

The Likelihood of Human Casualty in Highway Crashes

8th Briefing: Summary and Evaluation

**Based on an Investigation Conducted for
the FHWA/NHTSA Crash Analysis Center
at George Washington University, Virginia**

**August 28, 1996
DeBlois Associates
Washington, D.C.**

"The Likelihood of Casualty in Highway Crashes"

Introduction

This is the eight briefing concerning the cited subject. Work reported here: (a) summarizes work reported in earlier briefings; (b) presents algorithms of casualty occurrence with as much resolution as currently available data allow; and (c) evaluates the predictive and sensitivity merits of said algorithms.

Except for an expansion and quality control of the so called "compelling injuries", all data and data processing used in this briefing are as described in earlier briefings. However, it is always pointed out, if and when the analytical approaches differ from earlier versions. When differences between this and earlier briefings are encountered, the methods and results appearing in this Summary Report supercede all earlier methods and results.

Raw Data

The data compiled in the eight years, 1988-1995, of NASS/CDS are the basic data used. The NASS weights are used as weighing factors in any data processing procedure. As per suggestion of the NCSA Math Analysis Division, a "weight trimming" is applied in order to eliminate observations with a suspiciously high weight.

Specifically, observations with a weight exceeding the 98th percentile weight are excluded from consideration. Note that the processed results are not very sensitive to the introduction of "weight trimming" or to the specific value selected from trimming.

"Compelling Injuries"

In the absence of a better name, we use: "Compelling Injuries" for the characterization of a class of injuries suggested by emergency physicians, e.g. by Dr. H. Champion in August 1996, as deserving top emergency medical attention. A list of these injuries is presented in the Appendix, following the coding convention of the AIS-90 protocol. The three years, 1993-1995, of NASS/CDS are the basic data used for the compilation of compelling injuries, by reason of availability of such coding only in the cited NASS years.

Harm

Among the most important attributes used for resolution in this investigation are the injury and outcome severity. For this purpose we distinguish: fatalities, and injured survivors by severity of the most severe injury (MAIS), i.e. maximum rating in the Abbreviated Injury Scale (AIS).

Given that these descriptors are not directly additive due to the highly nonhomogeneous consequences associated with each level of severity, we adopt the concept of "harm" as an integrator of these very different consequences.

Harm is essentially a weighed sum of fatal outcomes, injured survivors, and other losses incurred in crashes. The weights in this summation are scaled essentially in accordance with the monetary and other costs of these losses. As is possible with straight casualty counts, harm also can be partitioned according to various classification attributes of crashes, crash involved vehicles, and people in the crash.

Because of their unusual complexity, the quantification of crash consequences and the assignment of monetary and other costs to such consequences are still tentative. This is especially true when a comprehensive coverage is desired.

More complex than the evaluation of fatal outcomes is the evaluation of costs for less severe outcomes which, although less severe, are much more frequent. For example, neither sufficient data nor adequate analyses are available yet for addressing and quantifying the consequences for crash survivors injured by multiple injuries. For this reason, the analyses performed in this investigation are based on an injured person's most severe injury.

With the provisions discussed above, we have adopted the comprehensive costs published recently by the NHTSA (see Appendix A, in "The Economic Costs of Motor Vehicle Crashes", NHTSA, July 1996) as weighing factors in this investigation. The specific schedule of costs under consideration is shown in Table XXIII below.

The cited costs include the strictly economic costs, plus a valuation of the less tangible costs of reduced functional capacity and diminished quality of life of survivors and their families.

Table XXIII

Injury Outcome	Cost in '94\$
Survived MAIS 1	\$10,840
MAIS 2	\$133,700
MAIS 3	\$472,290
MAIS 4	\$1,193,860
MAIS 5	\$2,509,310
Fatality	\$2,854,500

Incidence of Car Crashes, Casualties, and Harm

Specifically presented here is the incidence (U.S. counts per year) of cars involved in towaway crashes, and of involved occupants, injured occupants, incurred injuries by severity, and overall harm, as a function of most influential attributes, such as crash severity. The basic U.S. counts per year are shown below:

Table XXIV

	U.S. Counts per Year	
	1988-1995	1993-1995
Population		
Towaway Cars	1,850,000	1,600,000
Involved Occupants	2,820,000	2,440,000
Injured Occupants	1,390,000	1,200,000
Seriously Injured	172,700	158,260
w Compelling Injury	-	49,000
Overall Harm	\$139B	\$120B

Seriously injured occupants are those with MAIS 3+ and/or hospitalized. The noticeable difference of casualty counts and harm, between the two shown time frames, originates from the fact that incidence of casualties was higher in pre-93 years.

Resolution by Crash Severity

Car crash frequency, the probability of serious casualty (fatality or MAIS 3+) in a car crash, and the overall harm incurred by occupants are strongly influenced by crash severity, delta v.. These functions are illustrated in Figs 87 and 88.

The "needle in a haystack" impression conveyed by Fig. 87, should be tempered by the results of Fig. 88 showing how rapidly harm is rising as crash severity increases: 50% of cumulative harm at about 20 mph delta V, over 75% cumulative harm at about 30 mph, notwithstanding the fact that the probability of individual casualty occurrence is relatively small and rises slowly.

Occupant Populations and Harm Resolved

For further perspective, occupant populations according to occurrence and nature (compelling or not) of the injury, are resolved among injury severities, Fig. 89, and outcome severities, Fig. 91. Similar resolutions for the harm to the cited occupants are shown in Figs 90 and 92.

The Projection of Casualty Probabilities

Many outcomes and their severity may be considered individually or in combinations for the purpose of casualty projection in towaway car crashes. Four car related and five occupant related probabilities are addressed in this investigation. The four car related probabilities are:

C1 the probability of a crash involved car with at least one occupant incurring an injury of severity 1+, including fatality;

C2 the probability of a crash involved car with at least one occupant incurring an injury of severity 2+, including fatality;

C3 the probability of a crash involved car with at least one occupant incurring an injury of severity 3+, including fatality;

CK the probability of a crash involved car with at least one occupant fatality;

and the five occupant related probabilities are:

O1 the probability of a crash involved occupant with at least one injury of MAIS 1+;

O2 the probability of a crash involved occupant with at least one injury of MAIS 2+;

O3 the probability of a crash involved occupant with at least one injury of MAIS 3+;

OC the probability of a crash involved occupant with at least one compelling injury; and

OK the probability of a crash involved occupant being a fatality.

Probability Predictors

Many crash, car, occupant, and injury attributes are in principle available in the accident experience to assist in the derivation of algorithms that predict one or more of the cited probabilities, on the basis of values assumed by the predictors.

The number and type of predictors are often limited by practical considerations imposed by: (a) the type of contemplated application of an algorithm; (b) the strength of probability--predictor correlation; and (c) the amount and quality of available data for the derivation of the algorithms.

Currently, the probabilities: C1, C2, C3, and CH are predicted on the basis of the few attributes to be obtained from the near term applications of the Automated Collision Notification (ACN) system. These include a car's:

Delta V in Planar Crashes,
Direction of Force in Planar Crashes,
Rollover Occurrence, by Quarter Turns, and
Pre-Crash Travel Speed (possibly).

In future applications, a much larger pool of predictors could be made available, either at the time of the crash, by more sophisticated ACN systems and/or by on the scene observation.

Occupant's Age and Gender,
Restraint Use, and Type,
Seating Position,
Ejection Occurrence,
General Area of Damage in Addition to Force Direction,
Extent of Damage,
Specific Horizontal and Vertical Location of the Crush,
Crush Distribution,
Size, Shape, and Rigidity of Collision Partner,
Car Weight or Make, Model, and Model Year as Surrogates
Door Opening, and Other.

Most of the cited predictors, in either of the above categories, have been assumed to be available in this investigation for the purpose of deriving algorithms concerning the occupant related probabilities: O1, O2, O3, OC, and OK.

Nominal Procedure for Processing the Raw Data

In view of the dichotomous outcome under consideration (e.g. "Yes" or "No" Fatality or MAIS 3+) a maximum likelihood procedure, specifically a logistic regression with weighing factors, is used to fit various models to the raw data. Essentially, the probability of casualty is modeled as:

$$P = 1 / [1 + \exp(-w)] \quad (1)$$

$$\text{where } w = A_0 + A_1*x_1 + A_2*x_2 + \text{etc}; \quad (2)$$

where x_1 , x_2 , etc are the selected predictors; and A_0 , A_1 , A_2 , etc are coefficients estimated by the logistic regression.

The logistic regression also provides the covariance matrix that is needed for the estimation of variance and thus the standard error, SEP, of any predicted probability value, P.

When dealing with analyses of data from the NASS, it must be taken into account that this file contains a sample as opposed to a census of national data. In order to deal with this, the applicable statistical procedures are those prescribed in "Survey Data Analysis" (SUDAAN) software, Research Triangle Institute, Research Triangle Park, North Carolina, 1992. Such procedures are applicable in the analysis of data from multi-stage sample designs, like that of the NASS.

Estimation of Standard Errors and Confidence Bounds

The SUDAAN logistic procedure yields values for coefficients: A_0 , A_1 , A_2 , etc appearing in (2). The same procedure provides also the covariance matrix: $\text{COV}(A_i, A_j)$. This helps in the calculation of the variance of the argument w of the probability appearing in (1). Specifically, the variance of w is given by:

$$\text{var}(w) = \text{Sum}[\text{Cov}(A_i, A_j)*x_i*x_j] \quad \text{over all } i \text{ and } j \quad (3)$$

Note that i or j assume the values: 0, 1, 2, etc, corresponding to the intercept and the predictors appearing in relation (2). When an analyst assigns desirable values to x_i and x_j , an application of (3) yields the variance: $\text{var}(w)$.

To a first approximation the variance of the probability (1) is given by:

$$\text{var}(P) = (\exp(-2w) / [1 + \exp(-w)]^{**4}) * \text{var}(w) \quad (4)$$

and the standard error of P is:

$$seP = \text{square root } [\text{var}(P)] \quad (5)$$

Also to a first approximation, the 95% confidence bounds of P are given by: $P +/-(1.96 * seP)$

Programmable Algorithms for C1, C2, C3, and CK

Each of these car based probabilities is given by:

$$P = 1 / [1 + \exp(-w)] \quad (6)$$

w = A0 + A1*DVTOTAL + A2*DOFF + A3*DOFS where

DVTOTAL = Total Delta V in mph Continuously;
 DOFF=1 if Direction of Force is 11 to 1 O'Clock; else DOFF=0;
 DOFS=1 if Direction of Force is (8 to 10) or (2 to 4);
 else DOFS=0;
 DOFF=0 & DOFS=0 if Direction of Force is 5 to 7.

