is calculated and the crossings ranked by accident predictions. Then select the X percent of the crossings with the highest accident prediction and let Y denote the percent of accidents which occur within this selected set and Z denote the percent of total sum of predicted accidents represented by this selected set of crossings. The X percent power factor is Y/X and the X percent prediction factor is Y/Z. Power factor expresses the ability of a formula to determine relative accident rate. It expresses the formula's ability to answer the question: Is crossing A more hazardous than crossing B, for all pairs A and B? Prediction factor expresses the ability of a formula to determine absolute accident rate. It expresses the formula's ability to answer the question: How much more hazardous is crossing A than crossing B? By expressing these factors as a percentage, formulas can be compared using different sets of crossings (also a different number of crossings in a set) and accident data for different time periods. High power factors are desired as well as prediction factors near 1.0. In judging the capability of formulas in this analysis, values for X = 0.5, 1.0, 2.0, 3.0, 5.0, 10.0, 15.0, 20.0 are used.

The April 1986 inventory and the accidents for the years 1981 through 1985 were used for this analysis. There are 197,538 crossings in this inventory. This inventory was divided randomly into three equal independent sets labelled A, B, and C. To derive the basic formulas, coefficients were determined using set A and the BMDP statistical programs while power factors and prediction

factors were calculated with set B. Determination of the final normalization coefficients was done with set C. The total number of accidents for the five years is used both for the dependent variable for the statistical programs and for the accident data for calculating power factors and prediction factors.

A total of 117 different computer runs were made for the entire study in deriving the formulas. This consisted of calculations using the statistical programs to determine coefficients; calculations for power factors and prediction factors; and calculations for determining normalizataion constants. It also consisted of calculations for determining the basic formulas for the accident history coefficients, and the severity prediction formulas. Due to the large amount of computer output obtained it will be practical to list only a small portion of it here. This portion, however, will be enough to demonstrate the procedure and to quantitatively measure the capability of the formulas chosen. All of the results will be retained by the authors for future reference if needed.

2.1 DEVELOPMENT OF BASIC FORMULAS

Three basic formulas were developed: one for crossings with warning device class 4 (crossbucks); one for crossings with warning device class 7 (flashing lights); and one for crossings with warning device class 8 (gates). The symbols used in this section are defined in Appendix A.

2.1.1 Crossbuck (Class 4) Basic Formula

The following six formulas were derived and tested with power factors and prediction factors. Note that $a = e^h$ and x stands for multiplication.

Formula 1

$$h = 0.37 \times \log(cxt+.2) + .0077 \times ms + .1780 \times \log(d+.2) - .5966 \times hp - 5.7947$$

Formula 2

$$a = .002268 \left(\frac{cxt+.2}{.2}\right)^{.3334} e^{.2094mt} \left(\frac{d+.2}{.2}\right)^{.1336} e^{-.6160(hp-1)} e^{.0077ms} e^{-.1000(ht-1)}$$

Formula 3

h = .2484 x log (cxt+.2) + .1216 x mt + .0079 x ms - .1501 x ht

+.1569 x log (d+.2) -.7937 x hp -3.8939

Formula 4

h = .3596 x log (cxt+.2) + .0076 x ms - .5949 x ht + .1905 x log (d+.2)

- .5920 x hp - 5.4242

Formula 5

h = .2368 x log (cxt+.2) + .1898 x ht +.0087 x ms - .1281 x ht

+ .1875 x log (d+.2) - .7630 x hp -4.2600

Formula 6

h = .3401 x log (cxt+.2) - 5.9122

The power factors (PW) and prediction factors (PD) for these formulas are shown in Table 2-1. Formula 1 is selected to be the new basic formula for passive crossings (Class 1,2,3,4). When written in the form preferred for practical use, it becomes:

$$a = .0006938 \left(\frac{cxt+.2}{.2}\right)^{.37} \left(\frac{d+.2}{.2}\right)^{.178} e^{.0077MS} e^{-.5966(hp-1)} \tag{1}$$

Formula 2 is called the "old formula" because it is the old basic formula. The coefficients were determined using 1976 data. Formula 3 is called the "old specification." It contains the same variables as the old formula but the coefficients were determined by the data in this analysis (1986 data). Formulas 4 and 5 represent an attempt to find better formulas. Formula 6 shows the best formula that contains only exposure as the independent variable.

It is seen that the old formula (Formula 2) is quite good and is nearly as good as the new formula (Formula 1). However, the simplicity of the new formula tips the scales in its favor. It is surprising that the old specification (Formula 3) is not as good as the old formula (Formula 2).

TABLE 2-1.   POWER FACTORS AND PREDICTION FORMULAS FOR CROSSBUCKS

Percent of Crossings	Formula 1		Formula 2		Formula 3		Formula 4		Formula 5		Formula 6	
	PW	PD	PW	PD	PW	PD	PW	PD	PW	PD	PW	PD
0.5	6.42	.72	6.06	.73	5.76	.86	6.26	.70	5.28	.76	4.84	.84
1.0	5.70	.76	5.50	.78	5.36	.91	5.62	.74	5.13	.85	4.33	.86
2.0	5.10	.81	4.88	.82	5.02	.99	5.11	.81	4.92	.95	3.79	.86
3.0	4.87	.87	4.79	.91	4.66	1.01	4.89	.87	4.57	.98	3.98	.99
5.0	4.44	.93	4.49	.99	4.38	1.08	4.52	.94	4.31	1.05	3.62	1.02
10.0	3.56	.95	3.54	.98	3.51	1.06	3.55	.94	3.51	1.05	3.19	1.09
15.0	3.09	.96	3.16	1.02	3.08	1.06	3.07	.96	3.09	1.06	2.88	1.12
20.0	2.73	.96	2.76	1.00	2.72	1.05	2.75	.97	2.72	1.04	2.60	1.12

2.1.2   Flashing Lights (Class 7) Basic Formula

The following five formulas were derived and tested with power factors and prediction factors:

Formula 1

h = .4106 x log (cxt+.2) + .1917 x mt + .1826 x hl + .1131 x log (d+.2) -7.3407

Formula 2

h = .2953 x log (cxt+.2) + .1088 x mt + .1380 x hl + .0470 x log (d+.2)

Formula 3

h = .3781 x log (cxt+.2) + .1859 x mt + .1794 x hl + .1294 x log (d+.2)
      +.2216 x ur

Formula 4

h = .4078 x log (cxt+.2) + .1964 x mt + .1810 x hl + .1143 x log (dt.2)
      + .2877 x SURF

Formula 5

h = .5019 x log (cxt+.2) - 7.5137

The power factors (PW) and prediction factors (PD) for these formulas are shown in Table 2-2. Formula 1 is selected to be the new basic formula for flashing light crossings (Class 5,6,7). When written in the form preferred for practical use, it becomes:

$$a = .0003351 \ \left(\frac{cxt+.2}{.2}\right)^{.4106} \left(\frac{d+.2}{.2}\right)^{.1131} e^{.1917mt} \ e^{.1826(hl-1)} \qquad (2)$$

It is also the old specification since it uses the same inventory parameters. Formula 2 is the old formula and Formula 3 is an attempt to see if the urban/rural factor produces any better results.

Formula 4 is an attempt to see if crossing surface is a contributing factor to crossing accidents. The test is based upon whether the surface is rubber or not. If it is rubber, SURF = 1. If it is not rubber, SURF = 0. The motivation

TABLE 2-2. POWER FACTORS AND PREDICTION FACTORS FOR FLASHING LIGHTS

Percent of Crossings	Formula 1		Formula 2		Formula 3		Formula 4		Formula 5	
	PW	PD	PW	PD	PW	PD	PW	PD	PW	PD
0.5	5.33	.68	5.27	1.14	5.33	.69	5.38	.66	5.33	.80
1.0	4.83	.74	4.57	1.13	4.89	.76	4.81	.72	4.69	.82
2.0	4.26	.79	4.47	1.27	4.48	.84	4.27	.78	4.14	.85
3.0	4.24	.89	4.26	1.32	4.26	.89	4.15	.86	3.72	.84
5.0	3.77	.93	3.79	1.31	3.73	.91	3.76	.91	3.48	.89
10.0	3.13	.97	3.08	1.25	3.13	.96	3.13	.96	3.07	.97
15.0	1.72	.97	2.71	1.24	2.74	.97	2.73	.97	2.69	.97
20.0	2.46	.98	2.43	1.20	2.44	.97	2.47	.98	2.35	.94

for this test comes from the fact that crossings with a rubber surface have a noticeably high accident rate.[3] For the year 1984, the rate is 0.085 accidents per crossing as opposed to the next highest rate of 0.062 accidents per crossing for concrete slab and a national average of 0.032 accidents per crossing. The result of the regression calculation shows that the t-value for a rubber surface is 2.385. This is high enough to believe it is significant. However, a rubber surface may be a proxy for some other contributing factor, possibly one that is not in the Inventory. Therefore, there may not be any justification in concluding that a rubber surface itself is a contributing factor in causing accidents. However, no evidence can be found from the available data to believe that a rubber surface contributes to lowering accident rates. From Table 2-2, it is seen that the performance for Formula 4 is almost identical with Formula 1 and hence, the simpler one (Formula 1) is preferred.

Formula 5 is the best formula that contains only exposure as the independent variable.

As in the crossbuck case, the power factors for the old formula (Formula 2) are nearly as good as they are for the new formula (Formula 1).

2.1.3 Gates (Class 8) Basic Formula

The following four formulas were derived and tested with power factors and prediction factors:

Formula 1

$$h = .2942 \times \log (cxt+.2) + .1512 \times mt \times .1420 \times hl + .1781 \times \log (d+.2) - 6.8438$$

Formula 2

$$h = .3116 \times \log (cxt+.2) + .2912 \times mt + .1036 \times hl$$

Formula 3

$$h = .3769 \times \log (cxt+.2) + .2174 \times mt + .0859 \times hl$$

Formula 4

$$h = .4460 \times \log (cxt+.2) - 7.6057$$

The power factors (PW) and prediction factors (PD) for these formulas are shown in Table 2-3. Formula 1 is selected to be the new basic formula for gates (Class 8). When written in the form preferred for practical use, it becomes:

$$a = .0005745 \left(\frac{cxt+.2}{.2}\right)^{.2942} \left(\frac{d+.2}{.2}\right)^{.1781} e^{.1512mt} e^{.1420(hl-1)} \tag{3}$$

Formula 2 is the old formula and Formula 3 is the old specification. Formula 4 is the best formula that contains only exposure as the independent variable.

As in the previous two cases, the performance of the old formula (Formula 2) is nearly as good as for the new formula (Formula 1).

2.2 SIGNIFICANCE TEST FOR BASIC FORMULAS

The formula for performing significance tests when comparing two accident prediction formulas is given in Section 3.3. The percentage levels $\{\phi_i\}$ and the corresponding weights $\{W_i\}$ are given as following:

ϕ_i	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	7.0	9.0	11.0	14.0	17.0	20.0	25.0	30.0
W_i	7	5	4	3	3	3	3	3	3	3	3	3	3	3	3	3

The t-values for the three equations are, when comparing the new formula (Formula 1) to the old formula (Formula 3):

	t-values
Crossbucks	-.18
Flashing Lights	.95
Gates	.11

These t-values are so small that the best conclusion in all three cases is that there is no significant difference. The particular weights assigned to the percentage levels have some effect on the t-values. This set of weights puts greater emphasis on crossings with higher accident predictions. However, the weights chosen involve a judgment that the analyst must make, but any reasonable choice would probably lead to the same result. Of course, the percentage levels chosen also affect the t-values.

TABLE 2-3. PERFORMANCE OF FORMULAS FOR GATES

Percent of Crossings	Formula 1		Formula 2		Formula 3		Formula 4	
	PW	PD	PW	PD	PW	PD	PW	PD
0.5	5.37	.91	4.80	.79	5.03	.85	4.11	.84
1.0	4.46	.87	3.94	.78	4.06	.79	3.77	.85
2.0	3.91	.90	3.80	.91	3.89	.90	4.26	1.08
3.0	3.45	.87	3.70	.99	3.95	1.01	3.60	.99
5.0	3.47	1.01	3.46	1.06	3.48	1.01	3.48	1.07
10.0	2.84	1.01	2.91	1.10	2.76	.98	2.76	1.00
15.0	2.53	1.02	2.54	1.09	2.58	1.03	2.41	.97
20.0	2.25	1.01	2.29	1.07	2.27	1.03	2.17	.95

2.3 ACCIDENT HISTORY

The unnormalized accident prediction formula that contains accident history is:

$$B = \frac{T_o}{T_o+T} (a) + \frac{T}{T_o+T} \left(\frac{N}{T}\right), \text{ where } T_o = \frac{C}{D+a} \tag{4}$$

The problem is to determine the constants C and D that produce the best accident prediction formula. This was done by a trial and error method for each of the three new basic formulas. That is, the function used for a, was Formula 1 for crossbucks, flashing lights, and gates, respectively.

