The Likelihood of Human Casualty in Highway Crashes

4th Briefing: Nominal Procedure & ACN Algorithms

Based on an Investigation Conducted for
the FHWA/NHTSA Crash Analysis Center
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Introduction

This is the fourth briefing concerning the cited subject. Work reported here addresses and evaluates: (a) a nominal procedure applied in the derivation of algorithms prescribed by the Automatic Collision Notification (ACN) system; (b) programmable algorithms derived by the cited procedure; and (c) illustrative results from applications of such algorithms in several cases.

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. Table X in this briefing compares: No Trimming, v. 2% Trimming, v. 5% Trimming for several cases.

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:

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

where $w = A0 + A1*x1 + A2*x2 + etc;$ (2)

where x1, x2, etc are the selected predictors; and A0, A1, A2, 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: A0, A1, A2, etc appearing in (2). The same procedure provides also the covariance matrix: COV(Ai, Aj). 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:

var(w) = Sum[Cov(Ai, Aj)*xi*xj] over all i and j (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 xi and xj, an application of (3) yields the variance: var(w).

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

var(P) = (exp(-2w) / [1 + exp(-w)]**4) * var(w) (4)

and the standard error of P is:

seP = square root [var(P)] (5)

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

Nominal Procedure Results v. Jackknife Procedure Results

As an assurance of obtaining P and seP, given by (1) and (5) of the nominal procedure, without any unexpected surprises, we compare these results with results from the simplistic jackknife procedure.

In this comparison, jackknife results are obtained from four independent and nearly equal subpopulations of the main population of raw data. Each of these four subpopulations yields a probability. A total of four: P1, P2, P3, and P4, are obtained.

These four values are used to obtain a mean and a standard error: JP and JseP, which are then compared to the: P and seP values obtained from the nominal procedure. The comparison is shown in Table VIII below for a range of predictor values.

Applications Concerning ACN Algorithms

By stipulation, all algorithms developed for this briefing concern the prediction of probability of fatality or MAIS = 2+ for car occupants in towaway crashes . Algorithms were developed for several cases of stipulated predictor availability, in order of increasing complexity, as follows:

Case I, Planar Crashes: Total Delta V, and Direction of Force;
Case I, Rollover: No or Yes.

Case II, Planar Crashes: Longitudinal and Lateral Delta V;
Case II, Rollover: No or Yes, by Number of Quarter Turns.

Case III, Planar Crashes: Total Delta V, Direction of Force, Occupant Age and Gender, and Car Size;
Case III, Rollover: No or Yes, by Number of Quarter Turns, Occupant Age and Gender, and Car Size;

Presentation of Programmable Algorithms

Fully detailed algorithms are presented below as follows:

Results from Application of the Algorithms

Illustrative results are tabulated as follows:

Results are also illustrated in several figures.

Programmable Algorithm for Planar Car Crashes, Case I

Probability of Car Occupant Fatality or MAIS=2+

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

Model:

w = A0 + A1*DVTOTAL + A2*DOFF + A3*DOFL + A4*DOFR

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

Observations used in the analysis : 20607
Number of non-zero responses: 5243

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-4.94	0.21	0.0000
DVTOTAL	0.09	0.00	0.0000
DOFF	1.34	0.19	0.0000
DOFL	1.75	0.20	0.0000
DOFR	1.70	0.21	0.0000

seP = square root [var(P)]

var(P) = (exp(-2w) / [1 + exp(-w)]**4) * var(w)

var(w) = Sum [Cov(Ai, Aj)*xi*xj] over all i and j

Covariance Matrix: i, j = 0 to 4

0.044290	-.00039985	-0.036158	-0.037760	-0.036860
-0.000400	0.00001356	0.000122	0.000178	0.000141
-0.036158	0.00012237	0.035375	0.034162	0.033993
-0.037760	0.00017788	0.034162	0.041829	0.034549
-0.036860	0.00014138	0.033993	0.034549	0.042286

i or j = 0 : Intercept,
i or j = 1 : DVTOTAL,
i or j = 2 : DOFF,
i or j = 3 : DOFL,
i or j = 4 : DOFR.