Coefficients for C1 (car with MAIS 1+)

Predictor	A	Std Err	Probabil. of A=0
Intercept	-2.18	0.12	0.0000
DVTOTAL	0.18	0.01	0.0000
DOFF	0.49	0.08	0.0000
DOFS	1.01	0.09	0.0000

Coefficients for C2 (car with MAIS 2+)

Intercept	-4.10	0.13	0.0000
DVTOTAL	0.15	0.01	0.0000
DOFF	0.59	0.09	0.0000
DOFS	1.04	0.10	0.0000

Coefficients for C3 (car with MAIS 3+)

Intercept	-6.06	0.15	0.0000
DVTOTAL	0.19	0.01	0.0000
DOFF	0.90	0.11	0.0000
DOFS	1.48	0.12	0.0000

Coefficients for CK (car with Fatality)

Predictor	A	Std Err	Probabil. of A=0
Intercept	-9.05	0.30	0.0000
DVTOTAL	0.20	0.01	0.0000
DOFF	0.51	0.26	0.0485
DOFS	1.78	0.27	0.0000

Programmable Algorithms for O1, O2, O3, OC, & OK

Each of these occupant based probabilities is given by:

$$P = 1 / [1 + \exp(-w)] \quad (7)$$

$$w = A_0 + A_1*DVTOTAL + A_2*SINGLE + A_3*ROLL + A_4*GADF + A_5*GADS \\ A_6*EXT1 + A_7*EXT2 + A_8*EXT3 + A_9*EXT4 + A_{10}*OCCRE + \\ A_{11}*AGE + A_{12}*GENDER + A_{13}*EJC + A_{14}*EJP$$

where

DVTOTAL = Total Delta V in mph Continuously;
 SINGLE=1 if this is a Single Vehicle Crash; else SINGLE=0;
 ROLL=1 if Car Rollover occurs; else ROLL=0;
 GADF=1 if the Area of Damage is Frontal; else GADF=0;
 GADS=1 if the Area of Damage is Side; else GADS=0;
 GADF=0 & GADS=0 if the Area of Damage is Rear;
 EXT1=1 if the Extent of Damage is Zone 1; else EXT1=0;
 EXT2=1 if the Extent of Damage is Zone 2; else EXT2=0;
 EXT3=1 if the Extent of Damage is Zone 3; else EXT3=0;
 EXT4=1 if the Extent of Damage is Zone 4; else EXT4=0;
 EXT1=EXT2=EXT3=EXT4=0 if the Extent of Damage is 5+;
 OCCRE=1 if the Occupant is Restrained; else OCCRE=0;
 AGE = Occupant's Age in Years Continuously;
 GENDER=1 if the occupant is a Male; else GENDER=0;
 EJC=1 if a Complete Ejection occurs; else EJC=0;
 EJP=1 if a Partial Ejection occurs; else EJP=0;
 EJC=EJP=0 if No Ejection Occurs.

The coefficients needed for an application of (7) are given below, for each of the five probabilities at issue, i.e. for an occupant injured at MAIS 1+, MAIS 2+, MAIS 3+, with a compelling injury, and fatally injured.

Logistic Regression Coefficients for MAIS=1+

Predictor	A	Std Err	Probabil. of A=0
Intercept	-1.44	0.15	0.0000
TOTALDV	0.14	0.01	0.0000
SINGLE	0.09	0.09	0.3096
ROLL	1.24	0.48	0.0098
GADF	0.60	0.08	0.0000
GADS	0.70	0.09	0.0000
EXT1	-0.30	0.12	0.0113
EXT2	-0.00	0.12	0.9939
EXT3	0.21	0.13	0.1093
EXT4	0.21	0.17	0.2177
OCCRE	-0.71	0.06	0.0000
AGE	0.01	0.00	0.0000
GENDER	-0.73	0.05	0.0000
EJC	3.97	0.30	0.0000
EJP	3.12	0.20	0.0000

Logistic Regression Coefficients for MAIS=2+

Predictor	A	Std Err	Probabil. of A=0
Intercept	-3.97	0.16	0.0000
TOTALDV	0.12	0.01	0.0000
SINGLE	0.30	0.08	0.0002
ROLL	0.98	0.23	0.0000
GADF	0.98	0.13	0.0000
GADS	1.07	0.12	0.0000
EXT1	-0.72	0.15	0.0000
EXT2	-0.57	0.13	0.0000
EXT3	-0.10	0.12	0.4137
EXT4	0.25	0.15	0.0877
OCCRE	-0.64	0.06	0.0000
AGE	0.02	0.00	0.0000
GENDER	-0.30	0.06	0.0000
EJC	2.31	0.39	0.0000
EJP	1.36	0.33	0.0000

Logistic Regression Coefficients for MAIS=3+

Predictor	A	Std Err	Probabil. of A=0
Intercept	-6.73	0.21	0.0000
TOTALDV	0.16	0.01	0.0000
SINGLE	0.47	0.10	0.0000
ROLL	1.21	0.22	0.0000
GADF	2.02	0.18	0.0000
GADS	2.10	0.17	0.0000
EXT1	-1.46	0.19	0.0000
EXT2	-0.96	0.14	0.0000
EXT3	-0.52	0.14	0.0002
EXT4	-0.14	0.16	0.3686
OCCRE	-0.64	0.07	0.0000
AGE	0.03	0.00	0.0000
GENDER	-0.37	0.07	0.0000
EJC	3.11	0.35	0.0000
EJP	1.65	0.28	0.0000

Coefficients for Compelling Injury

Predictor	A	Std Err	Probabil. of A=0
Intercept	-7.95	0.66	0.0000
TOTALDV	0.12	0.01	0.0000
SINGLE	0.38	0.25	0.1274
ROLL	0.86	0.67	0.1997
GADF	2.42	0.38	0.0000
GADS	2.83	0.40	0.0000
EXT1	-2.99	0.35	0.0000
EXT2	-1.49	0.25	0.0000
EXT3	-0.81	0.25	0.0011
EXT4	0.21	0.29	0.4709
OCCRE	-0.55	0.18	0.0022
AGE	0.04	0.00	0.0000
GENDER	2.24	0.47	0.0000
EJC	2.24	0.47	0.0000
EJP	1.15	0.49	0.0199

Coefficients for Fatality Occurrence

Predictor	A	Std Err	Probabil. of A=0
Intercept	-10.28	0.42	0.0000
TOTALDV	0.14	0.01	0.0000
SINGLE	0.20	0.22	0.3636
ROLL	0.61	0.29	0.0375
GADF	3.01	0.33	0.0000
GADS	3.44	0.33	0.0000
EXT1	-3.74	0.47	0.0000
EXT2	-2.73	0.23	0.0000
EXT3	-1.57	0.21	0.0000
EXT4	-0.92	0.23	0.0001
OCCRE	-0.70	0.15	0.0000
AGE	0.05	0.00	0.0000
GENDER	-0.37	0.15	0.0125
EJC	3.03	0.36	0.0000
EJP	1.76	0.34	0.0000

Illustrative Results

Illustrative results concerning probability projections and algorithm evaluations are presented in Tables XXV to XXX and in Figures 93 to 99.

Table XXV. Evaluation of Algorithm for Cars with MAIS 1+

Prob Level	Correct		Incorrect			Percentages				
	Event	Non- Event	Event	Non- Event	Event	Correct	Sensi- tivity	Speci- ficity	False POS	False NEG
0.100	14291	0	3169	0	81.8	100.0	0.0	18.2	.	
0.120	14290	0	3169	1	81.8	100.0	0.0	18.2	100.0	
0.140	14289	3	3166	2	81.9	100.0	0.1	18.1	40.0	
0.160	14288	3	3166	3	81.8	100.0	0.1	18.1	50.0	
0.180	14288	5	3164	3	81.9	100.0	0.2	18.1	37.5	
0.200	14281	8	3161	10	81.8	99.9	0.3	18.1	55.6	
0.220	14272	30	3139	19	81.9	99.9	0.9	18.0	38.8	
0.240	14271	30	3139	20	81.9	99.9	0.9	18.0	40.0	
0.260	14248	56	3113	43	81.9	99.7	1.8	17.9	43.4	
0.280	14233	74	3095	58	81.9	99.6	2.3	17.9	43.9	
0.300	14200	110	3059	91	82.0	99.4	3.5	17.7	45.3	
0.320	14176	139	3030	115	82.0	99.2	4.4	17.6	45.3	
0.340	14122	186	2983	169	81.9	98.8	5.9	17.4	47.6	
0.360	14049	253	2916	242	81.9	98.3	8.0	17.2	48.9	
0.380	13942	329	2840	349	81.7	97.6	10.4	16.9	51.5	
0.400	13770	442	2727	521	81.4	96.4	13.9	16.5	54.1	
0.420	13674	523	2646	617	81.3	95.7	16.5	16.2	54.1	
0.440	13486	665	2504	805	81.0	94.4	21.0	15.7	54.8	
0.460	13331	764	2405	960	80.7	93.3	24.1	15.3	55.7	
0.480	13255	819	2350	1036	80.6	92.8	25.8	15.1	55.8	
0.500	12797	1101	2068	1494	79.6	89.5	34.7	13.9	57.6	
0.520	12793	1101	2068	1498	79.6	89.5	34.7	13.9	57.6	
0.540	12254	1425	1744	2037	78.3	85.7	45.0	12.5	58.8	
0.560	12254	1425	1744	2037	78.3	85.7	45.0	12.5	58.8	
0.580	11681	1708	1461	2610	76.7	81.7	53.9	11.1	60.4	
0.600	11506	1780	1389	2785	76.1	80.5	56.2	10.8	61.0	
0.620	10776	1999	1170	3515	73.2	75.4	63.1	9.8	63.7	
0.640	10630	2049	1120	3661	72.6	74.4	64.7	9.5	64.1	
0.660	9995	2227	942	4296	70.0	69.9	70.3	8.6	65.9	
0.680	9833	2271	898	4458	69.3	68.8	71.7	8.4	66.3	
0.700	9038	2447	722	5253	65.8	63.2	77.2	7.4	68.2	
0.720	8871	2489	680	5420	65.1	62.1	78.5	7.1	68.5	
0.740	8047	2635	534	6244	61.2	56.3	83.1	6.2	70.3	
0.760	8047	2639	530	6244	61.2	56.3	83.3	6.2	70.3	
0.780	7147	2765	404	7144	56.8	50.0	87.3	5.4	72.1	
0.800	6372	2856	313	7919	52.9	44.6	90.1	4.7	73.5	
0.820	6084	2880	289	8207	51.3	42.6	90.9	4.5	74.0	
0.840	5579	2932	237	8712	48.7	39.0	92.5	4.1	74.8	
0.860	4877	2998	171	9414	45.1	34.1	94.6	3.4	75.8	
0.880	4327	3034	135	9964	42.2	30.3	95.7	3.0	76.7	
0.900	3764	3069	100	10527	39.1	26.3	96.8	2.6	77.4	
0.920	2898	3109	60	11393	34.4	20.3	98.1	2.0	78.6	
0.940	2462	3133	36	11829	32.0	17.2	98.9	1.4	79.1	
0.960	1603	3148	21	12688	27.2	11.2	99.3	1.3	80.1	
0.980	897	3164	5	13394	23.3	6.3	99.8	0.6	80.9	
1.000	0	3169	0	14291	18.2	0.0	100.0	.	81.8	