The values of C and D tested are given in Table 2-4. These calculations are done with two years of accident history, 1981 and 1982 (T=2). The test years are 1983, 1984, and 1985.

It was found that the performance of the accident history formula, in terms of power factors and prediction factors, was not very sensitive to the range of C and D values given in the table. From the results, it was decided that a reasonable choice for C and D should be C = 1.0 and D = .05, the same as before. This selection applies to all three cases. No theoretical explanation for this choice is known to the authors.

2.4 PROCEDURE FOR OBTAINING NORMALIZING COEFFICIENTS

After the value of B is obtained from equation (4), the final predicted accidents A is obtained by the following:

$$A = \begin{cases} .8644 \ B & \text{PASSIVE} \\ .8887 \ B & \text{FLASHING LIGHTS} \\ .8131 \ B & \text{GATES} \end{cases} \tag{5}$$

These coefficients were obtained so that the sum of the predicted accidents in each group (passive, flashing lights, gates) for the top 20 percent most hazardous crossings exactly equals the number of accidents that occurred in 1985.

It is felt that the basic formulas and the accident history coefficients will not change for many years. However, these normalizing coefficients may need to be retuned periodically. If it is decided to do this annually, the

TABLE 2-4.   VALUES OF C AND D TESTED WITH ACCIDENT HISTORY

CROSSBUCKS		FLASHING LIGHTS		GATES	
C	D	C	D	C	D
1.0	.03	1.0	.03	.75	.03
1.0	.05	1.0	.05	.75	.05
1.0	.07	1.0	.07	.75	.07
.75	.03	.75	.03	1.0	.03
.75	.05	.75	.05	1.0	.05
.75	.07	1.3	.03	1.0	.07
1.3	.03	1.3	.05	1.3	.03
1.3	.05	1.3	.07	1.3	.05
1.3	.07	10000	.05	1.3	.07
10000	.05				
10000	10000				
2500	1000				
5000	1000				

following steps would be taken for the next accident year (1986) for the passive crossings:

1. Rank the passive crossings by Formula 4 using T = 5 and accident history for 1981 through 1985. Upgrades during this period are handled by the method in Section 5.1.2 of the User's Guide[2].

2. Identify the 20 percent most hazardous crossings and determine the sum of the predicted accidents PA and the sum of the observed accidents OA for these crossings for the year 1986.

3. The new coefficient for the passive formula is .8644 x OA/PA.

These same steps should be followed for flashing light crossings and gate crossings, respectively, to determine the two other new coefficients.

2.5 PERFORMANCE OF FINAL FORMULAS

The performance of the three formulas in (4) determined by each group separately, are shown in Table 2-5. Also shown is the performance when all groups are combined. In the latter case, the procedure is to rank crossings from all eight warning device classes combined. For these calculations 2/3 of the inventory was used and T = 4, with accident history based on 1981 through 1984 accidents. The test was against 2/3 of the 1985 accident file.

It is interesting to note that the power factors for combined crossings is greater than that for each of the three groups at all percentage levels. Also, the prediction factors for combined crossings fall between the lowest and highest of the three groups at all percentage levels. This phenomenon has been observed before.

2.6 FREQUENCY DISTRIBUTION TABLE OF CROSSINGS

A frequency distribution of all non-gate crossings is shown in Tables 2-6, 2-7 and 2-8 for the April 1986 Inventory. The final accident prediction formulas produced in this study with T = 5 were used. Table 2-6 is for passive (Classes 1,2,3,4) single track crossings; Table 2-7 is for passive (Classes 1,2,3,4) multiple track crossings; and Table 2-8 is for flashing light (Classes 5,6,7) crossings. These crossings are those that would be entered into the resource allocation model.

TABLE 2-5. PERFORMANCE OF FINAL FORMULAS

Percent of Crossings	PASSIVE		FLASHING LIGHTS		GATES		COMBINED	
	PW	PD	PW	PD	PW	PD	PW	PD
0.5	12.28	.82	11.13	.82	10.90	.97	13.75	.86
1.0	10.35	.86	9.52	.87	8.10	.89	10.98	.87
2.0	8.35	.89	7.65	.89	6.70	.93	8.79	.90
3.0	7.36	.92	6.42	.87	5.84	.93	7.41	.89
5.0	5.87	.90	5.55	.93	4.42	.85	6.07	.91
10.0	4.18	.89	4.06	.93	3.49	.90	4.36	.92
15.0	3.49	.93	3.34	.94	2.91	.91	3.52	.93
20.0	2.99	.93	2.99	.95	2.53	.92	3.03	.94

TABLE 2-6. FREQUENCY DISTRIBUTION FOR PASSIVE, SINGLE TRACK CROSSINGS

PRED ACC INT.	NO.	CUM. NO.	PRED ACC.	CUM PRED ACC.
0.97	1	1	0.971	0.97
0.72	1	2	0.722	1.69
0.66	1	3	0.670	2.36
0.65	1	4	0.656	3.02
0.60	1	5	0.601	3.62
0.59	1	6	0.593	4.21
0.55	2	8	1.115	5.33
0.53	2	10	1.071	6.40
0.51	2	12	1.029	7.43
0.50	2	14	1.011	8.44
0.48	3	17	1.452	9.89
0.46	1	18	0.467	10.36
0.45	2	20	0.916	11.27
0.44	1	21	0.443	11.72
0.43	3	24	1.304	13.02
0.42	2	26	0.853	13.87
0.41	2	28	0.833	14.71
0.40	1	29	0.403	15.11
0.39	5	34	1.970	17.08
0.38	2	36	0.766	17.85
0.37	4	40	1.501	19.35
0.36	4	44	1.456	20.80
0.35	4	48	1.429	22.23
0.34	9	57	3.116	25.35
0.33	7	64	2.352	27.70
0.32	9	73	2.928	30.63
0.31	8	81	2.524	33.15
0.30	11	92	3.334	36.49
0.29	15	107	4.423	40.91
0.28	6	113	1.708	42.62
0.27	18	131	4.940	47.56
0.26	26	157	6.900	54.46
0.25	30	187	7.664	62.12
0.24	30	217	7.329	69.45
0.23	27	244	6.314	75.76
0.22	37	281	8.291	84.06
0.21	25	306	5.369	89.42
0.20	41	347	8.427	97.85
0.19	67	414	13.054	110.91
0.18	71	485	13.139	124.04
0.17	75	560	13.108	137.15
0.16	119	679	19.645	156.80
0.15	115	794	17.880	174.68
0.14	159	953	23.050	197.73
0.13	179	1132	24.192	221.92
0.12	255	1387	31.819	253.74
0.11	309	1696	35.360	289.10
0.10	410	2106	42.994	332.09
0.09	547	2653	51.762	383.86
0.08	666	3319	56.620	440.48
0.07	919	4238	68.563	509.04
0.06	1174	5412	76.162	585.20
0.05	1570	6982	85.718	670.92
0.04	2252	9234	100.693	771.61
0.03	4293	13527	147.986	919.60
0.02	9085	22612	220.859	1140.46
0.01	21618	44230	308.196	1448.65
0.00	56617	100847	214.456	1663.11

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TABLE 2-7. FREQUENCY DISTRIBUTION FOR PASSIVE, MULTIPLE TRACK CROSSING

PRED ACC INT.	NO.	CUM. NO.	PRED ACC.	CUM PRED ACC.
3.00	1	1	3.552	3.552
1.60	1	2	1.667	5.220
0.97	1	3	0.973	6.193
0.90	1	4	0.901	7.094
0.86	1	5	0.866	7.961
0.83	1	6	0.839	8.801
0.79	1	7	0.792	9.593
0.67	1	8	0.675	10.269
0.64	1	9	0.648	10.917
0.62	3	12	1.878	12.795
0.61	1	13	0.618	13.414
0.59	1	14	0.591	14.005
0.58	1	15	0.583	14.588
0.57	1	16	0.574	15.163
0.56	2	18	1.127	16.290
0.55	2	20	1.110	17.400
0.54	1	21	0.544	17.944
0.53	2	23	1.070	19.015
0.52	1	24	0.527	19.543
0.51	1	25	0.512	20.056
0.50	1	26	0.500	20.556
0.48	2	28	0.970	21.527
0.46	3	31	1.396	22.923
0.45	2	33	0.907	23.831
0.44	4	37	1.787	25.618
0.43	3	40	1.304	26.922
0.42	3	43	1.268	28.191
0.41	2	45	0.833	29.024
0.40	6	51	2.414	31.439
0.39	3	54	1.188	32.628
0.38	2	56	0.771	33.399
0.37	14	70	5.257	38.657
0.36	11	81	4.004	42.661
0.35	9	90	3.182	45.843
0.34	7	97	2.415	48.259
0.33	3	100	1.003	49.263
0.32	7	107	2.277	51.541
0.31	11	118	3.459	55.000
0.30	10	128	3.047	58.047
0.29	13	141	3.828	61.876
0.28	16	157	4.555	66.432
0.27	12	169	3.297	69.729
0.26	24	193	6.367	76.097
0.25	30	223	7.657	83.754
0.24	35	258	8.561	92.315
0.23	38	296	8.909	101.224
0.22	36	332	8.099	109.323
0.21	51	383	10.940	120.264
0.20	34	417	6.972	127.237
0.19	51	468	9.954	137.191
0.18	54	522	9.975	147.167
0.17	71	593	12.425	159.592
0.16	73	666	12.017	171.609
0.15	112	778	17.279	188.889
0.14	147	925	21.310	210.199
0.13	144	1069	19.454	229.653
0.12	163	1232	20.365	250.019
0.11	239	1471	27.448	277.467
0.10	315	1786	33.008	310.475
0.09	305	2091	28.894	339.369
0.08	400	2491	33.851	373.220
0.07	517	3008	38.544	411.764
0.06	714	3722	46.346	458.110
0.05	941	4663	51.562	509.671
0.04	1334	5997	59.719	569.390
0.03	2609	8606	90.035	659.425
0.02	4828	13434	117.944	777.369
0.01	8426	21860	123.399	900.768
0.00	11078	32938	44.828	945.596

TABLE 2-8. FREQUENCY DISTRIBUTION FOR FLASHING LIGHT CROSSINGS

PRED ACC INT.	NO.	CUM. NO.	PRED ACC.	CUM PRED ACC.
2.00	1	1	2.079	2.080
1.70	1	2	1.752	3.832
1.30	3	5	4.138	7.971
1.20	3	8	3.711	11.682
1.10	8	16	9.032	20.714
1.00	7	23	7.195	27.909
0.99	1	24	0.994	28.904
0.98	1	25	0.985	29.889
0.97	1	26	0.977	30.867
0.96	3	29	2.892	33.760
0.95	2	31	1.911	35.671
0.93	1	32	0.933	36.605
0.92	1	33	0.924	37.529
0.90	2	35	1.809	39.339
0.89	1	36	0.890	40.229
0.88	2	38	1.774	42.004
0.87	3	41	2.622	44.627
0.86	1	42	0.867	45.494
0.85	1	43	0.859	46.354
0.84	1	44	0.843	47.197
0.83	3	47	2.506	49.704
0.82	1	48	0.820	50.525
0.81	5	53	4.070	54.595
0.80	4	57	3.230	57.826
0.78	1	58	0.786	58.612
0.77	2	60	1.548	60.161
0.75	2	62	1.511	61.672
0.74	3	65	2.235	63.908
0.72	5	70	3.620	67.528
0.71	3	73	2.140	69.668
0.70	3	76	2.116	71.785
0.69	2	78	1.392	73.177
0.68	1	79	0.685	73.863
0.67	5	84	3.366	77.229
0.66	3	87	1.986	79.215
0.65	4	91	2.619	81.834
0.64	8	99	5.161	86.996
0.63	3	102	1.906	88.903
0.62	5	107	3.128	92.031
0.61	10	117	6.142	98.174
0.60	11	128	6.662	104.836
0.59	8	136	4.769	109.605
0.58	11	147	6.434	116.039
0.57	7	154	4.024	120.064
0.56	6	160	3.384	123.448
0.55	6	166	3.336	126.784
0.54	10	176	5.446	132.231
0.53	8	184	4.280	136.511
0.52	9	193	4.722	141.234
0.51	8	201	4.129	145.363
0.50	10	211	5.053	150.417
0.49	7	218	3.462	153.980
0.48	11	229	5.325	159.205
0.47	18	247	8.546	167.752
0.46	12	259	5.587	173.339
0.45	16	275	7.273	180.612

TABLE 2-8. FREQUENCY DISTRIBUTION FOR FLASHING LIGHT CROSSINGS (Cont.)