Programmable Algorithm for Car Rollover, Case I

Probability of Car Occupant Fatality or MAIS=2+

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

Model:

w = A0 + A1*RO

RO=1 if Rollover Occurs; else RO=0

Observations used in the analysis : 51595
Number of non-zero responses: 12953

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-2.19	0.02	0.0000
RO	0.84	0.06	0.0000

seP = square root [var(P)]

var(P) = { exp(-2w) / [1 + exp(-w)]**4 } * var(w)

var(w) = Sum [Cov(Ai, Aj)*xi*xj]   over all i and j

Covariance Matrix: i, j = 0 to 1

0.00043735	-.0004400
-.00043996	0.0037908

i or j = 0 :   Intercept,
i or j = 1 :   RO

Programmable Algorithm for Planar Car Crashes, Case II

Probability of Car Occupant Fatality or MAIS=2+

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

Models:

w = A0 + A1*DVFRONT + A2*DVLEFT
Observations used in the analysis : 12188
Number of non-zero responses: 3443

w = A0 + A1*DVFRONT + A2*DVRIGHT
Observations used in the analysis : 8040
Number of non-zero responses: 2073

w = A0 + A1*DVREAR + A2*DVLEFT
Observations used in the analysis : 2065
Number of non-zero responses: 269

w = A0 + A1*DVREAR + A2*DVRIGHT
Observations used in the analysis : 872
Number of non-zero responses: 161

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-3.40	0.09	0.0000
DVFRONT	0.08	0.00	0.0000
DVLEFT	0.07	0.01	0.0000
Intercept	-3.53	0.13	0.0000
DVFRONT	0.06	0.01	0.0000
DVRIGHT	0.09	0.01	0.0000
Intercept	-3.74	0.32	0.0000
DVREAR	0.03	0.01	0.0166
DVLEFT	0.12	0.02	0.0000
Intercept	-4.10	0.37	0.0000
DVREAR	0.03	0.01	0.0146
DVRIGHT	0.16	0.02	0.0000

Algorithm for Planar Car Crashes, Case II Cont'd

Covariance Matrices

Front, Left

0.0089169	-.00031967	-.00026808
-.0003197	0.00001757	0.00000268
-.0002681	0.00000268	0.00003518

Front, Right

0.015981	-.00051074	-.00050190
-0.000511	0.00003126	0.00000150
-0.000502	0.00000150	0.00004562

Rear, Left

0.099364	-.0028562	-.0052943
-0.002856	0.0001362	0.0001192
-0.005294	0.0001192	0.0005231

Rear Right

0.14054	-.0030133	-.0052120
-0.00301	0.0001858	0.0000424
-0.00521	0.0000424	0.0003443

Programmable Algorithm for Car Rollover, Case II

Probability of Car Occupant Fatality or MAIS=2+

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

Model:

w = A0 +A1*RO1 + A2*RO23 + A3*RO45

RO1=1 if Rollover Occurs with 1 Qrtr Turn; else RO1=0;
RO23=1 if Rollover Occurs with 2-3 Qrtr Turns; else RO23=0;
RO45=1 if Rollover Occurs with 4+ Qrtr Turns; else RO45=0;
If No Rollover Occurs then RO1=RO23=RO45=0.

Observations used in the analysis : 51595
Number of non-zero responses: 12953

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-2.19	0.02	0.0000
RO1	0.40	0.16	0.0151
RO23	0.67	0.09	0.0000
RO45	1.15	0.09	0.0000

Covariance Matrix

0.00043735	-0.000443	-.0004404	-.0004384
-.00044290	0.027118	0.0004399	0.0004422
-.00044036	0.000440	0.0089888	0.0004390
-.00043836	0.000442	0.0004390	0.0075658

Programmable Algorithm for Planar Car Crashes, Case III

Probability of Car Occupant Fatality or MAIS=2+

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

Model:

w = A0 + A1*DVTOTAL + A2*DOFF + A3*DOFL + A4*DOFR +
A5*AGE + A6*CARL + A7*CARM + A8*GENDER

DVTOTAL = Total Delta V in mph Continuously;
DOFF=1 if Direction of Force is 11 to 1 O'Clock; else DOFF=0;
DOFL=1 if Direction of Force is 8 to 10; else DOFL=0;
DOFR=1 if Direction of Force is 2 to 4; else DOFR=0;
DOFF=DOFL=DOFR=0 if Direction of Force is 5 to 7.
AGE = Occupant Age in Years Continuously;
CARL = 1 if Car is Large; else CARL=0;
CARM = 1 if Car is Midsize; else CARM=0;
CARL = CARM = 0 if Car is Small;
GENDER = 1 if Occupant is Male; else GENDER=0.