Table XXVI. Evaluation of Algorithm for Cars with MAIS 2+

Prob Level	Correct		Incorrect		Percentages				
	Event	Non- Event	Event	Non- Event	Correct	Sensi- tivity	Speci- ficity	False POS	False NEG
0.000	7214	0	10246	0	41.3	100.0	0.0	58.7	.
0.020	7214	1	10245	0	41.3	100.0	0.0	58.7	0.0
0.040	7202	80	10166	12	41.7	99.8	0.8	58.5	13.0
0.060	7145	470	9776	69	43.6	99.0	4.6	57.8	12.8
0.080	7049	1229	9017	165	47.4	97.7	12.0	56.1	11.8
0.100	6957	1731	8515	257	49.8	96.4	16.9	55.0	12.9
0.120	6650	3152	7094	564	56.1	92.2	30.8	51.6	15.2
0.140	6440	3987	6259	774	59.7	89.3	38.9	49.3	16.3
0.160	6155	4857	5389	1059	63.1	85.3	47.4	46.7	17.9
0.180	5880	5604	4642	1334	65.8	81.5	54.7	44.1	19.2
0.200	5523	6379	3867	1691	68.2	76.6	62.3	41.2	21.0
0.220	5166	7022	3224	2048	69.8	71.6	68.5	38.4	22.6
0.240	5166	7022	3224	2048	69.8	71.6	68.5	38.4	22.6
0.260	4811	7615	2631	2403	71.2	66.7	74.3	35.4	24.0
0.280	4390	8197	2049	2824	72.1	60.9	80.0	31.8	25.6
0.300	4390	8197	2049	2824	72.1	60.9	80.0	31.8	25.6
0.320	4030	8560	1686	3184	72.1	55.9	83.5	29.5	27.1
0.340	3630	8910	1336	3584	71.8	50.3	87.0	26.9	28.7
0.360	3630	8910	1336	3584	71.8	50.3	87.0	26.9	28.7
0.380	3275	9162	1084	3939	71.2	45.4	89.4	24.9	30.1
0.400	3275	9162	1084	3939	71.2	45.4	89.4	24.9	30.1
0.420	2959	9407	839	4255	70.8	41.0	91.8	22.1	31.1
0.440	2959	9407	839	4255	70.8	41.0	91.8	22.1	31.1
0.460	2617	9597	649	4597	70.0	36.3	93.7	19.9	32.4
0.480	2460	9675	571	4754	69.5	34.1	94.4	18.8	32.9
0.500	2355	9738	508	4859	69.3	32.6	95.0	17.7	33.3
0.520	2082	9869	377	5132	68.4	28.9	96.3	15.3	34.2
0.540	2082	9869	377	5132	68.4	28.9	96.3	15.3	34.2
0.560	1795	9957	289	5419	67.3	24.9	97.2	13.9	35.2
0.580	1795	9957	289	5419	67.3	24.9	97.2	13.9	35.2
0.600	1615	10022	224	5599	66.6	22.4	97.8	12.2	35.8
0.620	1615	10022	224	5599	66.6	22.4	97.8	12.2	35.8
0.640	1387	10072	174	5827	65.6	19.2	98.3	11.1	36.7
0.660	1279	10097	149	5935	65.2	17.7	98.5	10.4	37.0
0.680	1203	10114	132	6011	64.8	16.7	98.7	9.9	37.3
0.700	1060	10150	96	6154	64.2	14.7	99.1	8.3	37.7
0.720	1060	10150	96	6154	64.2	14.7	99.1	8.3	37.7
0.740	904	10166	80	6310	63.4	12.5	99.2	8.1	38.3
0.760	803	10187	59	6411	62.9	11.1	99.4	6.8	38.6
0.780	685	10200	46	6529	62.3	9.5	99.6	6.3	39.0
0.800	685	10202	44	6529	62.4	9.5	99.6	6.0	39.0
0.820	606	10215	31	6608	62.0	8.4	99.7	4.9	39.3

0.840	524	10223	23	6690	61.6	7.3	99.8	4.2	39.6
0.860	456	10226	20	6758	61.2	6.3	99.8	4.2	39.8
0.880	399	10232	14	6815	60.9	5.5	99.9	3.4	40.0
0.900	296	10239	7	6918	60.3	4.1	99.9	2.3	40.3
0.920	254	10239	7	6960	60.1	3.5	99.9	2.7	40.5
0.940	166	10241	5	7048	59.6	2.3	100.0	2.9	40.8
0.960	118	10243	3	7096	59.3	1.6	100.0	2.5	40.9
0.980	62	10244	2	7152	59.0	0.9	100.0	3.1	41.1
1.000	0	10246	0	7214	58.7	0.0	100.0	.	41.3

Table XXVII. Evaluation of Algorithm for Cars with MAIS 3+

Prob Level	Correct		Incorrect		Percentages				
	Event	Non- Event	Event	Non- Event	Correct	Sensi- tivity	Speci- ficity	False POS	False NEG
0.000	5085	0	12375	0	29.1	100.0	0.0	70.9	.
0.020	5046	1070	11305	39	35.0	99.2	8.6	69.1	3.5
0.040	4830	3657	8718	255	48.6	95.0	29.6	64.3	6.5
0.060	4576	5616	6759	509	58.4	90.0	45.4	59.6	8.3
0.080	4238	7408	4967	847	66.7	83.3	59.9	54.0	10.3
0.100	4044	8138	4237	1041	69.8	79.5	65.8	51.2	11.3
0.120	3820	8890	3485	1265	72.8	75.1	71.8	47.7	12.5
0.140	3558	9594	2781	1527	75.3	70.0	77.5	43.9	13.7
0.160	3305	10046	2329	1780	76.5	65.0	81.2	41.3	15.1
0.180	3044	10454	1921	2041	77.3	59.9	84.5	38.7	16.3
0.200	3006	10518	1857	2079	77.5	59.1	85.0	38.2	16.5
0.220	2764	10846	1529	2321	77.9	54.4	87.6	35.6	17.6
0.240	2549	11126	1249	2536	78.3	50.1	89.9	32.9	18.6
0.260	2532	11149	1226	2553	78.4	49.8	90.1	32.6	18.6
0.280	2293	11402	973	2792	78.4	45.1	92.1	29.8	19.7
0.300	2268	11432	943	2817	78.5	44.6	92.4	29.4	19.8
0.320	2086	11598	777	2999	78.4	41.0	93.7	27.1	20.5
0.340	2065	11616	759	3020	78.4	40.6	93.9	26.9	20.6
0.360	1855	11771	604	3230	78.0	36.5	95.1	24.6	21.5
0.380	1828	11787	588	3257	78.0	35.9	95.2	24.3	21.6
0.400	1686	11847	528	3399	77.5	33.2	95.7	23.8	22.3
0.420	1590	11923	452	3495	77.4	31.3	96.3	22.1	22.7
0.440	1590	11923	452	3495	77.4	31.3	96.3	22.1	22.7
0.460	1448	12002	373	3637	77.0	28.5	97.0	20.5	23.3
0.480	1448	12005	370	3637	77.1	28.5	97.0	20.4	23.3
0.500	1257	12071	304	3828	76.3	24.7	97.5	19.5	24.1
0.520	1236	12078	297	3849	76.3	24.3	97.6	19.4	24.2
0.540	1236	12078	297	3849	76.3	24.3	97.6	19.4	24.2
0.560	1093	12152	223	3992	75.9	21.5	98.2	16.9	24.7

0.580	1093	12153	222	3992	75.9	21.5	98.2	16.9	24.7
0.600	982	12201	174	4103	75.5	19.3	98.6	15.1	25.2
0.620	971	12204	171	4114	75.5	19.1	98.6	15.0	25.2
0.640	841	12232	143	4244	74.9	16.5	98.8	14.5	25.8
0.660	827	12244	131	4258	74.9	16.3	98.9	13.7	25.8
0.680	758	12270	105	4327	74.6	14.9	99.2	12.2	26.1
0.700	752	12275	100	4333	74.6	14.8	99.2	11.7	26.1
0.720	652	12297	78	4433	74.2	12.8	99.4	10.7	26.5
0.740	644	12301	74	4441	74.1	12.7	99.4	10.3	26.5
0.760	577	12315	60	4508	73.8	11.3	99.5	9.4	26.8
0.780	569	12316	59	4516	73.8	11.2	99.5	9.4	26.8
0.800	493	12332	43	4592	73.5	9.7	99.7	8.0	27.1
0.820	439	12338	37	4646	73.2	8.6	99.7	7.8	27.4
0.840	433	12341	34	4652	73.2	8.5	99.7	7.3	27.4
0.860	379	12348	27	4706	72.9	7.5	99.8	6.7	27.6
0.880	315	12355	20	4770	72.6	6.2	99.8	6.0	27.9
0.900	282	12359	16	4803	72.4	5.5	99.9	5.4	28.0
0.920	242	12360	15	4843	72.2	4.8	99.9	5.8	28.2
0.940	176	12365	10	4909	71.8	3.5	99.9	5.4	28.4
0.960	133	12367	8	4952	71.6	2.6	99.9	5.7	28.6
0.980	78	12372	3	5007	71.3	1.5	100.0	3.7	28.8
1.000	0	12375	0	5085	70.9	0.0	100.0	.	29.1

Table XXVIII. Evaluation of Algorithm for Cars with Fatality

Prob Level	Correct		Incorrect			Percentages			
	Event	Non- Event	Event	Non- Event	Correct	Sensi- tivity	Speci- ficity	False POS	False NEG
0.000	955	0	16505	0	5.5	100.0	0.0	94.5	.
0.020	700	13867	2638	255	83.4	73.3	84.0	79.0	1.8
0.040	551	15049	1456	404	89.3	57.7	91.2	72.5	2.6
0.060	464	15515	990	491	91.5	48.6	94.0	68.1	3.1
0.080	398	15753	752	557	92.5	41.7	95.4	65.4	3.4
0.100	349	15941	564	606	93.3	36.5	96.6	61.8	3.7
0.120	320	16036	469	635	93.7	33.5	97.2	59.4	3.8
0.140	282	16121	384	673	93.9	29.5	97.7	57.7	4.0
0.160	271	16146	359	684	94.0	28.4	97.8	57.0	4.1
0.180	245	16216	289	710	94.3	25.7	98.2	54.1	4.2
0.200	232	16244	261	723	94.4	24.3	98.4	52.9	4.3
0.220	220	16264	241	735	94.4	23.0	98.5	52.3	4.3
0.240	196	16322	183	759	94.6	20.5	98.9	48.3	4.4
0.260	188	16340	165	767	94.7	19.7	99.0	46.7	4.5
0.280	179	16347	158	776	94.7	18.7	99.0	46.9	4.5
0.300	163	16366	139	792	94.7	17.1	99.2	46.0	4.6
0.320	155	16375	130	800	94.7	16.2	99.2	45.6	4.7
0.340	141	16383	122	814	94.6	14.8	99.3	46.4	4.7