- PRED ACC INT.	NO.	CUM. NO.	PRED ACC.	CUM PRED ACC.
0.44	16	291	7.123	187.74
0.43	17	308	7.394	195.13
0.42	18	326	7.637	202.77
0.41	21	347	8.696	211.46
0.40	25	372	10.131	221.59
0.39	17	389	6.715	228.31
0.38	24	413	9.229	237.54
0.37	28	441	10.525	248.06
0.36	33	474	12.053	260.12
0.35	42	516	14.906	275.02
0.34	42	558	14.537	289.56
0.33	28	586	9.377	298.94
0.32	40	626	12.999	311.93
0.31	37	663	11.644	323.58
0.30	49	712	14.902	338.48
0.29	65	777	19.160	357.64
0.28	59	836	16.794	374.44
0.27	75	911	20.581	395.02
0.26	85	996	22.533	417.55
0.25	83	1079	21.167	438.72
0.24	91	1170	22.243	460.96
0.23	110	1280	25.844	486.80
0.22	115	1395	25.797	512.60
0.21	126	1521	27.111	539.71
0.20	147	1668	30.123	569.83
0.19	161	1829	31.390	601.22
0.18	196	2025	36.222	637.45
0.17	220	2245	38.454	675.90
0.16	255	2500	41.979	717.88
0.15	280	2780	43.315	761.19
0.14	339	3119	49.098	810.29
0.13	423.	3542	57.162	867.45
0.12	421	3963	52.614	920.07
0.11	518	4481	59.416	979.49
0.10	573	5054	60.163	1039.65
0.09	683	5737	64.852	1104.50
0.08	873	6610	74.008	1178.51
0.07	1163	7773	86.941	1265.45
0.06	1515	9288	97.847	1363.30
0.05	2165	11453	118.522	1481.82
0.04	3291	14744	146.889	1628.71
0.03	5035	19779	174.762	1803.47
0.02	7014	26793	173.397	1976.87
0.01	7729	34522	117.959	2094.83
0.00	8135	42657	24.727	2119.55

Each table consists of five columns. The first column, labeled "PRED ACC INT." defines the predicted accident interval; the second column, labeled "NO." gives the number of crossings in the predicted accident interval; the third column labeled "CUM NO.", gives the cumulative number of crossings that have a predicted accident rate greater than that in the first column; the fourth column, labeled "PRED ACC." gives the predicted accidents for the crossings in the predicted accident interval; and the fifth column, labeled "CUM PRED ACC." gives the cumulative predicted accident rate greater than that in the first column. For example, in Table 2-6 consider the line that has 0.20 in the first column. The table states that there are 41 crossings that have a predicted accident rate between 0.20 and 0.21 and there are 347 crossings that have a predicted accident rate greater than 0.20. The 41 crossings in this interval have a total predicted accident rate of 8.427 and the 347 crossings have a total predicted accident rate of 97.85. Tables 2-7 and 2-8 are used the same way.

2.7 COST-BENEFIT RESULTS FOR NATIONWIDE CROSSINGS

The new formulas (1), (2), (3), (4) have been incorporated into the resource allocation model. An example of an application of this model with the new formulas is shown in Table 2-9. The standard effectiveness values and life cycle costs were used.[2] The resource allocation model was used for a series of funding levels. For each funding level, the table presents the number of crossings nominated for improvement consideration with flashing lights and flashing lights with gates, and the expected number of accidents prevented per year. The bottom row, with a funding level of $14,539,600,000, represents the case where gates are installed at all public crossings in the U.S.
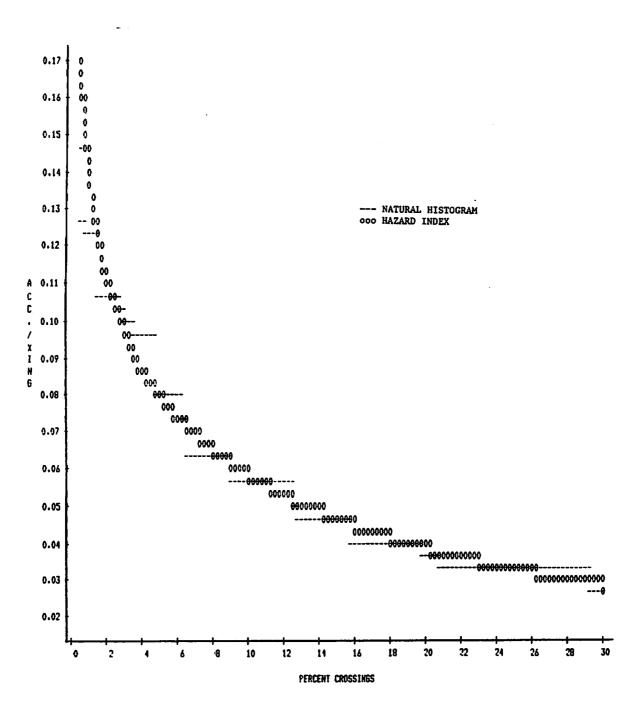
2.8 EXAMPLE OF NATURAL HISTOGRAM

The theory behind the natural histogram is given in Section 3.2. An example of a natural histogram is shown in Figure 2-1 for Formula 1 for crossbucks (See Section 2.1). This figure presents a plot of accidents/crossing versus percent of crossings.

TABLE 2-9.   RESOURCE ALLOCATION RESULTS FOR VARIOUS FUNDING LEVELS
FOR ALL CROSSINGS NATIONWIDE, APRIL 1986 INVENTORY

TOTAL FUNDING LEVEL BASED ON 1983 LIFE CYCLE COSTS ($)	BENEFIT ACCIDENTS PREVENTED PER YEAR	NUMBER OF CROSSINGS UPGRADED		
		PASSIVE TO FLASHING LIGHTS	PASSIVE TO GATES	FLASHING LIGHTS TO GATES
$55,400,000	264	186	105	471
$96,400,000	381	341	199	789
$192,900,000	595	772	464	1,445
$435,100,000	974	2,001	1,174	2,938
$654,100,000	1,213	3,083	1,896	4,222
$800,500,000	1,360	3,907	2,391	4,997
$999,300,000	1,525	4,889	3,117	6,086
$1,268,000,000	1,716	6,124	4,173	7,541
$2,384,400,000	2,269	10,741	9,041	13,428
$6,893,100,000	3,266	29,793	33,769	31,430
$14,539,600,000	3,628	0	133,785	42,657

FIGURE 2-1. EXAMPLE OF NATURAL HISTOGRAM

3. ANALYTICAL METHODS FOR HAZARD INDEX DEVELOPMENT

3.1 GENERAL DISCUSSION

We define a railroad crossing hazard index as a formula for estimating the expected number of accidents per year at a railroad-highway grade crossing. The estimate is based on crossing characteristics such as daily car and train traffic and warning device class, and sometimes accident history.

Our task is to determine "good" hazard indexes. In comparing formulas for estimating some quantity, the criterion is primarily accuracy. However, since the number of accidents at any crossing in a given year is usually zero, it is rather difficult to speak directly of the accuracy of a hazard index. (In some sense, a hazard index which predicts zero accidents for all but the very few which have an average of more than 0.5 accidents per year would be the most accurate, but this would not be very useful.) Since a hazard index gives an expected number of accidents, we might judge accuracy by finding how many accidents on an average occur in a given year at crossings with the hazard index in a given range. This is a useful check, but not enough. For example, predicting .03 accidents for each crossing in the year 1984 would be very accurate in this sense since that was the average for that year.

What is needed is a measure of the hazard index's ability to distinguish high hazard crossings from low hazard crossings. This is not simply a measure of accuracy in the usual sense, but a measure of discrimination power in the statistical sense. Consequently, we call the measure developed for this purpose the "power factor." The power factors are a set of statistical measures developed to assess the discrimination power of a hazard index. There are a set of power factors for each hazard index because power factor is a function of a percentage level. Specifically, the power factor for a given percentage level is defined as follows:

> The power factor at the p% level is the ratio of the percentage of all accidents which occur at the p% most hazardous crossings (according to the given hazard index) to p%. Thus, if the top 5 percent crossings in hazard according to a given hazard index have 20 percent of the accidents, then this hazard index has a power factor of 20/5 = 4.0 at the 5 percent level.

The "prediction factor" was developed to help measure accuracy in the average sense. Specifically, the p% prediction factor is defined to be the percent of the hazard index sum divided into the percent of accidents for the p% most hazardous crossings according to the given hazard index. This measure is too aggregate to judge the local accuracy of the hazard index in each range of values, so the "natural histogram plot" was developed. In use, the natural histogram plot is straightforward. It shows the predicted and actual frequency of accidents in each range of hazard index (for ease in plotting this is shown only for the 30 percent most hazardous crossings which are the crossings of most interest). This allows a direct assessment of the accuracy of the hazard index. The principle and theory behind this plot are described in Section 3.2.

Next, we note that although the power factors are the primary method of comparing hazard indexes, it is not easy to assess the statistical significance of the differences between the power factors for two different hazard indexes. Therefore, we developed a separate program in SAS to determine the statistical significance of the differences in power factors between two hazard indexes. To use this program, up to 20 different percentage levels of interest are specified by the user and weights representing the importance of each (or roughly the expected frequency of use of the hazard index for discrimination at that level) are specified (more or less subjectively) by the user. Based on these weights, an overall statistical significance is calculated for the differences in power factors at the specified levels. If the difference in power factors changes sign from one of the specified percent levels to another, the weighted average may tend to cancel out and the overall difference in power factors may not be significant. The program takes this and the sample sizes of the independent counts involved into account in determining an overall significance level. The way this significance is calculated is described in Section 3.3 In addition, the statistical significance of the difference in power factors at each of the specified percentage levels is calculated. These individual "local" significance values are not meant to be combined by the user to find an overall significance. For that the overall significance as provided by the program should be used. The individual local significance values should be used with caution and are only included because the data needed for their calculation is available when computing the overall significance level. The local values may be of some use, but should not be used for formal decisions. The theory behind these significance values is outlined in Section 3.3.

Finally, we describe how the non-linear regressions for constructing hazard indexes work and how one chooses between two slightly different methods. First, let us note that estimating the expected number of accidents in a year at a given crossing is very similar to estimating the probability of one or more accidents in a year. There is an artifice which converts the problem of finding an estimating function for the expected number of accidents at a crossing to that of estimating a function for the probability of an event. For this we produce a file with one record for each crossing and one record for each accident. Then, we develop a function which estimates the probability that a given record is an accident record. Let this probability be p. Then:

$$p = A/(A + C) = 1/(1 + (A/C)^{-1}) \qquad (6)$$

where A is the number of accidents and C the number of crossings with certain characteristics. But the probability is computed in the form of a logic function:

$$p = 1/(1 + e^{-L}) \qquad (7)$$

where L is some linear function of the crossing characteristics.

Therefore:

$$1/(1 + (A/C)^{-1}) = 1/(1 + e^{-L}) \qquad (8)$$

So:

$$A/C = e^{L} \qquad (9)$$

Here, A/C is the estimate of the expected frequency of accidents which we shall call h. Thus, if:

$$p = 1/(1 + e^{-L}) \qquad (10)$$

then:

$$h = e^{L} \qquad (11)$$

Therefore, we estimate h by using logistic regression to estimate p.