Observations used in the analysis : 20414
Number of non-zero responses: 5234

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-5.80	0.25	0.0000
DVTOTAL	0.10	0.00	0.0000
DOFF	1.42	0.19	0.0000
DOFL	1.76	0.21	0.0000
DOFR	1.68	0.21	0.0000
AGE	0.02	0.00	0.0000
CARL	0.27	0.11	0.0149
CARM	0.21	0.10	0.0436
GENDER	-0.21	0.07	0.0019

Algorithm for Planar Car Crashes, Case III Cont'd

Covariance Matrix (9 by 9)

0.060510	-.00045348	-0.037860	-0.038195	-0.036203
-0.000453	0.00001452	0.000141	0.000189	0.000148
-0.037860	0.00014150	0.036344	0.034936	0.034723
-0.038195	0.00018933	0.034936	0.042793	0.035209
-0.036203	0.00014772	0.034723	0.035209	0.043578
-0.000166	0.00000102	0.000023	0.000014	-0.000006
-0.007363	-.00003204	-0.001064	-0.002914	-0.002020
-0.008458	-.00001105	-0.000063	-0.001065	-0.001576
-0.002673	0.00000166	0.000226	0.001274	0.000596

-.00016605	-0.007363	-0.008458	-.0026729
0.00000102	-0.000032	-0.000011	0.0000017
0.00002298	-0.001064	-0.000063	0.0002263
0.00001439	-0.002914	-0.001065	0.0012739
-.00000610	-0.002020	-0.001576	0.0005955
0.00000285	0.000037	0.000025	0.0000037
0.00003735	0.012026	0.008327	-.0006014
0.00002505	0.008327	0.010507	-.0001454
0.00000367	-0.000601	-0.000145	0.0046873

Programmable Algorithm for Car Rollover, Case III

Probability of Car Occupant Fatality or MAIS=2+

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

Model:

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w = A0 + A1*RO1 + A2*RO23 + A3*RO45 +  A4*CARL +
         A5*CARM + A6*AGE + A7*GENDER
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RO1 = 1 if Rollover Occurs with 1 Qrtr Turn; else RO1=0;
RO23 = 1 if Rollover Occurs with 2-3 Qrtr Turns; else RO23=0;
RO45 = 1 if Rollover Occurs with 4+ Qrtr Turns; else RO45=0;
RO1 = RO23 = RO45 = 0 if No Rollover Occurs.
CARL = 1 if Car is Large; else CARL=0;
CARM = 1 if Car is Midsize; else CARM=0;
CARL = CARM = 0 if Car is Small;
AGE = Occupant Age in Years Continuously;
GENDER = 1 if Occupant is Male; else GENDER=0.

Observations used in the analysis : 50924
Number of non-zero responses: 12926

Logistic Regression Coefficients

Predictor	A	Std Err	Probabil. of A=0
Intercept	-2.79	0.07	0.0000
RO1	0.44	0.16	0.0075
RO23	0.77	0.10	0.0000
RO45	1.22	0.09	0.0000
CARL	0.22	0.06	0.0006
CARM	0.15	0.06	0.0095
AGE	0.02	0.00	0.0000
GENDER	-0.09	0.04	0.0226

Algorithm for Car Rollover, Case III Cont'd

Covariance Matrix (8 by 8)

0.0051307	-0.000247	-.0004844	-.0004424	-.0031744
-.0002474	0.027039	0.0006082	0.0005991	-.0005564
-.0004844	0.000608	0.0091662	0.0006062	-.0004122
-.0004424	0.000599	0.0006062	0.0078184	-.0004039
-.0031744	-0.000556	-.0004122	-.0004039	0.0039996
-.0030607	-0.000281	-.0000712	-.0001950	0.0028011
-.0000458	0.000006	0.0000085	0.0000072	0.0000115
-.0009395	-0.000200	-.0001890	-.0000374	0.0000291

-.0030607	-.000045804	-.0009395
-.0002812	0.000006332	-.0001996
-.0000712	0.000008528	-.0001890
-.0001950	0.000007176	-.0000374
0.0028011	0.000011550	0.0000291
0.0035527	0.000006859	0.0001640
0.0000069	0.000001075	0.0000015
0.0001640	0.000001549	0.0015871

Table VIII.