0.360	134	16396	109	821	94.7	14.0	99.3	44.9	4.8
0.380	134	16402	103	821	94.7	14.0	99.4	43.5	4.8
0.400	129	16410	95	826	94.7	13.5	99.4	42.4	4.8
0.420	122	16413	92	833	94.7	12.8	99.4	43.0	4.8
0.440	114	16423	82	841	94.7	11.9	99.5	41.8	4.9
0.460	110	16426	79	845	94.7	11.5	99.5	41.8	4.9
0.480	110	16428	77	845	94.7	11.5	99.5	41.2	4.9
0.500	107	16437	68	848	94.8	11.2	99.6	38.9	4.9
0.520	100	16444	61	855	94.8	10.5	99.6	37.9	4.9
0.540	92	16455	50	863	94.8	9.6	99.7	35.2	5.0
0.560	87	16458	47	868	94.8	9.1	99.7	35.1	5.0
0.580	82	16459	46	873	94.7	8.6	99.7	35.9	5.0
0.600	76	16459	46	879	94.7	8.0	99.7	37.7	5.1
0.620	73	16462	43	882	94.7	7.6	99.7	37.1	5.1
0.640	69	16467	38	886	94.7	7.2	99.8	35.5	5.1
0.660	67	16468	37	888	94.7	7.0	99.8	35.6	5.1
0.680	60	16471	34	895	94.7	6.3	99.8	36.2	5.2
0.700	60	16474	31	895	94.7	6.3	99.8	34.1	5.2
0.720	55	16477	28	900	94.7	5.8	99.8	33.7	5.2
0.740	53	16479	26	902	94.7	5.5	99.8	32.9	5.2
0.760	51	16484	21	904	94.7	5.3	99.9	29.2	5.2
0.780	49	16484	21	906	94.7	5.1	99.9	30.0	5.2
0.800	46	16485	20	909	94.7	4.8	99.9	30.3	5.2
0.820	40	16489	16	915	94.7	4.2	99.9	28.6	5.3
0.840	40	16490	15	915	94.7	4.2	99.9	27.3	5.3
0.860	37	16495	10	918	94.7	3.9	99.9	21.3	5.3
0.880	33	16496	9	922	94.7	3.5	99.9	21.4	5.3
0.900	26	16497	8	929	94.6	2.7	100.0	23.5	5.3
0.920	24	16500	5	931	94.6	2.5	100.0	17.2	5.3
0.940	19	16501	4	936	94.6	2.0	100.0	17.4	5.4
0.960	14	16502	3	941	94.6	1.5	100.0	17.6	5.4
0.980	11	16503	2	944	94.6	1.2	100.0	15.4	5.4
1.000	0	16505	0	955	94.5	0.0	100.0	.	5.5

Table XXIX. Evaluation of Algorithm for Occupants
Compelling Injury

Prob Level	Correct		Incorrect		Percentages				
	Event	Non- Event	Event	Non- Event	Correct	Sensi- tivity	Speci- ficity	False POS	False NEG
0.000	1068	0	8444	0	11.2	100.0	0.0	88.8	.
0.020	964	4998	3446	104	62.7	90.3	59.2	78.1	2.0
0.040	873	6175	2269	195	74.1	81.7	73.1	72.2	3.1
0.060	807	6761	1683	261	79.6	75.6	80.1	67.6	3.7
0.080	739	7109	1335	329	82.5	69.2	84.2	64.4	4.4
0.100	695	7351	1093	373	84.6	65.1	87.1	61.1	4.8
0.120	661	7531	913	407	86.1	61.9	89.2	58.0	5.1
0.140	620	7649	795	448	86.9	58.1	90.6	56.2	5.5
0.160	586	7760	684	482	87.7	54.9	91.9	53.9	5.8
0.180	562	7846	598	506	88.4	52.6	92.9	51.6	6.1
0.200	525	7922	522	543	88.8	49.2	93.8	49.9	6.4
0.220	495	7971	473	573	89.0	46.3	94.4	48.9	6.7
0.240	468	8009	435	600	89.1	43.8	94.8	48.2	7.0
0.260	437	8048	396	631	89.2	40.9	95.3	47.5	7.3
0.280	415	8083	361	653	89.3	38.9	95.7	46.5	7.5
0.300	397	8108	336	671	89.4	37.2	96.0	45.8	7.6
0.320	381	8129	315	687	89.5	35.7	96.3	45.3	7.8
0.340	368	8163	281	700	89.7	34.5	96.7	43.3	7.9
0.360	351	8185	259	717	89.7	32.9	96.9	42.5	8.1
0.380	334	8214	230	734	89.9	31.3	97.3	40.8	8.2
0.400	313	8231	213	755	89.8	29.3	97.5	40.5	8.4
0.420	298	8247	197	770	89.8	27.9	97.7	39.8	8.5
0.440	281	8268	176	787	89.9	26.3	97.9	38.5	8.7
0.460	263	8286	158	805	89.9	24.6	98.1	37.5	8.9
0.480	248	8293	151	820	89.8	23.2	98.2	37.8	9.0
0.500	238	8311	133	830	89.9	22.3	98.4	35.8	9.1
0.520	225	8321	123	843	89.8	21.1	98.5	35.3	9.2
0.540	211	8331	113	857	89.8	19.8	98.7	34.9	9.3
0.560	201	8341	103	867	89.8	18.8	98.8	33.9	9.4
0.580	186	8354	90	882	89.8	17.4	98.9	32.6	9.5
0.600	168	8363	81	900	89.7	15.7	99.0	32.5	9.7
0.620	153	8372	72	915	89.6	14.3	99.1	32.0	9.9
0.640	139	8381	63	929	89.6	13.0	99.3	31.2	10.0
0.660	130	8391	53	938	89.6	12.2	99.4	29.0	10.1
0.680	125	8393	51	943	89.6	11.7	99.4	29.0	10.1
0.700	115	8395	49	953	89.5	10.8	99.4	29.9	10.2
0.720	106	8399	45	962	89.4	9.9	99.5	29.8	10.3
0.740	102	8405	39	966	89.4	9.6	99.5	27.7	10.3
0.760	91	8406	38	977	89.3	8.5	99.5	29.5	10.4
0.780	81	8413	31	987	89.3	7.6	99.6	27.7	10.5

0.800	72	8418	26	996	89.3	6.7	99.7	26.5	10.6
0.820	60	8423	21	1008	89.2	5.6	99.8	25.9	10.7
0.840	55	8424	20	1013	89.1	5.1	99.8	26.7	10.7
0.860	51	8426	18	1017	89.1	4.8	99.8	26.1	10.8
0.880	48	8429	15	1020	89.1	4.5	99.8	23.8	10.8
0.900	35	8434	10	1033	89.0	3.3	99.9	22.2	10.9
0.920	23	8437	7	1045	88.9	2.2	99.9	23.3	11.0
0.940	12	8442	2	1056	88.9	1.1	100.0	14.3	11.1
0.960	9	8443	1	1059	88.9	0.8	100.0	10.0	11.1
0.980	2	8443	1	1066	88.8	0.2	100.0	33.3	11.2
1.000	0	8444	0	1068	88.8	0.0	100.0	.	11.2

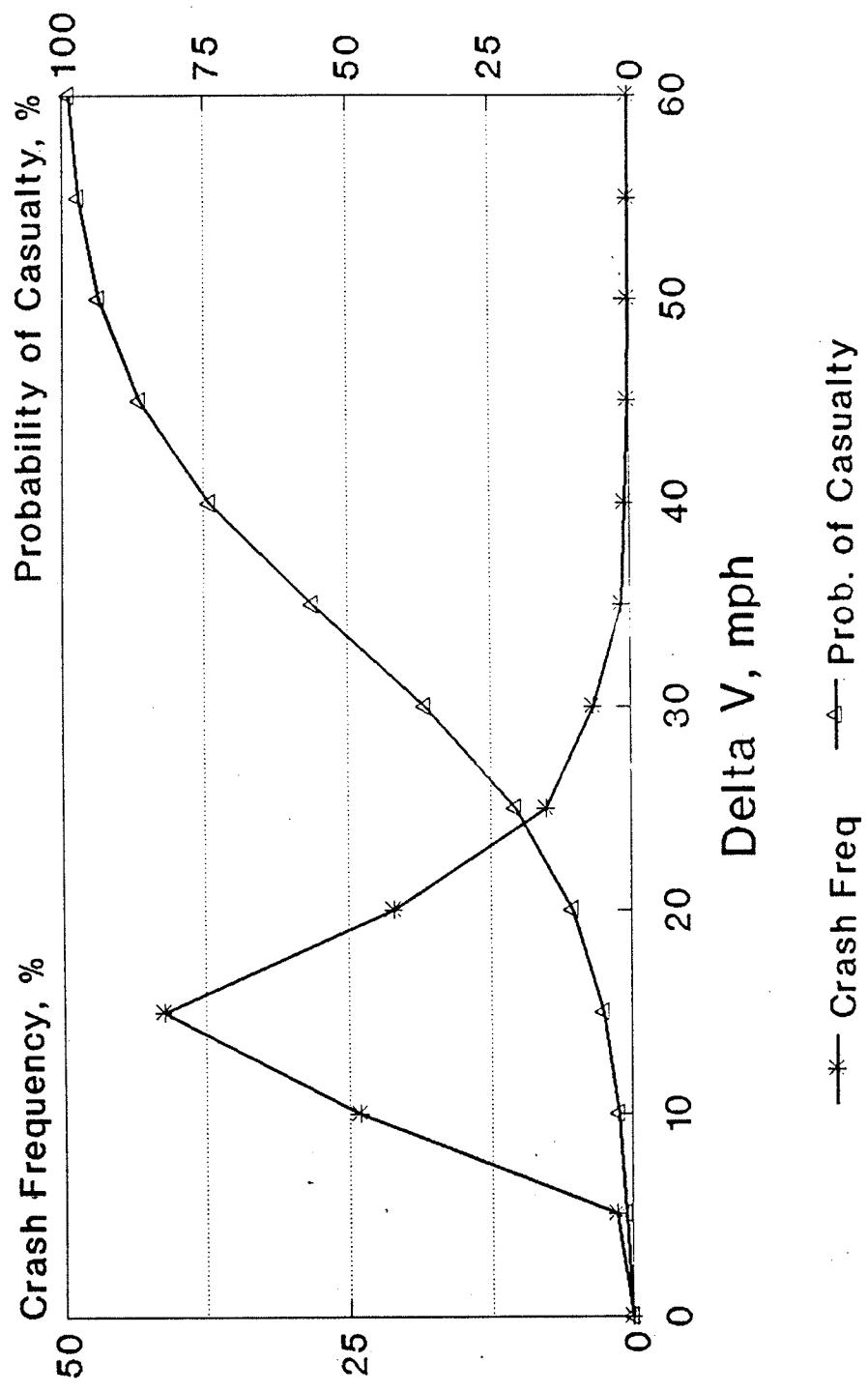
Table XXX. Illustrative Results Concerning the Probability of a Car Occupant with Compelling Injury

Probability, Percent

DV	Base	Single	Multi	w R/O	No R/O
5	0.3	0.4	0.3	0.7	0.3
10	0.6	0.8	0.5	1.3	0.6
15	1.0	1.4	1.0	2.4	1.0
20	1.9	2.5	1.7	4.3	1.8
25	3.4	4.5	3.1	7.5	3.3
30	6.0	7.9	5.6	12.9	5.9
35	10.4	13.6	9.7	21.2	10.2
40	17.5	22.3	16.4	32.9	17.2
45	27.9	34.3	26.3	47.2	27.4
50	41.3	48.8	39.4	61.9	40.8
55	56.2	63.4	54.2	74.8	55.6
60	70.0	76.0	68.4	84.4	69.6
65	81.0	85.2	79.7	90.8	80.6
70	88.6	91.3	87.8	94.7	88.4
75	93.4	95.0	92.9	97.0	93.3
80	96.3	97.2	96.0	98.3	96.2