Having decided to use logistic regression, there remains the choice of the criterion for fit. A wide family of functions representing the possible losses due to wrong decisions using probability estimates (and/or gains due to right decisions) can be represented as follows:

If probability is estimated as p and

    a)   event occurs, then cost is $-f(p)$

    b)   event does not occur, then cost is $-g(q)$

where $f(p)$ and $g(q)$ satisfy*

$$p\,f'(p) = q\,g'(q) \text{ or } f(p) = \int^{p}(r(x)/x)dx \qquad (12)$$

$$g(q) = \int^{q}(r(1-x)/x)dx \qquad (13)$$

where $r(x) \geq 0$ and where, as usual, $q = 1-p$.

In particular, if one chooses $r(x) = 1$, then, $f(p) = \log p$, $g(q) = \log q$. Minimizing this loss (i.e., sum of $-\log p$ over cases where event occurs plus sum of $-\log q$ over cases where the event does not occur) leads to the maximum likelihood estimate.

If one chooses $r(x) = 2x(1-x)$, then, $f(p) = -(1-p)^2$, $g(q) = -(1-q)^2 = -p^2$. Minimizing the corresponding loss leads to the least squares estimate.

---

*These cost functions ensure that the expected cost is minimized, conditioned on some information if p is the true probability conditioned on that information. These cost functions are general enough to represent the gains and losses which may be incurred in using the probabilities to make simple practical decisions.

There is no particular reason to choose least squares over maximum likelihood except:

a) Maximum likelihood estimates have more statistical stability than other estimates and this can usually result in somewhat more accuracy if the model specification is correct.

b) The least squares criterion gives more weight to cases where $p = .5$ than $p = 0$ or $p = 1$. This weights high hazard crossings more highly (since p is almost never over .5) in agreement with the expected use of the hazard index (and this argues in favor of the least squares estimate if the model specification is incorrect).

c) Outliers can have a large effect on the maximum likelihood criterion but are nearly inconsequential in the case of the least squares criterion (another effect of maximum likelihood criterion going to infinity at 0 and 1). This also tips the balance in favor of the least squares criterion.

d) Maximum likelihood enjoys a greater popularity and is more widely available.

Using BMD (accessed from SAS at NIH) both criteria are available and the relative merits of the models they generate are discussed in Section 2.

3.2 NATURAL HISTOGRAM

The power factors measure the ability of a given hazard index to discriminate high hazard from low hazard crossings. However, there is another property of a hazard index not measured by the power factor; that is, the ability to predict the actual number of accidents to be expected at a given crossing in a year. To measure how well a given hazard index does, we want to group crossings of a given hazard index and find the average number of accidents actually experienced. How well these numbers agree is the accuracy we seek. The problem is, which crossings should we group together? Apparently the groupings should be based on hazard index value, i.e., each group should be defined by a range of values (i.e., interval) of the hazard index. However, if we make the range too wide, we are not measuring the actual performance of the hazard index but the average performance over a range. In the extreme this range would cover all accidents and average performance would be nearly

3-5

meaningless. On the other hand, if we choose ranges too narrow, the accidents occurring at crossings within the range are too few and their number is too noisy and cannot reasonably be expected to give a reliable estimate of the true rate.

It turns out that there is a method available for adjusting the width to just the right size. We call the resultant intervals the "natural histogram". The intervals are chosen according to these requirements:
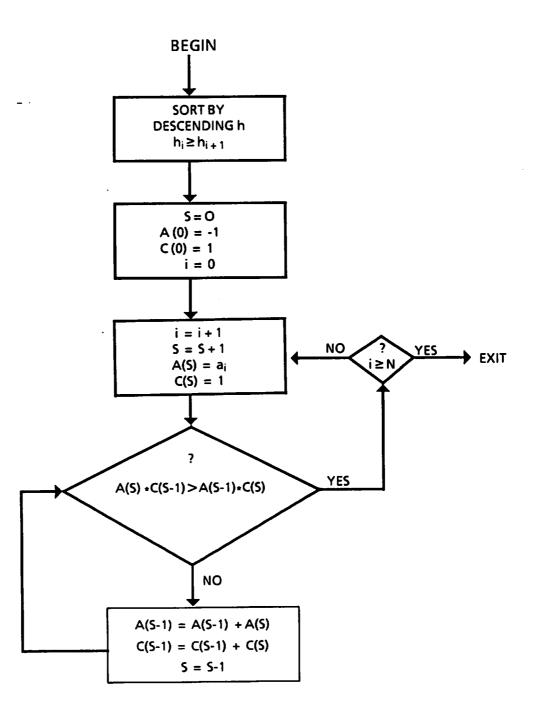
1. The average number of accidents per crossing is higher for any interval of higher hazard index than for any interval of lower hazard index.

2. If any interval were to be divided into two subintervals (in any way), the subinterval of higher hazard index would not have a higher average number of accidents per crossing than the other subinterval.

It may be shown that these criteria lead to a unique set of intervals. Furthermore, the resulting set of intervals minimizes any cost function of the type discussed in Section 3-2 over the set of probabilities that are constrained only to never decrease as the hazard index increases.

Consequently, the natural histogram summarizes the entire "shape" content in the data regarding the given hazard index. The comparison of the hazard index with the natural histogram gives a complete assessment of its ability to accurately predict accident rates.* Consequently, the natural histogram provides the complement to the power factors in assessing hazard indexes relative to a data set. (The prediction factors represent an aggregate summary of some of the information in the natural histogram.)

The natural histogram is easily calculated by the algorithm flow charted in Figure 3-1. The number of times each statement in this program is executed is easily shown to be less than 2N when N is the number of points in the data. The size of the arrays are found empirically (with some analysis) to be less than $1.5 \ N^{1/3} \ (LOG_e N)^{1/2} + 30$.

---

*There is some bias in the natural histogram at extremely high hazard crossings, but the bias is of the same order of magnitude there as the noise and is not especially troublesome. (The bias over estimates the expected frequency of accidents at the most hazardous crossings.)

BEGIN

```
┌──────────────────────┐
│      SORT BY         │
│   DESCENDING h       │
│   h_i ≥ h_{i+1}      │
└──────────────────────┘
```

$$\begin{array}{l} S = 0 \\ A(0) = -1 \\ C(0) = 1 \\ i = 0 \end{array}$$

$$\begin{array}{l} i = i + 1 \\ S = S + 1 \\ A(S) = a_i \\ C(S) = 1 \end{array}$$

NO — ? i ≥ N — YES → EXIT

?

$A(S) \cdot C(S-1) > A(S-1) \cdot C(S)$ — YES

NO

$$\begin{array}{l} A(S-1) = A(S-1) + A(S) \\ C(S-1) = C(S-1) + C(S) \\ S = S-1 \end{array}$$

Note: a_i is the number of accidents at the ith crossing from the top according to hazard index h. After exit, S is the number of steps in the natural histogram, C(s) is the number of crossings in step s, and $p = A(s)/C(s)$ is the estimated probability for step s.

FIGURE 3-1. CALCULATION OF NATURAL HISTOGRAM

3.3 SIGNIFICANCE OF DIFFERENCES IN POWER FACTORS

The power factor is completely specified by giving the number of accidents $A(\phi)$ which occur at the ϕ percent most hazardous crossings according to the given hazard index. This also gives a measure of the benefit for one way of using the hazard index. Thus, suppose that the ϕ percent most hazardous crossings are selected using the given hazard index, and are subjected to some treatment which reduces the number of accidents from the $A(\phi)$ expected without treatment to $(1-E)A(\phi)$. The $EA(\phi)$ accidents saved are the benefit. If the hazard index is used $W(\phi)$ times with this benefit (perhaps in different localities), then the total benefit at this percentage level is $W(\phi)EA(\phi)$. If this scenario is repeated at several percentage levels $\phi_1, \phi_2, \ldots \phi_K$,

then the total benefit is:

$$E\sum_{k=1}^{K} W(\phi_k)\, A(\phi_k) \tag{14}$$

or more briefly,

$$E\sum_{k=1}^{K} W_k\, A_k \tag{15}$$

We propose to summarize the total discrimination value of any hazard index by the sum:

$$\sum_{k=1}^{K} W_k\, A_k \tag{16}$$

where as noted the percentage levels $\phi_1, \phi_2, \ldots \phi_K$ and the weights $W_1, W_2, \ldots W_K$ are assigned by the analyst (subjectively if necessary). The number A_k is the total number of accidents occurring at the crossing $N\phi_k/100$ from the top and all more hazardous crossings, number 1 being the most hazardous. (Note that $A_k = A(\phi_k)$, $W_k = W(\phi_k)$ as a matter of simplified notation.)

We shall loosely refer to the sum:

$$B = \sum_{k=1}^{K} W_k\, A_k \tag{17}$$

as the "benefit" of the given hazard index. If we have two hazard indexes h_1 and h_2 and if the A_k values are $A_{k,1}$ and $A_{k,2}$ respectively, then

$$B_1 - B_2 = \sum_{k=1}^{K} W_k\, (A_{k,1} - A_{k,2}) \tag{18}$$

Now let n_{rs} be the number of accidents that are between ϕ_{r-1} and ϕ_r with respect to hazard index h_1 and between ϕ_{s-1} and ϕ_s with respect to hazard index h_2. Then:

$$A_{k,1} = \sum_{r=1}^{k} \sum_{s=1}^{K} n_{rs} \tag{19}$$

and

$$A_{k,2} = \sum_{s-1}^{k} \sum_{r=1}^{K} n_{rs} \tag{20}$$

Therefore:

$$B_1 - B_2 = \sum_{k=1}^{K} W_k \left(\sum_{s=1}^{k} \sum_{r=1}^{K} n_{rs} - \sum_{r=1}^{k} \sum_{s=1}^{K} n_{rs} \right) \tag{21}$$

$$= \sum_{r=1}^{K} \sum_{s=1}^{K} n_{rs} (Q_s - Q_r)$$

where

$$Q_1 = 0 \text{ and } Q_r = Q_{r-1} + W_{r-1} \tag{22}$$

i.e.,

$$Q_r = \sum_{k=1}^{r-1} W_k \tag{23}$$

Therefore, a best unbiased estimate of the expected value of the difference in benefits $B_1 - B_2$ is

$$\sum_{r=1}^{K} \sum_{s=1}^{K} n_{rs} (Q_s - Q_r) . \tag{24}$$

and an unbiased estimate of the variance of this estimate is

$$\sum_{r=1}^{K} \sum_{s=1}^{K} n_{rs} (Q_s - Q_r)^2 \tag{25}$$

This is because n_{rs} can be considered as Poisson distributed and so an unbiased estimate of its mean is n_{rs} and an unbiased estimate of its variance is n_{rs}. Furthermore, and this is the point of the above decomposition, n_{rs} is independent of $n_{r's'}$ unless $r=r'$ and $s=s'$. Note that this variance computation treats the ranking of crossings by h_1 and h_2 as fixed and not having a statistically variable component. We do not comment further on this assumption except to say that even if it is not philosophically exact, it should be all right practically since most variability or "noise" comes in the random occurrence of accidents.

A SAS program has been written which uses PROC FREQ to calculate n_{rs} and then calculates estimates of $B_1 - B_2$ and its variance $\sigma^2(B_1 - B_2)$. The statistic used to say whether two power factors differ significantly is $t = (B_1 - B_2)/ \sigma(B_1 - B_2)$.

4. SOFTWARE

4.1 USER'S OPERATING INSTRUCTIONS

The accident prediction and resource allocation programs can be very conveniently run using the command language procedure. The desired reports can be generated according to the following general steps:

- Log-on to National Institute of Health (NIH)

- Input parameters and job submission

- Output printing

- Logging-off

4.1.1 Log-On to NIH System

This procedure enables the user to get access to the NIH computer system, where the software is stored. A user is supposed to have a valid account number, user-ID and initials. The various steps of the log-on procedure are as follows:

a. Using data phone dial 492-2221 and at high pitch tone make the contacts with the system

b. Key-in 37 and press RETURN key

c. Enter three character initials, e.g., GXM

d. Enter four character account number, e.g., XTP1

e. Enter three character keyword, e.g., GZU

f. Enter terminal type, e.g., NONE

g. Enter SET VOLUME FRASIR.

You are now successfully logged on to the NIH WYLBUR system to have access to the software.