Probability of Fatality or MAIS=3+ for 30 Yr Old Drivers in Frontal Crashes; Comparison of Results from Nominal Procedure with Jackknife Results.
P, SEP = Probability & Std Error from Nominal Procedure;
P1 to P4 = Probabilities from Four Jackknifed Subpopulations;
JP, JSEP = Mean and Std Error of P1 to P4.

Restrained

DV	P	SEP	P1	P2	P3	P4	JP	JSEP
5	0.3	0.04	0.3	0.2	0.4	0.2	0.28	0.05
10	0.5	0.07	0.6	0.3	0.7	0.4	0.50	0.09
15	0.9	0.11	1.0	0.6	1.2	0.7	0.88	0.14
20	1.6	0.18	1.9	1.3	2.2	1.4	1.70	0.21
25	2.8	0.30	3.4	2.6	3.9	2.6	3.13	0.32
30	5.0	0.52	6.0	5.0	6.8	4.9	5.68	0.45
35	8.8	0.91	10.3	9.6	11.8	9.0	10.18	0.60
40	14.9	1.56	17.4	17.7	19.6	16.0	17.68	0.74
45	24.2	2.49	27.7	30.2	30.8	26.7	28.85	0.98
50	36.8	3.51	41.1	46.5	44.8	41.1	43.38	1.36
55	51.5	4.19	56.0	63.6	59.6	57.2	59.10	1.68
60	65.9	4.18	69.8	77.9	72.9	71.9	73.13	1.72
65	77.9	3.54	80.8	87.7	83.1	83.1	83.68	1.45
70	86.5	2.63	88.5	93.5	89.9	90.4	90.58	1.05
75	92.1	1.79	93.3	96.6	94.2	94.7	94.70	0.70
80	95.5	1.15	96.2	98.3	96.7	97.2	97.10	0.45
85	97.5	0.71	97.9	99.2	98.2	98.5	98.45	0.28
90	98.6	0.43	98.8	99.6	99.0	99.2	99.15	0.17

Unrestrained

5	0.7	0.11	0.4	0.6	1.1	0.6	0.68	0.15
10	1.2	0.18	0.7	1.2	1.9	1.1	1.23	0.25
15	2.2	0.30	1.3	2.4	3.4	2.2	2.33	0.43
20	3.9	0.48	2.4	4.7	6.1	4.1	4.33	0.77
25	6.9	0.79	4.3	8.9	10.5	7.5	7.80	1.32
30	11.9	1.27	7.5	16.5	17.7	13.5	13.80	2.28
35	19.8	1.96	12.9	28.5	28.1	23.0	23.13	3.63
40	31.0	2.79	21.2	44.5	41.6	36.4	35.93	5.19
45	45.0	3.49	33.0	61.8	56.5	52.2	50.88	6.27
50	59.9	3.72	47.3	76.5	70.3	67.7	65.45	6.33
55	73.1	3.35	62.0	86.8	81.2	80.1	77.53	5.38
60	83.2	2.62	74.8	93.0	88.7	88.5	86.25	3.96
65	90.0	1.85	84.4	96.4	93.5	93.6	91.98	2.61
70	94.3	1.22	90.8	98.2	96.3	96.6	95.48	1.61
75	96.8	0.77	94.7	99.1	97.9	98.2	97.48	0.96
80	98.2	0.47	97.0	99.5	98.9	99.0	98.60	0.55
85	99.0	0.28	98.4	99.8	99.4	99.5	99.28	0.30
90	99.5	0.17	99.1	99.9	99.7	99.7	99.60	0.17

Table IX.

Results from Application of Algorithm for <u>Case I, Planar Car Crashes</u>: Probability of Fatality or MAIS=2+.