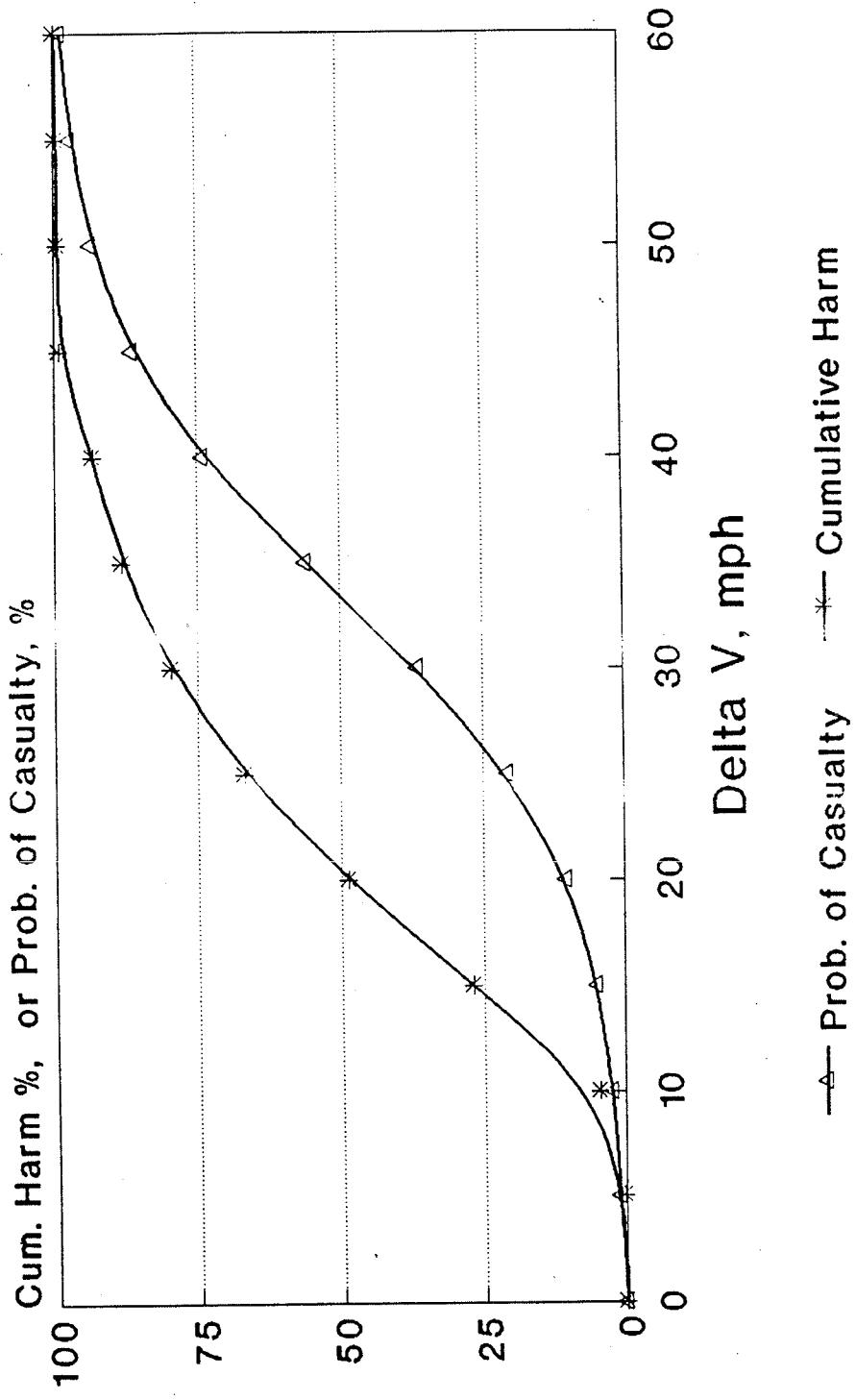
DV	Base	Restr	Unrestr	Young	Old
5	0.3	0.3	0.5	0.3	1.8
10	0.6	0.5	0.8	0.5	3.2
15	1.0	0.9	1.5	1.0	5.7
20	1.9	1.6	2.7	1.8	9.9
25	3.4	2.8	4.8	3.2	16.6
30	6.0	5.0	8.4	5.7	26.7
35	10.4	8.8	14.3	9.9	39.9
40	17.5	14.9	23.3	16.6	54.7
45	27.9	24.2	35.6	26.7	68.8
50	41.3	36.8	50.2	39.9	80.0
55	56.2	51.4	64.7	54.7	88.0
60	70.0	65.9	77.0	68.8	93.0
65	81.0	77.9	85.9	80.0	96.0
70	88.6	86.5	91.7	88.0	97.8
75	93.4	92.1	95.3	93.0	98.8
80	96.3	95.5	97.4	96.0	99.3

Fig. 87. Crash Frequency & Probability of Fatality or MAIS 3+, as a Function of Delta V for Planar Car Crashes



The NASS/CDS 1988-1995

Fig. 88. Cumulative Harm & Probability of Fatality or MAIS 3+, as a Function of Delta V for Planar Car Crashes



The NASS/CDS 1988-1995

Fig. 89. Resolution of Car Occupants among MAIS Values, by Nature (Compelling or Not) of Most Severe Injury

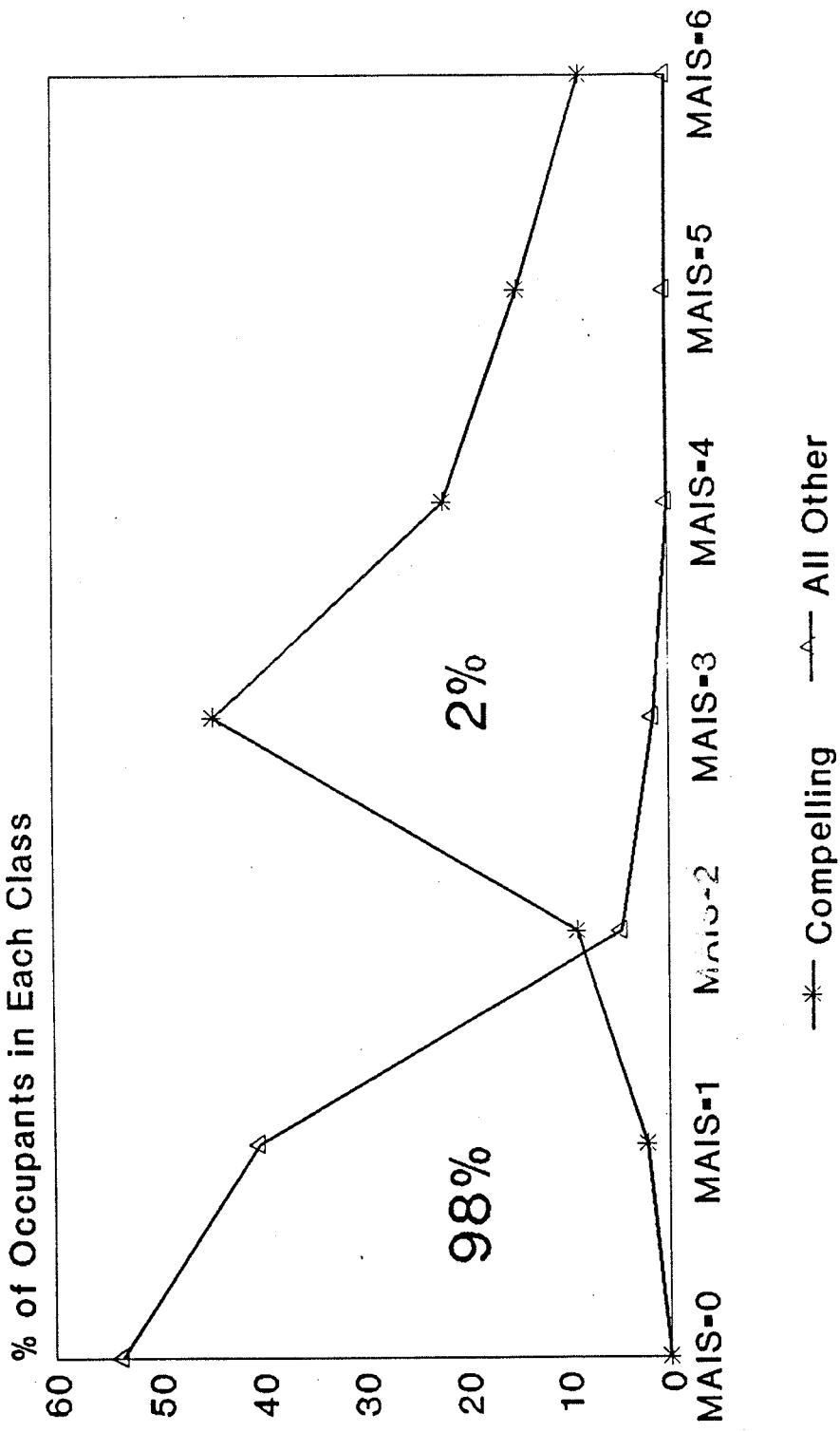
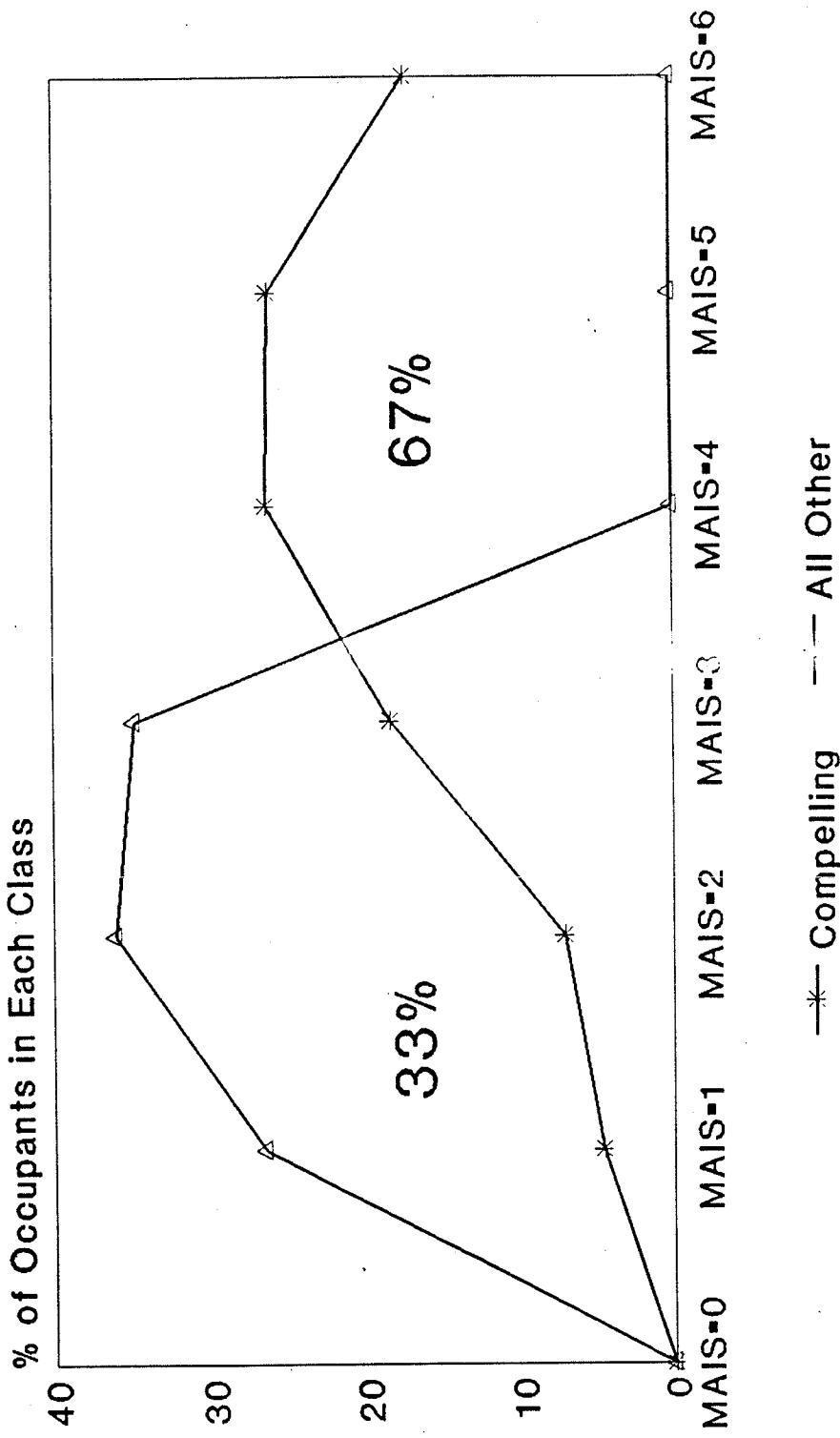
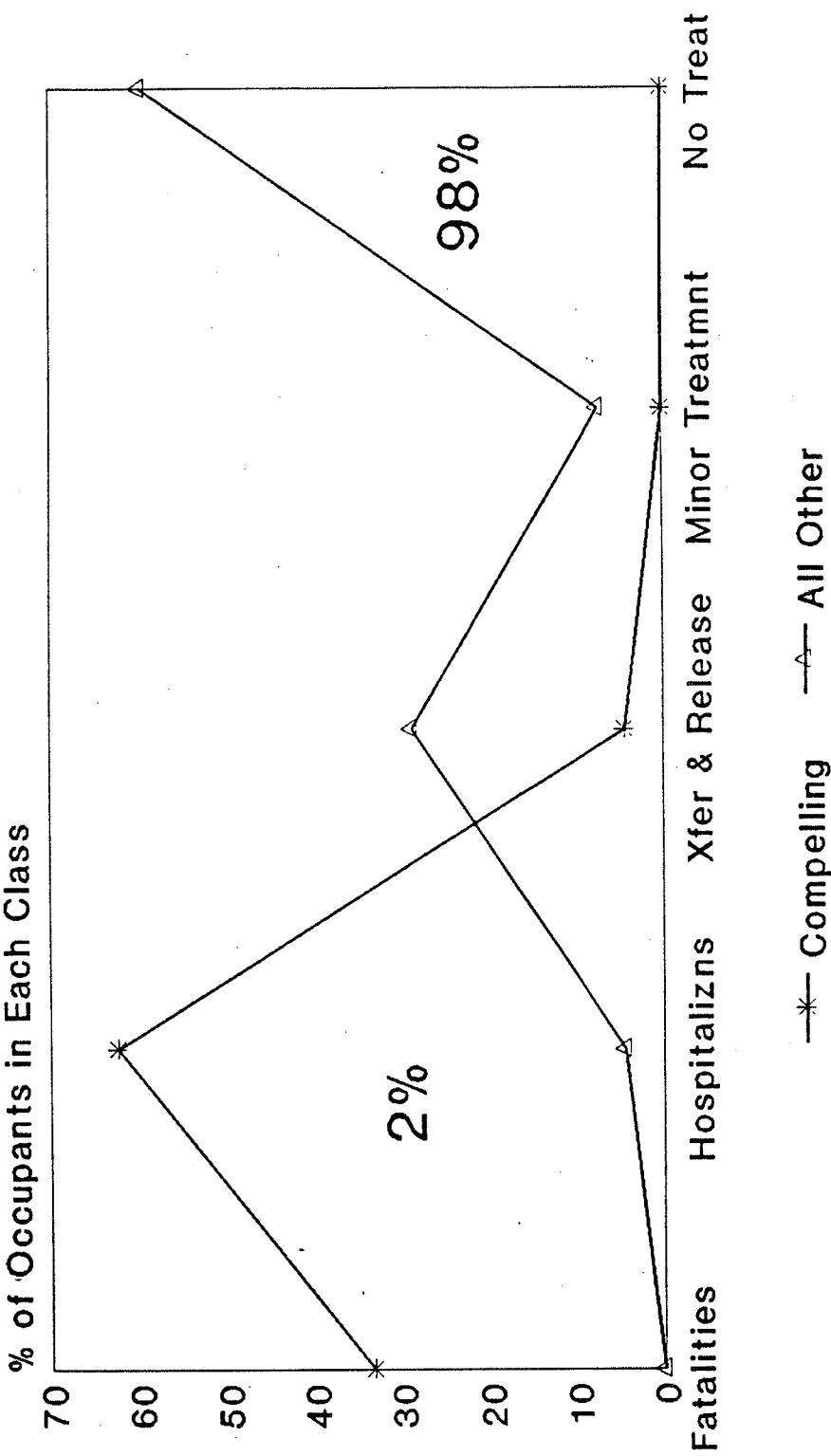