4.1.2 Input Parameters and Job Submission

This section describes how to access the command procedure which prompts for the various input parameters, validates them and passes their values to other programs which generate the desired report.

Figure 4-1 shows an example of how the procedure is invoked to submit a job for report generation. The example covers the details a user would go through. Both the system instructions and prompts offered at the terminal as well as the input parameters keyed in by the user are shown. The user responses are underlined in the example. (Underscoring will not show up on the terminal). The explanation of various input lines marked in circles in the example are as follows:

Line 1   The command line USE FROM INTER.COM CLEAR calls the command procedure in the active storage.

Line 2   EX (execute) starts executing the command procedure called earlier.

Line 3   The system prompts to find out if the user needs help.

Line 4   Specify the first title line to be printed at the top of each page in the printout.

Line 5   Specify the choice of either accident and severity prediction or resource allocation by entering 1 or 2.

Line 6   The system prompts for selecting one of the possible combinations of various location parameters, which can be used for subsetting the crossings for report generation. In the given example, combination 4 has been selected.

Line 7   Based on the selection made in response to the prompt in line 6 the user enters the state code and railroad ID. In most cases the parameter values entered by the user are checked for their validity and in case they do not pass the validation test (i.e., the upper and lower bound limit) the user is prompted to reenter the values.

Line 8   User is prompted to select one of the three possible measures of accident severity to be used for ranking the crossings and or resource allocation.

Line 9   If the third choice, combined casualty, is exercised in line 8, the user is prompted to input the fatality factor value after the displayed default value.

Y USE FROM INTER.COM CLR — — — — — — — — — — — — ①
? EX — — — — — — — — — — — — — ②

WELCOME TO THE DOT RAIL-HIGHWAY CROSSING
RESOURCE ALLOCATION PROCEDURE

        DO YOU NEED ANY HELP.? (Y/N) : Y — — — — — — — — — — — — ③
****
*   *
* IN THIS SESSION YOU WILL BE PROMPTED FOR THE VALUES *
* OF VARIABLES REQUIRED FOR THE REPORT GENERATION. *
* EACH VARIABLE VALUE ENTERED BY YOU WILL BE CHECKED *
* FOR ITS ALLOWABLE LIMIT, AND YOU MAY BE PROMPTED TO *
* REENTER THE VALUE IF IT DOES NOT FALL WITHIN THE   *
* RANGE.   *
* FOR THE RESOURCE ALLOCATION OPTION, SOME VARIABLES *
* HAVE DEFAULT VALUES. THESE VALUES WILL BE DISPLAYED *
* SO THAT YOU CAN DECIDE WHETHER TO USE THEM OR REPLACE *
* THEM WITH YOUR OWN VALUES.   *
* BEFORE SUBMITTING THE BATCH JOB FOR REPORT GENERATION *
* ALL PARAMETER VALUES USED IN THE PROGRAM WILL BE   *
* DISPLAYED FOR YOUR VERIFICATION. YOU WILL HAVE THE *
* OPTION TO REENTER ALL THE VALUES OR GO AHEAD.   *
* YOU CAN COME OUT OF THIS SESSION BY PRESSING THE   *
* BREAK KEY ANY TIME.   *
* FOR AN EXPLANATION OF THE RESOURCE ALLOCATION   *
* PROCEDURE, REFER TO THE USER'S GUIDE.   *
*   *
****
ENTER GO IF YOU READ THE HELP MESSAGE
? GO

PLEASE ENTER TITLE TO BE PRINTED ON REPORT: DEMONSTRATION-I   — — ④

CHOOSE ONE OF THE OPTIONS LISTED BELOW:

        1   ACCIDENT AND SEVERITY PREDICTION
        2   RESOURCE ALLOCATION

YOUR OPTION CHOICE= 2   — — — — ⑤

            SHOULD THE REPORT BE PREPARED FOR
            A GIVEN:

                    1   STATE, COUNTY, CITY AND RAILROAD
                    2   STATE, CITY AND RAILROAD
                    3   STATE, COUNTY AND RAILROAD
                    4   STATE AND RAILROAD
                    5   RAILROAD
                    6   STATE
                    7   STATE, COUNTY AND CITY
                    8   STATE AND CITY
                    9   STATE AND COUNTY
                    10   GIVEN RANGE OF CROSSING IDs
                    11   TOTAL INVENTORY

        FIGURE 4-1. EXAMPLE OF JOB REPORT PROCEDURE

ENTER YOUR CHOICE NUMBER: 4   — –– ⑥

ENTER STATE CODE (2 DIGITS) = 40

ENTER RAILROAD CODE (UP TO 4 CHARACTERS) = ATSF   — –– ⑦

SHOULD THE MEASURE OF SEVERITY BE:

    1   PREDICTED ACCIDENTS
    2   PREDICTED FATAL ACCIDENTS
    3   COMBINED CASUALTY INDEX

YOUR CHOICE: 3   — –––– ⑧

THE DEFAULT FATALITY FACTOR IS 50
SHOULD IT BE USED (Y/N): Y   — ––– ⑨

WHAT KIND OF EFFECTIVENESS VALUES WOULD YOU LIKE?

        1   STANDARD EFFECTIVENESS
        2   EXTENDED EFFECTIVENESS

        YOUR EFFECTIVENESS CHOICE #: 2   — ––– ⑩

DEFAULT EXTENDED EFFECTIVENESS VALUES ARE:

| | TRAINS <=10 | | TRAINS >=11 | |
	SINGLE TRACK	MULTI TRACK	SINGLE TRACK	MULTI TRACK
PASSIVE TO FLASHING:	.75	.65	.61	.57
PASSIVE TO GATES :	.90	.86	.80	.78
FLASHING TO GATES :	.89	.65	.69	.63

DO YOU WANT DEFAULT EFFECTIVENESS VALUES TO BE USED (Y/N): N –– ⑪

        EFFECTIVENESS VALUES THAT YOU ENTER MUST BE SPECIFIED
        AS A DECIMAL POINT FOLLOWED BY TWO DIGITS (e.g. .78)

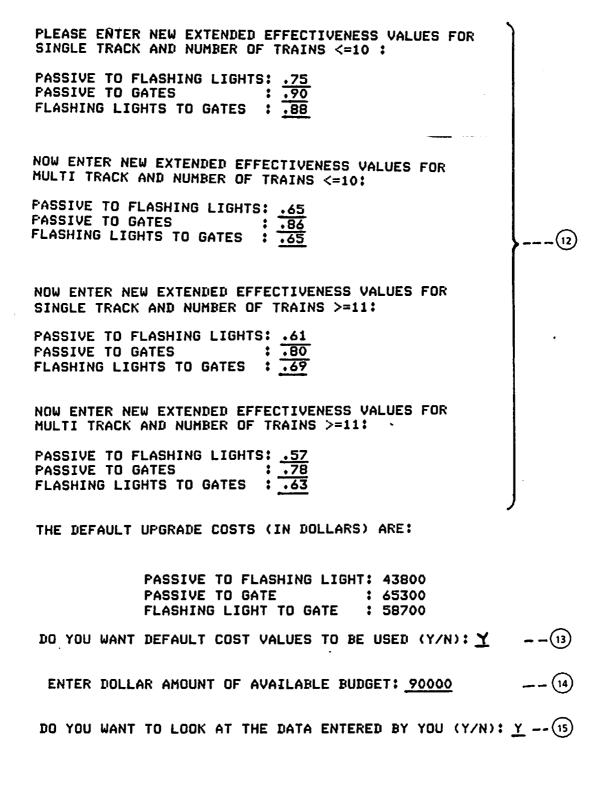FIGURE 4-1. EXAMPLE OF JOB REPORT PROCEDURE (Cont.)

PLEASE ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR
SINGLE TRACK AND NUMBER OF TRAINS <=10 :

PASSIVE TO FLASHING LIGHTS: .75
PASSIVE TO GATES   : .90
FLASHING LIGHTS TO GATES : .88

NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR
MULTI TRACK AND NUMBER OF TRAINS <=10:

PASSIVE TO FLASHING LIGHTS: .65
PASSIVE TO GATES   : .86
FLASHING LIGHTS TO GATES : .65   } ---⑫

NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR
SINGLE TRACK AND NUMBER OF TRAINS >=11:

PASSIVE TO FLASHING LIGHTS: .61
PASSIVE TO GATES   : .80
FLASHING LIGHTS TO GATES : .69

NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR
MULTI TRACK AND NUMBER OF TRAINS >=11:

PASSIVE TO FLASHING LIGHTS: .57
PASSIVE TO GATES   : .78
FLASHING LIGHTS TO GATES : .63

THE DEFAULT UPGRADE COSTS (IN DOLLARS) ARE:

          PASSIVE TO FLASHING LIGHT: 43800
          PASSIVE TO GATE   : 65300
          FLASHING LIGHT TO GATE   : 58700

DO YOU WANT DEFAULT COST VALUES TO BE USED (Y/N): Y   --⑬

 ENTER DOLLAR AMOUNT OF AVAILABLE BUDGET: 90000   --⑭

DO YOU WANT TO LOOK AT THE DATA ENTERED BY YOU (Y/N): Y --⑮

          FIGURE 4-1.   EXAMPLE OF JOB REPORT PROCEDURE (Cont.)

```
         VARIABLE NAME          VALUE

     TITLE      : DEMONSTRATION-I
     OPTION_    : RESOURCE ALLOCATION
     STATE      : 40
     COUNTY     : .
     CITY       : .
     RAILROAD   : ATSF
     ID1        :
     ID2        :
     SEVERITY   : 3- COMBINED CASUALTY INDEX
     K          : 50 -FATALITY FACTOR
                : 2-EXTENDED EFFECTIVENESS
                : 0.75 0.9 0.88
                : 0.65 0.86 0.65
                : 0.61 0.8 0.69
                : 0.57 0.78 0.63
     BUDGET     : 90000
     C1 C2 C3   : 43800 65300 58700- DEFAULT UPGRADE COSTS


     DO YOU WANT TO CHANGE ANY OF THE PARAMETERS? (Y/N): N       (16)

     SHOULD THE JOB BE SUBMITTED FOR DISCOUNT RUN? (Y/N): N      (17)
     JOB   88 FZUWTP1  SUBMITTED
     DO YOU WISH TO SUBMIT ANOTHER JOB (Y/N): N                  (18)
     ?
```

FIGURE 4-1. EXAMPLE OF JOB REPORT PROCEDURE (Cont.)

Line 10 The resource allocation program has a provision for using either
         standard effectiveness (3 values) or extended effectiveness (12
         values). In response to the prompt the user can select either of the
         two values by entering 1 or 2.

Line 11 Depending on the choice made in line 10, the system displays the built
         in default values of effectiveness and prompts the user if this should
         be used or not.

Line 12 If the answer in line 11 is N (no), the system prompts for all the
         values of effectiveness desired by the user. In the given example, all
         numeric values are user entered.

Line 13 The system displays the default upgrade costs and prompts the user for
         approval to use them. If the answer is N (no) the system will prompt
         for three upgrade costs.

Line 14 The system prompts for the available budget in dollars. The budget value must be entered as an integer without commas. In the example, 90000 represents $90,000.00.

Line 15 User's desire to view the parameter values entered earlier is ascertained. In response to a reply of Y (yes), the values are displayed.

Line 16 The user makes the decision of either to submit a batch job or reenter the command procedure at line 4 to revise the input parameters.

Line 17 The WYLBUR system accepts the batch job during the prime time or discount time (discount time is between 5:00 PM and 8:00 AM on weekdays and at all times on week ends). Depending on the user's choice the batch job is submitted accordingly and the job number is displayed.

Line 18 The user is prompted to exercise his/her option of submitting the next job. If the answer is N (no) the system will exit from the command procedure. Otherwise it will start reprompting from line 4 onwards.

4.1.3 Output Printing

The output of the batch job submitted earlier can be viewed either on the terminal and printed on the attached printer (if available), or can be routed for printing on the default system printer.

For terminal viewing, if the user is still logged on after the job submission, the system will display the end of job notification after the job is run. The following procedure is used to view the output.

a. Fetch nnnn clear (where the nnnn is the batch job number given by the system in line 17). (Job number 88 is shown in the example.)

b. List n1/n2. This will display lines n1 through n2. (For further information on selecting particular lines, the user is advised to refer to the WYLBUR fundamentals manual.)