Direction of Force	DeltaV	Probab. & Std Err P	sePProbab. & Std Err seP	95% Confid. Bounds Lower	95% Confid. Bounds Upper
11-1	5	4.1	0.3	3.5	4.7
11-1	10	6.3	0.3	5.7	6.9
11-1	15	9.5	0.4	8.7	10.3
11-1	20	14.2	0.5	13.2	15.2
11-1	25	20.6	0.7	19.2	22.0
11-1	30	28.9	1.1	26.7	31.1
11-1	35	38.9	1.6	35.8	42.0
11-1	40	50.0	2.1	45.9	54.1
11-1	45	61.1	2.4	56.4	65.8
11-1	50	71.1	2.4	66.4	75.8
11-1	55	79.4	2.2	75.1	83.7
11-1	60	85.8	1.8	82.3	89.3
11-1	65	90.5	1.5	87.6	93.4
11-1	70	93.7	1.1	91.5	95.9
11-1	75	95.9	0.8	94.3	97.5
11-1	80	97.3	0.6	96.1	98.5
11-1	85	98.3	0.4	97.5	99.1
11-1	90	98.9	0.3	98.3	99.5
2-4	5	5.8	0.6	4.6	7.0
2-4	10	8.8	0.8	7.2	10.4
2-4	15	13.1	1.0	11.1	15.1
2-4	20	19.2	1.4	16.5	21.9
2-4	25	27.1	1.8	23.6	30.6
2-4	30	36.8	2.3	32.3	41.3
2-4	35	47.8	2.7	42.5	53.1
2-4	40	58.9	2.9	53.2	64.6
2-4	45	69.2	2.8	63.7	74.7
2-4	50	77.9	2.5	73.0	82.8
2-4	55	84.7	2.1	80.6	88.8
2-4	60	89.7	1.6	86.6	92.8
2-4	65	93.2	1.2	90.8	95.6
2-4	70	95.5	0.9	93.7	97.3
2-4	75	97.1	0.6	95.9	98.3
2-4	80	98.1	0.4	97.3	98.9
2-4	85	98.8	0.3	98.2	99.4
2-4	90	99.2	0.2	98.8	99.6
8-10	5	6.1	0.5	5.1	7.1
8-10	10	9.2	0.7	7.8	10.6
8-10	15	13.7	1.0	11.7	15.7

Table IX. Cont'd

8-10	20	19.9	1.3	17.4	22.4
8-10	25	28.1	1.8	24.6	31.6
8-10	30	38.0	2.3	33.5	42.5
8-10	35	49.0	2.7	43.7	54.3
8-10	40	60.1	2.9	54.4	65.8
8-10	45	70.3	2.8	64.8	75.8
8-10	50	78.8	2.5	73.9	83.7
8-10	55	85.3	2.1	81.2	89.4
8-10	60	90.1	1.6	87.0	93.2
8-10	65	93.5	1.2	91.1	95.9
8-10	70	95.7	0.9	93.9	97.5
8-10	75	97.2	0.6	96.0	98.4
8-10	80	98.2	0.4	97.4	99.0
8-10	85	98.9	0.3	98.3	99.5
8-10	90	99.3	0.2	98.9	99.7
5-7	5	1.1	0.2	0.7	1.5
5-7	10	1.7	0.3	1.1	2.3
5-7	15	2.7	0.5	1.7	3.7
5-7	20	4.1	0.7	2.7	5.5
5-7	25	6.4	1.1	4.2	8.6
5-7	30	9.6	1.6	6.5	12.7
5-7	35	14.3	2.2	10.0	18.6
5-7	40	20.8	3.0	14.9	26.7
5-7	45	29.1	3.9	21.5	36.7
5-7	50	39.2	4.7	30.0	48.4
5-7	55	50.2	5.1	40.2	60.2
5-7	60	61.3	5.0	51.5	71.1
5-7	65	71.3	4.6	62.3	80.3
5-7	70	79.6	3.8	72.2	87.0
5-7	75	85.9	3.0	80.0	91.8
5-7	80	90.6	2.2	86.3	94.9
5-7	85	93.8	1.6	90.7	96.9
5-7	90	95.9	1.1	93.7	98.1

Table X.

Effect of NASS Weight Trimming on the Results Given in Table IX (Nominal Procedure).