Fig. 90. Occupant Harm Resolution among MAIS Values, by Nature (Compelling or Not) of Most Severe Injury



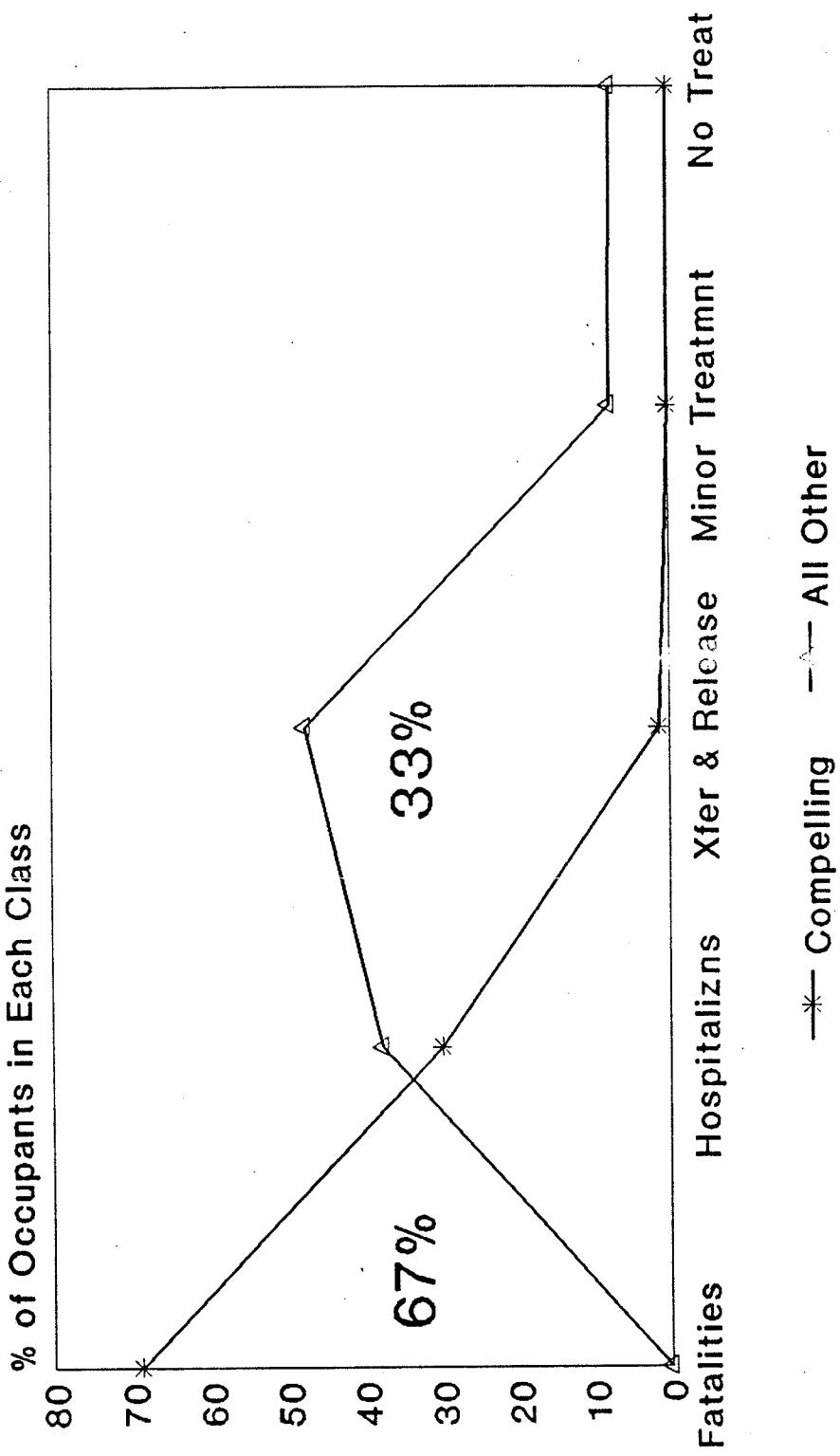
The NASS/CDS 1993-1995

Fig. 91. Resolution of Car Occupants
among Mortality/Treatment Bins by Nature
(Compelling or Not) of Most Severe Inj.



The NASS/CDS 1993-1995

Fig. 92. Occupant Harm Resolved among Mortality/Treatment Bins by Nature (Compelling or Not) of Most Severe Inj.