To route the job for printing on the default system printer use the command "PRINT nnnn". The printout can be later collected from the I/O desk.

4.1.4 Logging-Off

To log-off from the system use "LOGOUT CLEAR". The system will display the account summary and will disconnect the user.

4.2 INSTALLATION AND MAINTENANCE OF SOFTWARE

The accident prediction and resource allocation program configuration is available in 3 modules.

1. MAIN.COM

2. ACPD.NEW

3. RESAL.NEW

The MAIN.COM is the interactive command procedure tailor-made to work at the NIH installation using the WYLBUR System. This module interactively accepts the input data and passes on the information to the ACPD.NEW or RESAL.NEW programs and activates the batch run. The user's operating instructions, as given in Section 4.1, describe in detail the steps to be followed to execute this program.

The current software setup and maintenance procedure are described in the following:

1. Presently, all three modules are available on a special disk pack called FRASIR and are accessible by account #WTP1 and user ID, FZU. MAIN.COM uses two dummy files, PARAMS and ABC.XYZ. The former is created during every run and is available only when the user is in the command procedure. The latter is a permanent file and is modified during every run and is available even after the run execution. This file name should be available in the directory before the run execution.

2. The default parameters of effectiveness values, and upgrade costs, etc., are defined in lines 64 to 74 of MAIN.COM. The values can be redefined by using the WYLBUR editor. The default values of "." may not be redefined as these are meant for formatting the output.

3. The batch job gets submitted with the default option of "hold" which means the results will not automatically get printed on the line

printer. To disable this option, remove word "hold" in line 592 in the MAIN.COM program.

4. Presently, the command for a batch run submits the job in Category "A", i.e., up to 10 seconds of CPU time. The job submission category can be altered by changing A to B, C or E in line 1 of ACPD.NEW or RESAL.NEW programs.

5. Presently, the default printer ID is set up as R158. This can be changed with the line printer ID of the user's installation by changing line 3 in both the ACPD.NEW and RESAL.NEW programs.

6. Both of the batch programs ACPD.NEW and RESAL.NEW use datasets NEWTEST, CITY, and COUNTY as input. All these data sets are available on the disk pack FRASIR. The data set NEWTEST is a SAS dataset created from the data by merging the inventory file and accident file information. Further details of this are available in the User's Guide[2]. The data set CITY and COUNTY contain descriptive information relating city and county code numbers with their names. Any new dataset names can be given by changing the old names in the JCLs. (Program line numbers 9-14.)

7. Presently, the program uses accident data for five years from 1981-85. When the years change, the new years will replace the old years description in line 246-249 in the ACPD.NEW Program.

8. The FRA continously updates its inventory file. As such, for each inventory version a new SAS data set (NEWTEST) is created. The inventory date should be properly inserted in the third line from the bottom in both batch programs.

9. All JCL lines starting with // in the beginning of each batch program have to be properly adjusted depending upon the installation configuration.