				Nominal Procedure			
		No Trimming		2% Trimming		5% Trimming	
DOF	DELTAV	P	SEP	P	SEP	P	SEP
11-1	5	2.9	0.2	4.1	0.3	4.5	0.3
11-1	10	4.7	0.3	6.3	0.3	6.8	0.3
11-1	15	7.4	0.4	9.5	0.4	10.3	0.4
11-1	20	11.7	0.5	14.2	0.5	15.3	0.5
11-1	25	17.9	0.8	20.6	0.7	22.1	0.7
11-1	30	26.5	1.3	28.9	1.1	30.8	1.1
11-1	35	37.3	2.0	38.9	1.6	41.1	1.5
11-1	40	49.5	2.6	50.0	2.1	52.2	1.9
11-1	45	61.8	2.9	61.1	2.4	63.2	2.2
11-1	50	72.7	2.8	71.1	2.4	72.9	2.2
11-1	55	81.5	2.4	79.4	2.2	80.8	2.0
11-1	60	87.9	1.9	85.8	1.8	86.9	1.6
11-1	65	92.3	1.4	90.5	1.5	91.2	1.3
11-1	70	95.2	1.0	93.7	1.1	94.2	1.0
11-1	75	97.0	0.7	95.9	0.8	96.2	0.7
11-1	80	98.2	0.5	97.3	0.6	97.6	0.5
11-1	85	98.9	0.3	98.3	0.4	98.4	0.4
11-1	90	99.3	0.2	98.9	0.3	99.0	0.2
2-4	5	4.4	0.5	5.8	0.6	6.2	0.5
2-4	10	7.0	0.8	8.8	0.8	9.4	0.7
2-4	15	11.1	1.1	13.1	1.0	14.1	1.0
2-4	20	17.1	1.6	19.2	1.4	20.4	1.3
2-4	25	25.4	2.3	27.1	1.8	28.7	1.7
2-4	30	35.9	2.9	36.8	2.3	38.7	2.1
2-4	35	48.0	3.4	47.8	2.7	49.8	2.5
2-4	40	60.3	3.6	58.9	2.9	60.8	2.7
2-4	45	71.5	3.3	69.2	2.8	70.9	2.6
2-4	50	80.5	2.8	77.9	2.5	79.2	2.3
2-4	55	87.2	2.2	84.7	2.1	85.7	1.9
2-4	60	91.8	1.6	89.7	1.6	90.4	1.5
2-4	65	94.9	1.1	93.2	1.2	93.6	1.1
2-4	70	96.8	0.8	95.5	0.9	95.9	0.8
2-4	75	98.1	0.5	97.1	0.6	97.3	0.6
2-4	80	98.8	0.3	98.1	0.4	98.3	0.4
2-4	85	99.3	0.2	98.8	0.3	98.9	0.3
2-4	90	99.6	0.1	99.2	0.2	99.3	0.2
8-10	5	4.1	0.4	6.1	0.5	6.2	0.5
8-10	10	6.5	0.6	9.2	0.7	9.4	0.6

Table X. Cont'd

8-10	15	10.3	0.8	13.7	1.0	13.9	0.9
8-10	20	16.0	1.2	19.9	1.3	20.3	1.2
8-10	25	23.9	1.8	28.1	1.8	28.5	1.6
8-10	30	34.1	2.4	38.0	2.3	38.5	2.0
8-10	35	46.0	3.0	49.0	2.7	49.5	2.4
8-10	40	58.4	3.3	60.1	2.9	60.6	2.6
8-10	45	69.8	3.2	70.3	2.8	70.7	2.6
8-10	50	79.2	2.8	78.8	2.5	79.1	2.3
8-10	55	86.3	2.2	85.3	2.1	85.6	1.9
8-10	60	91.2	1.6	90.1	1.6	90.3	1.5
8-10	65	94.5	1.2	93.5	1.2	93.6	1.1
8-10	70	96.6	0.8	95.7	0.9	95.8	0.8
8-10	75	97.9	0.5	97.2	0.6	97.3	0.6
8-10	80	98.7	0.4	98.2	0.4	98.3	0.4
8-10	85	99.2	0.2	98.9	0.3	98.9	0.3
8-10	90	99.5	0.2	99.3	0.2	99.3	0.2
5-7	5	0.6	0.1	1.1	0.2	1.1	0.2
5-7	10	1.0	0.2	1.7	0.3	1.8	0.3
5-7	15	1.6	0.4	2.7	0.5	2.7	0.4
5-7	20	2.6	0.6	4.1	0.7	4.2	0.7
5-7	25	4.3	0.9	6.4	1.1	6.5	1.0
5-7	30	6.8	1.4	9.6	1.6	9.8	1.5
5-7	35	10.8	2.1	14.3	2.2	14.6	2.1
5-7	40	16.7	3.1	20.8	3.0	21.1	2.9
5-7	45	24.8	4.2	29.1	3.9	29.5	3.7
5-7	50	35.2	5.3	39.2	4.7	39.7	4.5
5-7	55	47.3	6.0	50.2	5.1	50.7	4.9
5-7	60	59.6	6.1	61.3	5.0	61.8	4.9
5-7	65	70.9	5.5	71.3	4.6	71.7	4.4
5-7	70	80.1	4.4	79.6	3.8	79.9	3.7
5-7	75	86.9	3.3	85.9	3.0	86.2	2.9
5-7	80	91.6	2.3	90.6	2.2	90.7	2.1
5-7	85	94.7	1.6	93.8	1.6	93.9	1.5
5-7	90	96.7	1.1	95.9	1.1	96.0	1.1