The NASS/CDS 1993-1995

Fig. 93 Probability of a Car with
at Least One Shown Injury
in Frontal Planar Crashes

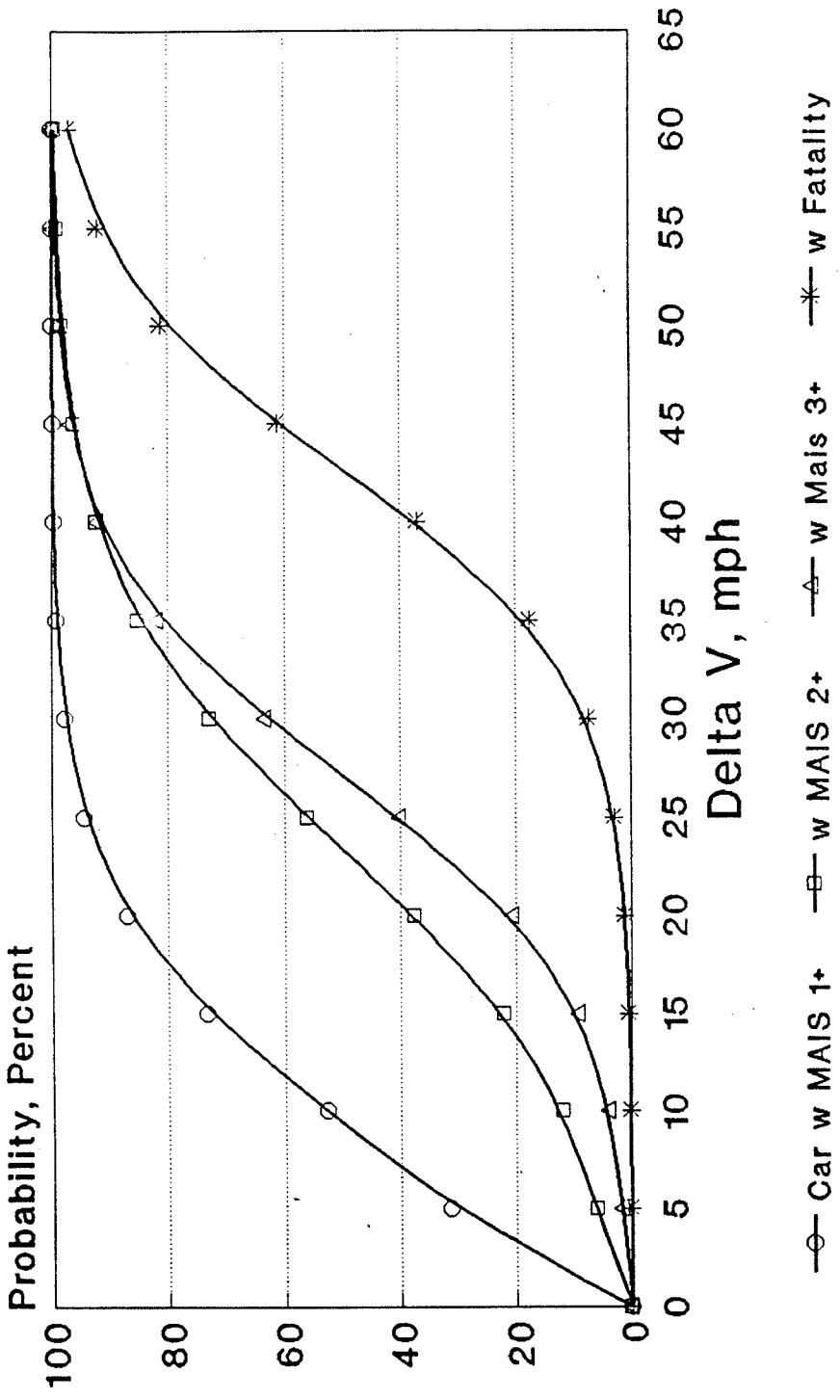


Fig. 94 Probability of a Car with
at Least One Shown Injury
in Side Planar Crashes

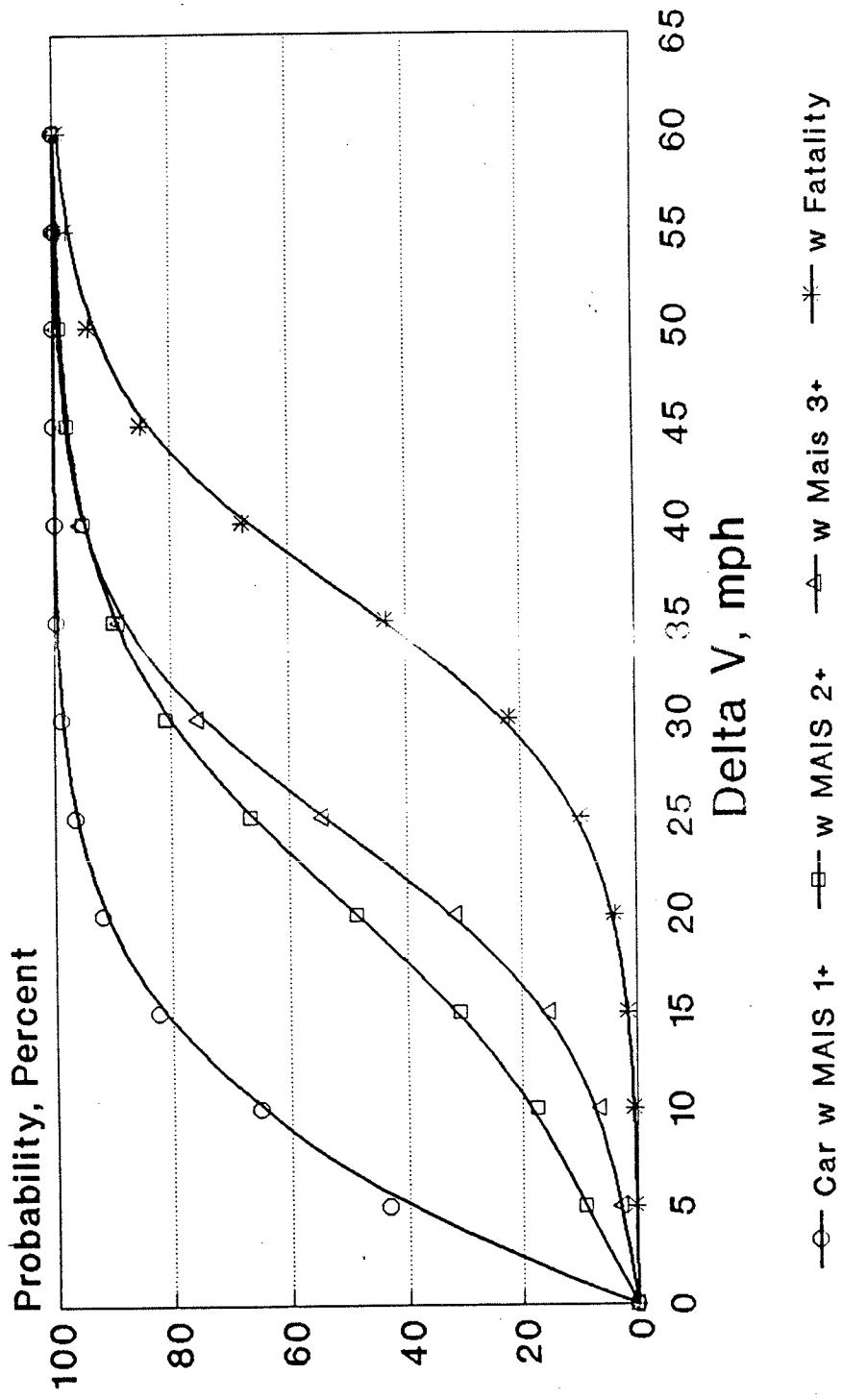


Fig. 95 Probability of a Car with
at Least One MAIS 3+ Injury
in Shown Planar Crashes