4.3 PROGRAM LISTING OF MAIN.COM

The program listing shown in this section is intended to be specifically useful to programming specialists.

```
%********************************************************************
% THIS COMMAND PROCEDURE IS PUT TOGETHER AS A PART OF THE
% PROJECT # T6421A TO INTERACTIVELY USE THE ACCIDENT PREDICTION
% AND RESOURCE ALLOCATION PROCEDURES, ETC.
%
% THE PROGRM INTERNALY CALLS THE FOLLOWING
%     -ACPD.NEW PROGRAM FOR COMPUTATION OF PREDICTED ACCIDENTS
%     -RESAL.NEW PROGRAM FOR RESOURCE ALLOCATION PROCEDURE
%     -A DUMMY FILE ABC.XYZ FOR TEMPORARY STORING INPUT DATA
%
% DEVELOPED AT TSC, CAMBRIDGE            NOV/DEC. 1986
%********************************************************************


% ---* DEFINE THE INPUT AND TEMPORARY VARIABLE NAMES *--
%
VARIABLE .TITLE .TEMP  LENGTH 80 STRING;
VARIABLE .SELECT .CHOICE .ACCD .OPTION .N .K .ID1 .ID2  INTEGER ;
VARIABLE .ANS LENGTH 1 STRING;
VARIABLE .STATE LENGTH 2 STRING;
VARIABLE .COUNTY LENGTH 3 STRING;
VARIABLE .CITY .RAILROAD LENGTH 4 STRING;
VARIABLE .S1 .S2 .S3 .BUDGET .C1 .C2 .C3 REAL;
VARIABLE .X1 .X2 .X3 .X4 .X5 .X6 REAL;
VARIABLE .X7 .X8 .X9 .X10 .X11 .X12 REAL;
VARIABLE .STRCONV STRING LENGTH 12 ;

%  ---* PRMPT AND GENERATE HELP SCREEN *---

TYPE ' '
TYPE 'WELCOME TO THE DOT RAIL-HIGHWAY CROSSING '
TYPE 'RESOURCE ALLOCATION PROCEDURE'
TYPE ' '
REQUEST .ANS PROMPT '    DO YOU NEED ANY HELP.? (Y/N) : '
IF (.ANS = 'Y' OR .ANS = 'y' ) THEN BEGIN
TYPE '***********************************************************'
TYPE '*                                                 *'
TYPE '* IN THIS SESSION YOU WILL BE PROMPTED FOR THE VALUES   *'
TYPE '* OF VARIABLES REQUIRED FOR THE REPORT GENERATION.     *'
TYPE '* EACH VARIABLE VALUE ENTERED BY YOU WILL BE CHECKED    *'
TYPE '* FOR ITS ALLOWABLE LIMIT, AND YOU MAY BE PROMPTED TO   *'
TYPE '* REENTER THE VALUE IF IT DOES NOT FALL WITHIN THE      *'
TYPE '* RANGE.                                          *'
TYPE '* FOR THE RESOURCE ALLOCATION OPTION, SOME VARIABLES    *'
TYPE '* HAVE DEFAULT VALUES. THESE VALUES WILL BE DISPLAYED   *'
TYPE '* SO THAT YOU CAN DECIDE WHETHER TO USE THEM OR REPLACE *'
TYPE '* THEM WITH YOUR OWN VALUES.                      *'
TYPE '* BEFORE SUBMITTING THE BATCH JOB FOR REPORT GENERATION *'
TYPE '* ALL PARAMETER VALUES USED IN THE PROGRAM WILL BE      *'
TYPE '* DISPLAYED FOR YOUR VERIFICATION. YOU WILL HAVE THE    *'
```

```
TYPE '* OPTION TO REENTER ALL THE VALUES OR GO AHEAD.        *'
TYPE '* YOU CAN COME OUT OF THIS SESSION BY PRESSING THE     *'
TYPE '* BREAK KEY ANY TIME.                              *'
TYPE '* FOR AN EXPLANATION OF THE RESOURCE ALLOCATION       *'
TYPE "* PROCEDURE, REFER TO THE USER'S GUIDE.             *"
TYPE '*                                           *'
TYPE '************************************************************'

PAUSE  'ENTER GO IF YOU READ THE HELP MESSAGE'
END;


% ---* INITIALIZE THE DEFAULT PARAMETER VALUES *---

@START:
.S1 = .70;  LET .S2= .83; LET .S3 = .69;
.X10= .57;  .X11= .78;  .X12= .63;
.X7= .65;  .X8= .86;  .X9= .65;
.X4= .61;  .X5= .80;  .X6= .69;;
.X1= .75;  .X2= .90;  .X3= .89;
.ANS= '.';  .CITY= '.';  .STATE= '.';  .COUNTY= '.';  .RAILROAD= '.';
.C1= 43800;  .C2= 65300;   .C3= 58700;
.N= 0;  .K= 50        ;
.ID1= 0;  .ID2= 0;

CREATE ACTIVE PARAMS CLEAR

%   ---* GET TITLE FOR THE REPORT *---

TYPE ' ';  TYPE ' ';
REQUEST .TITLE PROMPT 'PLEASE ENTER TITLE TO BE PRINTED ON REPORT: ';
TYPE ' '
LET LINE ('ACTIVE PARAMS',1)='TITLE    : ' .TITLE
TYPE ' '; TYPE ' ';

% ---* PROMPT AND GET THE TYPE OF REPORT DESIRED *---

TYPE 'CHOOSE ONE OF THE OPTIONS LISTED BELOW:';
TYPE ' ';
TYPE'      1      ACCIDENT AND SEVERITY PREDICTION';
TYPE'      2      RESOURCE ALLOCATION';
TYPE ' ';

DO BEGIN
     REQUEST .SELECT PROMPT 'YOUR OPTION CHOICE= ' DEBLANK;
     IF (.SELECT < 1 OR .SELECT > 2) THEN BEGIN
     TYPE 'INVALID CHOICE';
     NEXT;
     END;
END;
IF .SELECT =1 THEN .TEMP= 'ACCIDENT AND SEVERITY PREDICTION'
ELSE .TEMP = 'RESOURCE ALLOCATION';
LET LINE('ACTIVE PARAMS',2) = 'OPTION   : ' .TEMP;
```

```
%  ---* GET THE CHOICE OF GEOGRAPHICAL PARAMETER COMBINATION *---


TYPE ' '; TYPE ' ';
TYPE '    SHOULD THE REPORT BE PREPARED FOR';
TYPE '    A GIVEN: ';
TYPE ' ';
TYPE '         1   STATE, COUNTY, CITY AND RAILROAD';
TYPE '         2   STATE, CITY AND RAILROAD';
TYPE '         3   STATE, COUNTY AND RAILROAD';
TYPE '         4   STATE AND RAILROAD';
TYPE '         5   RAILROAD';
TYPE '         6   STATE';
TYPE '         7   STATE, COUNTY AND CITY';
TYPE '         8   STATE AND CITY';
TYPE '         9   STATE AND COUNTY';
TYPE '         10  GIVEN RANGE OF CROSSING IDs';
TYPE '         11  TOTAL INVENTORY';
TYPE ' '; TYPE ' ';

%  ---* VALIDATE THE COMBINATION DESIRED BY THE USER *---

DO BEGIN
      REQUEST .OPTION PROMPT 'ENTER YOUR CHOICE NUMBER: ';
      IF (.OPTION < 1 OR .OPTION > 11) THEN BEGIN
        TYPE 'INVALID OPTION';
        NEXT;
        END;
      END;

%  ---* GET THE PARAMETER VALUES AND VALIDATE THEM *---

IF .OPTION < 10 THEN BEGIN
TYPE ' ';
IF .OPTION NE 5 THEN DO BEGIN

%  ---* PROMPT FOR STATE CODE AND CHECK VALADITY *---

   REQUEST .STATE PROMPT 'ENTER STATE CODE (2 DIGITS) = ' ;
     IF (.STATE < '01' OR .STATE > '56')THEN BEGIN
     TYPE 'INVALID OPTION';
     NEXT;   END;
TYPE ' '
END;
IF (.OPTION=1 OR (.OPTION=3) OR (.OPTION=7) OR %%
     (.OPTION=9)) THEN DO BEGIN

%  ---* PROMPT FOR COUNTY CODE AND CHECK VALIDITY *---

   REQUEST .COUNTY PROMPT 'ENTER COUNTY CODE (3 DIGITS) = ' ;
     IF (.COUNTY < '01' OR .COUNTY > '9999')THEN BEGIN
     TYPE 'INVALID OPTION';
 NEXT;      END;
TYPE ' '
```

```
END;
IF (.OPTION < 3 OR (.OPTION > 6 AND .OPTION < 9))THEN DO BEGIN

%  ---* PROMPT FOR CITY CODE AND CHECK VALADITY *---

   REQUEST .CITY PROMPT 'ENTER CITY CODE (4 DIGITS) = ' ;
     IF (.CITY < '001' OR .CITY > '999')THEN BEGIN
     TYPE 'INVALID OPTION';
     NEXT;  END;
TYPE ' '
END;
IF .OPTION < 6 THEN  BEGIN

%  ---* PROMPT FOR RAILROAD ID AND CHECK THE VALADITY *---

   REQUEST  .RAILROAD  PROMPT  'ENTER  RAILROAD  CODE  (UP  TO  4
CHARACTERS) = ' ;
   END;
END;

%  ---* GET THE RANGE OF CROSSING REQUIRED FOR REPORT *---

IF .OPTION = 10 THEN BEGIN
TYPE ' ';
@IDSEL:
   REQUEST .ID1 PROMPT 'INTEGER VALUE OF CROSSING ID AT BOTTOM OF
RANGE: '%%
                                                DEBLANK;
   REQUEST .ID2 PROMPT 'INTEGER VALUE OF CROSSING ID AT TOP OF RANGE:
 '%%
                                        DEFAULT .ID1;
IF (.ID1 > .ID2 OR .ID1 > 999999 OR .ID2 > 999999) THEN BEGIN%%
TYPE ' '; TYPE 'INVALID IDs/OR SPECIFIED RANGE';
GO TO @IDSEL;
END;
TYPE ' YOU HAVE ASKED FOR NEARLY ' .ID2- .ID1+ 1 ' CROSSINGS ! '
REQUEST .ANS PROMPT 'DO YOU STILL WANT THESE CROSSINGS? (Y/N) '
IF (.ANS EQ 'Y' OR .ANS EQ 'y') THEN GO TO @RECORD;
GO TO @IDSEL;
END;
@RECORD:

%  ---* COPY THE PARAMETER VALUES TO TEMPORARY FILE *---

LET LINE('ACTIVE PARAMS',3) = 'STATE    : ' .STATE
LET LINE('ACTIVE PARAMS',4) = 'COUNTY   : ' .COUNTY
LET LINE('ACTIVE PARAMS',5) = 'CITY     : ' .CITY
LET LINE('ACTIVE PARAMS',6) = 'RAILROAD : ' .RAILROAD
LET LINE('ACTIVE PARAMS',7) = 'ID1      : ' .ID1
IF(.ID1 EQ 0) THEN LET LINE('ACTIVE PARAMS',7)='ID1     : '
LET LINE('ACTIVE PARAMS',8) = 'ID2      : ' .ID2
IF(.ID2 EQ 0) THEN LET LINE('ACTIVE PARAMS',8)='ID2     : '
TYPE ' '; TYPE ' ';
```

```
%   ---* GET THE TYPE OF SEVERITY DESIRED FOR THE REPORT *---

TYPE 'SHOULD THE MEASURE OF SEVERITY BE:';
TYPE ' ';
TYPE ' 1      PREDICTED ACCIDENTS      ';
TYPE ' 2      PREDICTED FATAL ACCIDENTS ';
TYPE ' 3      COMBINED CASUALTY INDEX ';
TYPE ' ';  TYPE ' ';
DO BEGIN
REQUEST .ACCD PROMPT 'YOUR CHOICE: ' DEBLANK;
IF( .ACCD < 1 OR .ACCD > 3) THEN BEGIN
TYPE 'INVALID ACCD';
NEXT;
END;  END;


IF .ACCD = 1 THEN .TEMP='PREDICTED ACCIDENTS      '
ELSE IF .ACCD = 2 THEN .TEMP= 'PREDICTED FATAL ACCIDENTS'
ELSE .TEMP= 'COMBINED CASUALTY INDEX'
LET LINE('ACTIVE PARAMS',9) = 'SEVERITY  : '.ACCD '- ' .TEMP

IF .ACCD = 3 THEN BEGIN
TYPE ' ';  TYPE ' ';

%   ---* PROMPT & GET VALUE FOR THE FATALITY FACTOR *---

TYPE 'THE DEFAULT FATALITY FACTOR IS  50    '
REQUEST .ANS PROMPT 'SHOULD IT BE USED (Y/N): '
IF (.ANS = 'Y' OR .ANS = 'y') THEN GO TO @LABY;
REQUEST .K PROMPT ' FATALITY FACTOR: ' DEFAULT 50;   END;
@LABY
LET LINE('ACTIVE PARAMS',10) = 'K       : '.K ' -FATALITY FACTOR'
IF(.ACCD NE 3)THEN LET LINE('ACTIVE PARAMS',10)='K       : .'

%   ---* IF RESOURCE ALOCATION IS DESIRED THEN PROMPT FOR *---
%   ---* ADDITIONAL PARAMETERS, ELSE PROMPT FOR NUMBER OF *---
%   ---* RECORDS DESIRED TO BE PRINTED IN THE REPORT     *---

IF (.SELECT EQ 2)THEN GO TO @RESALL;
TYPE ' ';  TYPE ' ';
REQUEST .ANS PROMPT 'SHOULD ALL RECORDS IN SET BE PRINTED (Y/N):';
IF(.ANS EQ 'Y' OR .ANS EQ 'y')THEN GO TO @LABX;
 REQUEST .N PROMPT 'NO. OF RANKED RECORDS DESIRED = :'DEFAULT 100000;;
@LABX:
TYPE ' ';  TYPE ' ';
LET LINE('ACTIVE PARAMS',11) ='N      : '%%
             .N ' - RECORDS TO BE PRINTED';
IF(.N = 0)THEN BEGIN
LET LINE ('ACTIVE PARAMS',11)='N      : ALL '

%   ---* ASSUME 199000 AS THE MAXIMUM NUMBER OF RECORDS *---
%   ---* AVAILBLE IN THE INVENTORY.                     *---

LET .N = 199000
END
```

```
ELSE LET LINE ('ACTIVE PARAMS',11)='N        : ' .N

GO TO @END;


@RESALL:
TYPE ' '; TYPE ' ';
TYPE ' '; TYPE ' ';


% ---*PROMPT GET AND VALIDATE THE TYPE OF EFFECTIVENESS DESIRED *---

TYPE 'WHAT KIND OF EFFECTIVENESS VALUES WOULD YOU LIKE?';
TYPE ' ';
TYPE '       1     STANDARD EFFECTIVENESS';
TYPE '       2     EXTENDED EFFECTIVENESS';
TYPE ' '; TYPE '   ';
@EFFECT:
REQUEST .OPTION PROMPT '       YOUR EFFECTIVENESS CHOICE #: ';
IF .OPTION >2 OR .OPTION < 1 THEN BEGIN
TYPE 'INVALID CHOICE OF EFFECTIVENESS';
GO TO @EFFECT;
END;
IF .OPTION = 1 THEN .TEMP= 'STANDARD EFFECTIVENESS'
ELSE .TEMP= 'EXTENDED EFFECTIVENESS'
LET LINE('ACTIVE PARAMS',12) ='        : '.OPTION '-' .TEMP

TYPE ' '; TYPE ' ';


% ---* DISPLAY STANDARD DEFAULT EFFECTIVENESS VALUES   *---
% ---* AND PROMPT FOR USER'S OPTION TO USE THEM        *---

IF .OPTION = 1 THEN BEGIN
TYPE 'DEFAULT STANDARD EFFECTIVENESS VALUES ARE:'
TYPE ' '
TYPE '      PASSIVE TO FLASHING LIGHT : .70 '
TYPE '      PASSIVE TO GATES          : .83 '
TYPE '      FLASHING LIGHTS TO GATES  : .69 '
TYPE ' '; TYPE ' ';
REQUEST .ANS PROMPT %%
'DO YOU WANT DEFAULT EFFECTIVENESS VALUES TO BE USED (Y/N): ';
  IF (.ANS = 'Y' OR .ANS= 'y') THEN BEGIN
LET LINE('ACTIVE PARAMS',13) ='        : ' .70 ' ' .83 ' ' .69%%
     '-DEFAULT STANDARD EFFECTIVENESS VALUES'; END;
  ELSE BEGIN


% ---* PROMPT AND GET USER DEFINED EFFECTIVENESS VALUES *---

TYPE ' '; TYPE ' ';
TYPE '     EFFECTIVENESS VALUES THAT YOU ENTER MUST BE SPECIFIED'
TYPE '     AS A DECIMAL POINT FOLLOWED BY TWO DIGITS (e.g. .78)'
TYPE ' '; TYPE ' ';
TYPE 'PLEASE ENTER NEW STANDARD EFFECTIVENESS VALUES FOR';
TYPE ' ';
DO BEGIN
```

```
REQUEST .S1 PROMPT 'PASSIVE TO FLASHING LIGHTS: ' DEBLANK;
REQUEST .S2 PROMPT 'PASSIVE TO GATES        : ' DEBLANK;
REQUEST .S3 PROMPT 'FLASHING LIGHTS TO GATES : ' DEBLANK;


%   ---* VALIDATE THE PARAMETERS FOR THEIR IMPLIED RANGE *---

        IF ((.S1 < 0 OR .S1 > 1) OR %%
           (.S2 < 0 OR .S2 > 1) OR %%
           (.S3 < 0 OR .S3 > 1)) THEN BEGIN
        TYPE 'INVALID EFFECTIVENESS VALUES';
        NEXT;
        END;  END;
LET LINE('ACTIVE PARAMS',13) ='       : '.S1 ' '.S2 ' '.S3%%
   ' - STANDARD EFFECTIVENESS VALUES';
 END;  END
ELSE IF (.OPTION = 2 ) THEN BEGIN


%   ---* THE FOLLOWING SECTION APPLIES TO THE EXTENDED EFFECTIVENESS
*---


%   ----* DISPLAY DEFAULT EXTENDED EFFECTIVENESS VALUES *---
%   ---* AND PROMPT FOR USER'S OPTION TO USE THEM        *---
TYPE 'DEFAULT EXTENDED EFFECTIVENESS VALUES ARE: '
TYPE ' '
TYPE '                    TRAINS <=10      TRAINS >=11'
TYPE '                SINGLE    MULTI   SINGLE   MULTI'
TYPE '                TRACK     TRACK   TRACK   TRACK'
TYPE ' '
TYPE '   PASSIVE TO FLASHING: .75       .65      .61     .57'
TYPE '   PASSIVE TO GATES  : .90       .86      .80     .78'
TYPE '   FLASHING TO GATES : .89       .65      .69     .63'
TYPE ' '
TYPE ' '; TYPE ' ';
REQUEST .ANS PROMPT %%
'DO YOU WANT DEFAULT EFFECTIVENESS VALUES TO BE USED (Y/N): ';
  IF (.ANS = 'Y' OR .ANS= 'y') THEN BEGIN


%   ---* COPY THE PARAMETER VALUES TO THE TEMPORARY FILE *---

LET LINE('ACTIVE PARAMS',13.1) = '       : '%%
        'DEFAULT EXTENDED EFFECTIVENESS VALUES';
LET LINE('ACTIVE PARAMS',14) = '       : '.X1 ' '.X2 ' '.X3
LET LINE('ACTIVE PARAMS',16) = '       : '.X4 ' '.X5 ' '.X6
LET LINE('ACTIVE PARAMS',15) = '       : '.X7 ' '.X8 ' '.X9
LET LINE('ACTIVE PARAMS',17) = '       : '.X10 ' '.X11 ' '.X12
END;
ELSE BEGIN
TYPE ' '
TYPE '   EFFECTIVENESS VALUES THAT YOU ENTER MUST BE SPECIFIED'
TYPE '   AS A DECIMAL POINT FOLLOWED BY TWO DIGITS (e.g. .78)'


%   ---* PROMPT GET AND VALIDATE THE 12 USER DEFINED EXTENDED   *---
%   ---*  EFFECTIVENESS VALUES                                  *---
```

```
TYPE ' '; TYPE ' ';
TYPE 'PLEASE ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR';
TYPE 'SINGLE TRACK AND NUMBER OF TRAINS <=10 :';
TYPE ' ';
DO BEGIN
REQUEST .X1 PROMPT 'PASSIVE TO FLASHING LIGHTS: ' DEBLANK;
REQUEST .X2 PROMPT 'PASSIVE TO GATES        : ' DEBLANK;
REQUEST .X3 PROMPT 'FLASHING LIGHTS TO GATES  : ' DEBLANK;
      IF ((.X1 < 0 OR .X1 > 1) OR %%
          (.X2 < 0 OR .X2 > 1) OR %%
          (.X3 < 0 OR .X3 > 1)) THEN BEGIN
TYPE ' '; TYPE ' ';
      TYPE 'INVALID EFFECTIVENESS VALUES';
      NEXT;
      END; END;
LET LINE('ACTIVE PARAMS',14) = '       : '.X1 ' ' .X2 ' ' .X3
TYPE ' '; TYPE ' ';
TYPE 'NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR';
TYPE 'MULTI TRACK AND NUMBER OF TRAINS <=10:';
TYPE ' ';
DO BEGIN
REQUEST .X7 PROMPT 'PASSIVE TO FLASHING LIGHTS: ' DEBLANK;
REQUEST .X8 PROMPT 'PASSIVE TO GATES        : ' DEBLANK;
REQUEST .X9 PROMPT 'FLASHING LIGHTS TO GATES  : ' DEBLANK;
      IF ((.X7 < 0 OR .X7 > 1) OR %%
          (.X8 < 0 OR .X8 > 1) OR %%
          (.X9 < 0 OR .X9 > 1)) THEN BEGIN
TYPE ' '; TYPE ' ';
      TYPE 'INVALID EFFECTIVENESS VALUES';
TYPE ' ';
      NEXT;
      END; END;
LET LINE('ACTIVE PARAMS',15) = '       : '.X7 ' ' .X8 ' ' .X9
TYPE ' '; TYPE ' ';
TYPE 'NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR';
TYPE 'SINGLE TRACK AND NUMBER OF TRAINS >=11:';
TYPE ' ';
DO BEGIN
REQUEST .X4 PROMPT 'PASSIVE TO FLASHING LIGHTS: ' DEBLANK;
REQUEST .X5 PROMPT 'PASSIVE TO GATES        : ' DEBLANK;
REQUEST .X6 PROMPT 'FLASHING LIGHTS TO GATES  : ' DEBLANK;
      IF ((.X4 < 0 OR .X4 > 1) OR %%
          (.X5 < 0 OR .X5 > 1) OR %%
          (.X6 < 0 OR .X6 > 1)) THEN BEGIN
TYPE ' '; TYPE ' ';
      TYPE 'INVALID EFFECTIVENESS VALUES';
TYPE ' ';
      NEXT;
      END; END;
LET LINE('ACTIVE PARAMS',16) = '       : '.X4 ' ' .X5 ' ' .X6
TYPE ' '; TYPE ' ';
TYPE 'NOW ENTER NEW EXTENDED EFFECTIVENESS VALUES FOR';
TYPE 'MULTI TRACK AND NUMBER OF TRAINS >=11:';
TYPE ' ';
```

```
DO BEGIN
REQUEST .X10 PROMPT 'PASSIVE TO FLASHING LIGHTS: ' DEBLANK;
REQUEST .X11 PROMPT 'PASSIVE TO GATES        : ' DEBLANK;
REQUEST .X12 PROMPT 'FLASHING LIGHTS TO GATES  : ' DEBLANK;
      IF ((.X10 < 0 OR .X10 > 1) OR %%
          (.X11 < 0 OR .X11 > 1) OR %%
          (.X12 < 0 OR .X12 > 1)) THEN BEGIN
TYPE ' '; TYPE ' ';
      TYPE 'INVALID EFFECTIVENESS VALUES';
TYPE ' ';
      NEXT;
      END; END;
LET LINE('ACTIVE PARAMS',17) = '        : '.X10 ' ' .X11 ' ' .X12
END;   END;
TYPE ' '; TYPE ' ';


%  ---* DISPLAY DEFAULT VALUES OF UPGRADE COSTS      *---

TYPE 'THE DEFAULT UPGRADE COSTS (IN DOLLARS) ARE: '
TYPE ' '
TYPE '          PASSIVE TO FLASHING LIGHT: 43800  '
TYPE '          PASSIVE TO GATE         : 65300  '
TYPE '          FLASHING LIGHT TO GATE  : 58700  '
TYPE ' '
REQUEST .ANS PROMPT %%
'DO YOU WANT DEFAULT COST VALUES TO BE USED (Y/N): ';

%  ---* PROMPT GET AND VALIDATE THE USER DEFINED     *  ---
%  ---* UPGRADE COSTS.                               *---

  IF (.ANS = 'Y' OR .ANS= 'y') THEN %%
LET LINE('ACTIVE PARAMS',19) = 'C1 C2 C3  : '.C1 ' ' .C2 ' ' .C3%%
    '- DEFAULT UPGRADE COSTS';
ELSE DO BEGIN
TYPE ' ';
TYPE '    ALL COSTS MUST BE IN DOLLARS, SPECIFIED AS INTEGERS '
TYPE '    WITH NO COMMAS (e.g. 43800 FOR FORTY-THREE THOUSAND '
TYPE '    EIGHT HUNDRED DOLLARS) '
TYPE ' '; TYPE ' ';
REQUEST .C1 PROMPT ' COST OF UPGRADE PASSIVE TO FLASHING:   '
REQUEST .C2 PROMPT ' COST OF UPGRADE PASSIVE TO GATES:      '
REQUEST .C3 PROMPT ' COST OF UPGRADE FLASHING TO GATE:      '
      IF (.C1 < 1 OR .C2 < 1 OR .C3 < 1) THEN BEGIN
TYPE ' '
      TYPE 'INVALID UPGRADE COST VALUES';
TYPE ' '
      NEXT;
      END;
LET LINE('ACTIVE PARAMS',19) = 'C1 C2 C3  : '.C1 ' ' .C2 ' ' .C3%%
    '- UPGRADE COSTS';
END;
TYPE ' '; TYPE ' ';
DO BEGIN
```

```
% ---* PROMPT GET AND VALIDATE THE $ VALUE OF AVAILABLE BUDGET *---

REQUEST .BUDGET PROMPT ' ENTER DOLLAR AMOUNT OF AVAILABLE BUDGET: '
;
IF (.BUDGET < 1) THEN BEGIN
TYPE ' '
 TYPE 'INVALID BUDGET AMOUNT'
TYPE ' ';
NEXT
END; END;
LET LINE('ACTIVE PARAMS',18) = 'BUDGET   : '.BUDGET

@END:

% ---* SAVE ALL INPUT PARAMETERS IN TEMPORARY FILE ABC.XYZ *---

QUIET: RESAVE ACTIVE PARAMS AS ABC.XYZ;
TYPE ' '; TYPE ' ';
REQUEST .ANS PROMPT %%
'DO YOU WANT TO LOOK AT THE DATA ENTERED BY YOU (Y/N): ';
IF (.ANS = 'Y' OR .ANS = 'y') THEN BEGIN
TYPE ' '; TYPE ' ';

% ---* DISPLAY ALL THE PARAMETER VALUES SELECTED FOR USE *---
% ---* IN THE REPORT PREPRATION                          *---

TYPE '      VARIABLE NAME      VALUE'
TYPE ' '; TYPE ' ';
USE ACTIVE A FROM ABC.XYZ CLR;
LIST ACTIVE A UNN;
TYPE ' '; TYPE ' ';
END;

% ---* IF CHANGE IN PARAMETER VALUES IS REQUIRED THEN *---
% ---* START THE PROMPTING PROCEDURE FROM BEGINING    *---

@CHANGE:
REQUEST .ANS PROMPT %%
 'DO YOU WANT TO CHANGE ANY OF THE PARAMETERS? (Y/N): '
IF (.ANS = 'Y' OR .ANS = 'y') THEN GO TO @START
IF .SELECT= 1 THEN BEGIN

% ---* THE PARAMETER VALUES ARE CONVERTED TO A STRING *---
% ---* VARIABLE AND PASSED ON TO THE ACCIDENT         *---
% ---* PREDICTION/ RESOURCE ALLOCATION PROGRAM        *---

USE ACTIVE B FROM ACPD.NEW CLR;     END;
ELSE BEGIN
USE ACTIVE B FROM RESAL.NEW CLR;     END;
QUIET: CHANGE 'STATEVAL' TO .STATE IN 51/L ACTIVE B;
QUIET: CHANGE 'COUNTVAL' TO .COUNTY IN 51/L ACTIVE B;
QUIET: CHANGE 'RAILVAL' TO .RAILROAD IN 51/L ACTIVE B;
QUIET: CHANGE 'CITYVAL' TO .CITY IN 51/L ACTIVE B;
.STRCONV = .ID1
```

```
QUIET: CHANGE 'ID1VAL' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .ID2
QUIET: CHANGE 'ID2VAL' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .SELECT
QUIET: CHANGE 'SELVAL' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .OPTION
QUIET: CHANGE 'OPTVAL' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .ACCD
QUIET: CHANGE 'ACCVAL' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .C1
QUIET: CHANGE 'CS1' TO .STRCONV IN 51/L ACTIVE B
.STRCONV= .C2
QUIET: CHANGE 'CS2' TO .STRCONV IN 51/L ACTIVE B
.STRCONV= .C3
QUIET: CHANGE 'CS3' TO .STRCONV IN 51/L ACTIVE B
.STRCONV = .S1
QUIET: CHANGE 'S1' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .S2
QUIET: CHANGE 'S2' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .S3
QUIET: CHANGE 'S3' TO .STRCONV IN 51/L ACTIVE B
.STRCONV= .X4
QUIET: CHANGE 'X4' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X5
QUIET: CHANGE 'X5' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X6
QUIET: CHANGE 'X6' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X7
QUIET: CHANGE 'X7' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X8
QUIET: CHANGE 'X8' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X9
QUIET: CHANGE 'X9' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X10
QUIET: CHANGE 'X10' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X11
QUIET: CHANGE 'X11' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X12
QUIET: CHANGE 'X12' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X1
QUIET: CHANGE 'X1' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X2
QUIET: CHANGE 'X2' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .X3
QUIET: CHANGE 'X3' TO .STRCONV IN 51/L ACTIVE B;
.STRCONV= .K
QUIET: CHANGE 'KK' TO .STRCONV IN 51/L ACTIVE B
.STRCONV= .N
QUIET: CHANGE 'NN' TO .STRCONV IN 51/L ACTIVE B
.STRCONV= .BUDGET
QUIET: CHANGE 'BUDGETX' TO .STRCONV IN 51/L ACTIVE B
QUIET: CHANGE 'TITVAL' TO .TITLE IN 51/L ACTIVE B;
TYPE ' ';
```

```
%  ---* CHECK IF THE JOB IS TO BE SUBMITTED FOR DISCOUNT RUN *---

REQUEST .ANS PROMPT %%
     'SHOULD THE JOB BE SUBMITTED FOR DISCOUNT RUN? (Y/N): ';
IF (.ANS= 'Y' OR .ANS = 'y') THEN %%
%  ---* SUBMIT THE BATCH JOB                        *---
RUN ACTIVE B UNN HOLD DISCOUNT
ELSE RUN ACTIVE B UNN HOLD;

%  ---* CHECK IF ANOTHER JOB IS REQUIRED TO BE SUBMITTED    *---
%  ---* IF SO, RESTART THE PROCESS FROM THE BEGINNING      *---

REQUEST .ANS PROMPT 'DO YOU WISH TO SUBMIT ANOTHER JOB (Y/N): '
IF (.ANS = 'Y' OR .ANS = 'y') THEN GO TO @START
```