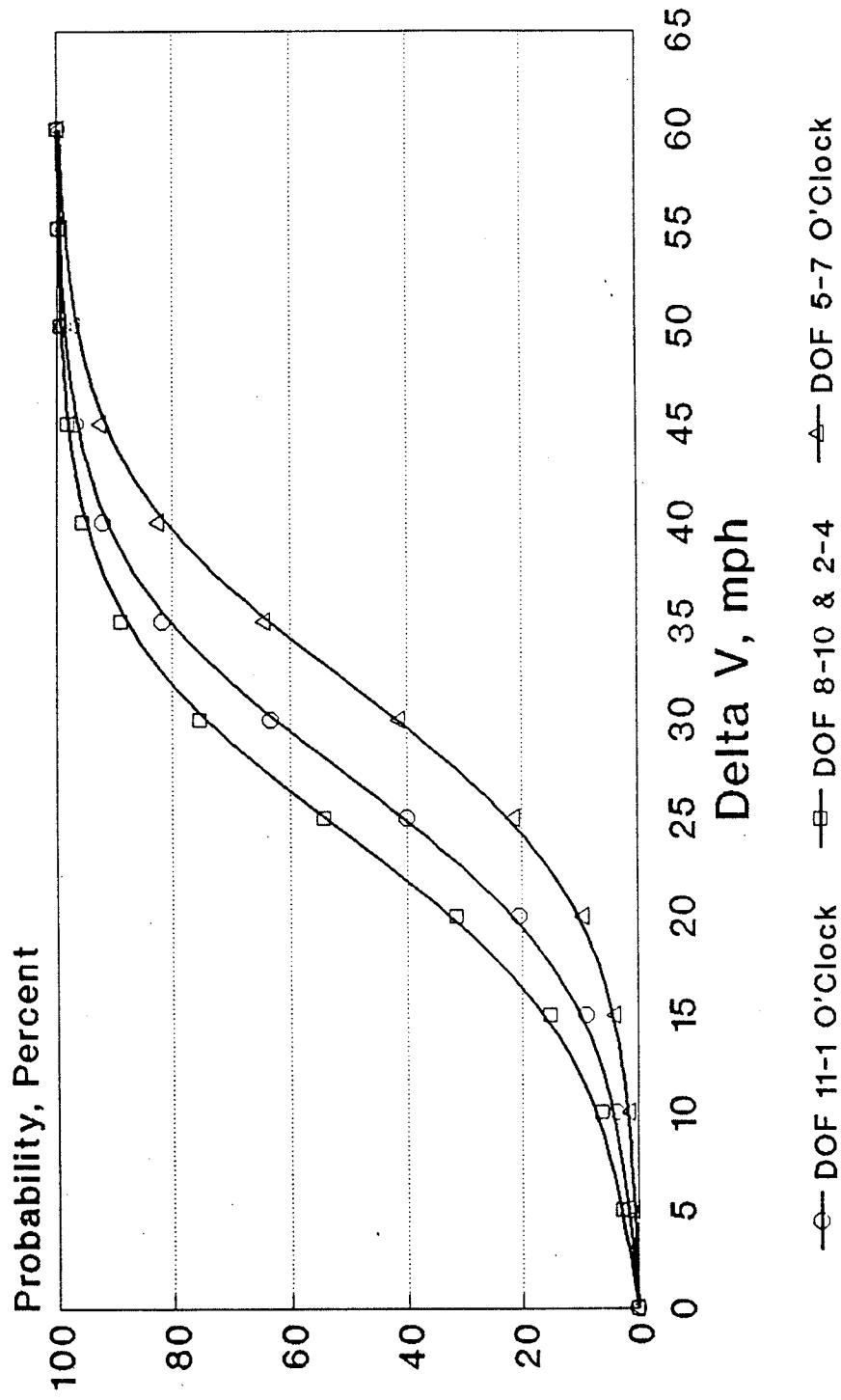


Fig. 96 Evaluation of Projecting the Probability of a Car with MAIS 1+

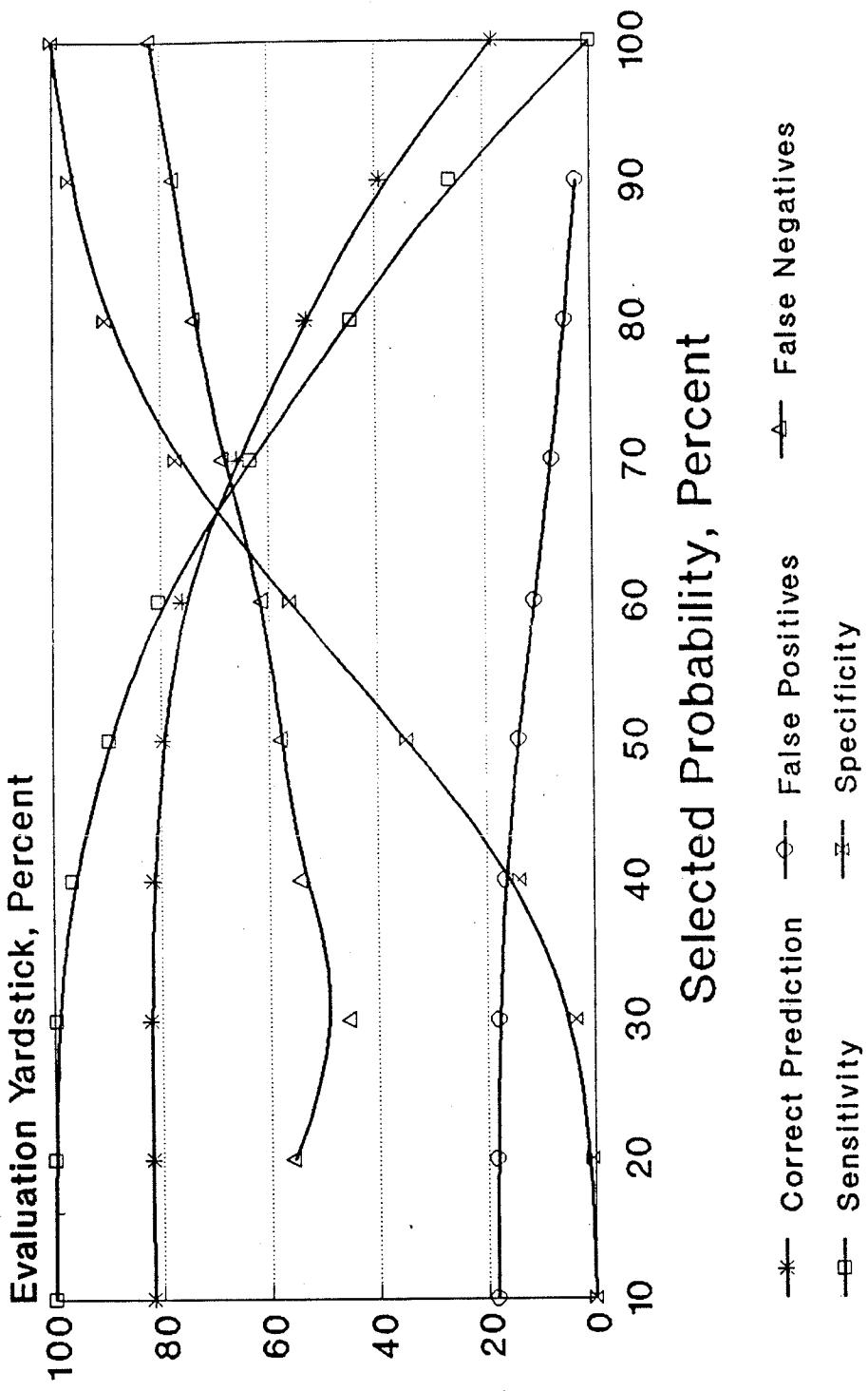


Fig. 97 Evaluation of Projecting the Probability of a Car with MAIS 2+

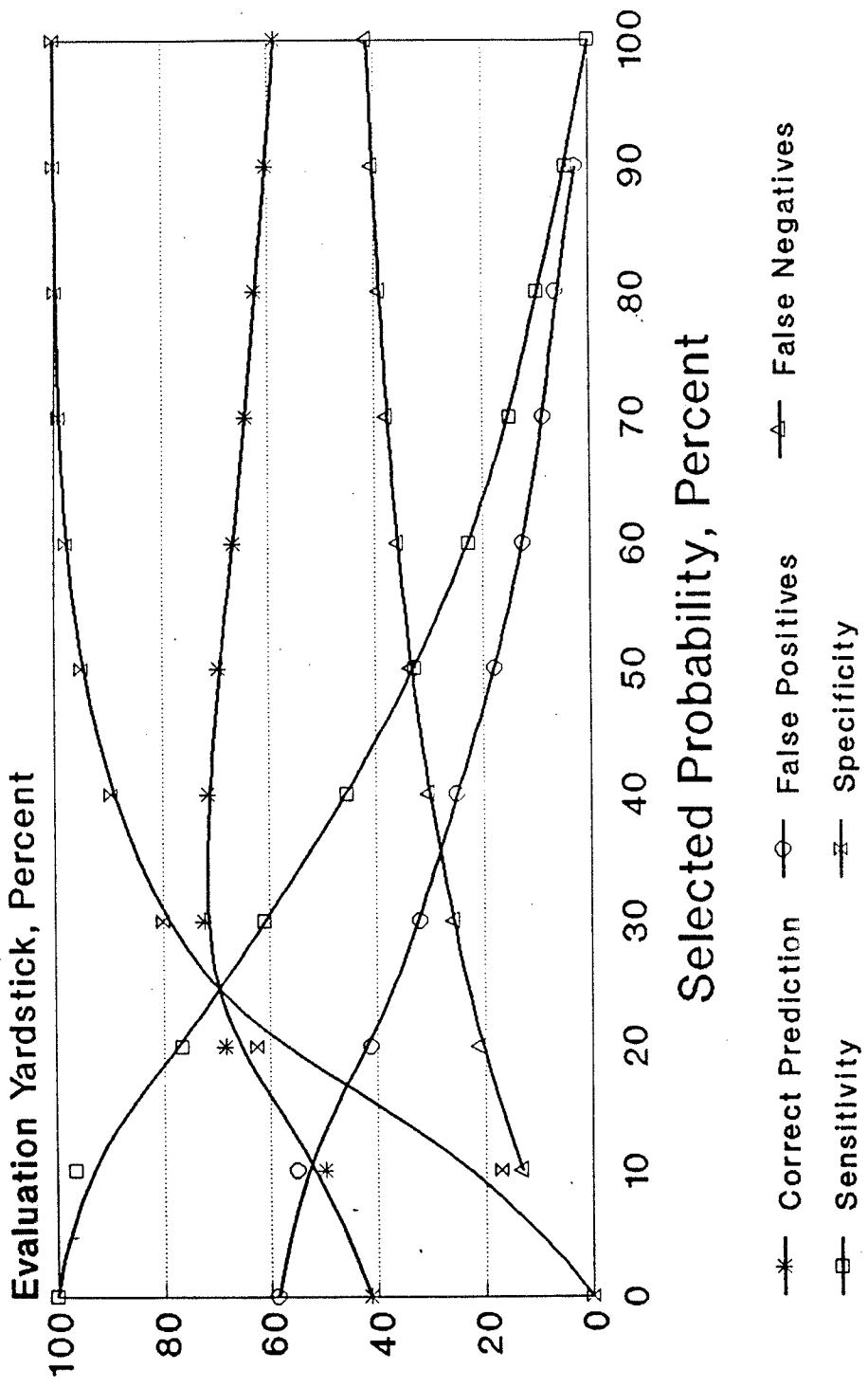


Fig. 98 Evaluation of Projecting the Probability of a Car with MAIS 3+

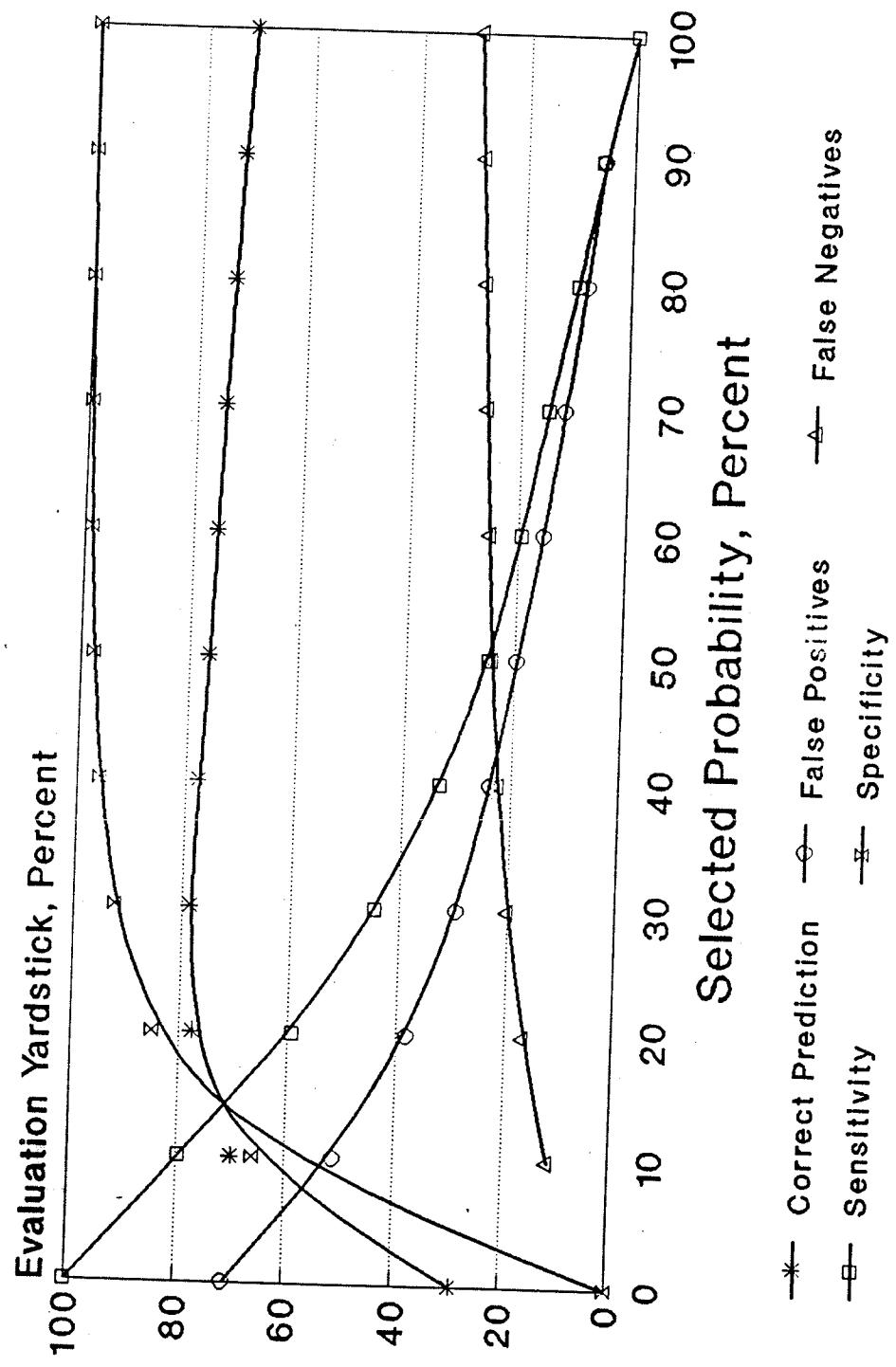


Fig. 99 Evaluation of Projecting the Probability of a Car with a Fatality