5. REFERENCES

1. "Summary of the DOT Rail-Highway Crossing Resource Allocation Procedure-Revised", U.S. Department of Transportation, Federal Railroad Administration, Washington, DC 20590, Report No, DOT-TSC-FRA-86-2, to be published in 1987.

2. "Rail-Highway Crossing Resource Allocation Procedure-User's Guide, Third Edition", U.S. Department of Transportation, Federal Railroad Administration, Washington, DC 20590, Report No. DOT-TSC-FRA-87-1, to be published in 1987.

3. "Rail-Highway Crossing Accident/Incident and Inventory Bulletin", U.S. Department of Transportation, Federal Railroad Administrator, Washington, DC 20590, Report No. 7, June 1985, page 39.

APPENDIX A

The symbols used in Section 2 are defined below:

c = Highway vehicles per day (AADT)

t = Total Train Movements per day

d = Day thru trains per day

ms = Maximum timetable speed

hp = Highway paved

mt = Main tracks

hl = Highway lanes

ht = Highway type

a = Unnormalized predicted accidents (from basic formula)

ts = Total switch trains per day

tt = Total thru trains per day

ur = Urban/rural

tk = Total tracks

T = Years of accident history (usually T = 5)

N = Number of accidents in T years

A = Final predicted accidents per year

PD = Prediction Factor

PW = Power factor

C = Constant

D = Constant

PC(FA|A) = Probability of a fatal accident given that an accident occurred

PC(CA|A) = Probability of a casualty accident given that an accident occurred

FA = Fatal accidents per year

CA = Casualty accidents per year

k = Fatality factor

CCI = Combined casualty index