Table XI.

Results from Application of Algorithm for Cases I & II, Car Rollover: Probability of Fatality or MAIS=2+.

		Probab. & Std Err		95% Confid. Bounds	
Case I Rollover	Qrtr Turns	P	seP	Lower	Upper
No	0	10.1	0.2	9.7	10.5
Yes	Any	20.6	0.9	18.8	22.4
Case II					
No	0	10.1	0.2	9.7	10.5
Yes	1	14.3	2.0	10.4	18.2
Yes	2-3	17.9	1.4	15.2	20.6
Yes	4+	26.1	1.6	23.0	29.2

Table XII.

Selected Results from Application of Algorithm for <u>Case III, Planar Car Crashes</u>.

Probability P of Fatality or MAIS=2+, and Std Error seP

Item	Total DeltaV	Force Directn	Occpnt Age	Occpnt Gender	Car Size	P	seP
1	10	8-10	15	Male	Large	5.0	0.7
2	10	8-10	15	Male	Small	6.4	0.7
3	10	8-10	15	Female	Large	6.1	0.8
4	10	8-10	15	Female	Small	7.8	0.8
5	10	8-10	75	Male	Large	14.8	1.8
6	10	8-10	75	Male	Small	18.5	1.9
7	10	8-10	75	Female	Large	17.7	1.9
8	10	8-10	75	Female	Small	21.9	2.0
9	10	5-7	15	Male	Large	0.9	0.2
10	10	5-7	15	Male	Small	1.2	0.2
11	10	5-7	15	Female	Large	1.1	0.2
12	10	5-7	15	Female	Small	1.4	0.3
13	10	5-7	75	Male	Large	2.9	0.6
14	10	5-7	75	Male	Small	3.8	0.8
15	10	5-7	75	Female	Large	3.6	0.7
16	10	5-7	75	Female	Small	4.6	1.0
17	20	8-10	15	Male	Large	12.5	1.6
18	20	8-10	15	Male	Small	15.7	1.4
19	20	8-10	15	Female	Large	14.9	1.7
20	20	8-10	15	Female	Small	18.7	1.5
21	20	8-10	75	Male	Large	32.1	3.2
22	20	8-10	75	Male	Small	38.2	2.9
23	20	8-10	75	Female	Large	36.8	3.2
24	20	8-10	75	Female	Small	43.3	2.9
25	20	5-7	15	Male	Large	2.4	0.5
26	20	5-7	15	Male	Small	3.1	0.6
27	20	5-7	15	Female	Large	2.9	0.6
28	20	5-7	15	Female	Small	3.8	0.7
29	20	5-7	75	Male	Large	7.5	1.4
30	20	5-7	75	Male	Small	9.6	1.8
31	20	5-7	75	Female	Large	9.1	1.7
32	20	5-7	75	Female	Small	11.[illegible]	2.2
33	30	8-10	15	Male	Large	27.9	3.1
34	30	8-10	15	Male	Small	33.[illegible]	2.5
35	30	8-10	15	Female	Large	32.3	3.2
36	30	8-10	15	Female	Small	38.5	2.6
37	30	8-10	75	Male	Large	56.2	3.9
38	30	8-10	75	Male	Small	62.7	3.2
39	30	8-10	75	Female	Large	61.3	3.5

Table XII. Cont'd

40	30	8-10	75	Female	Small	67.5	2.9
41	30	5-7	15	Male	Large	6.2	1.2
42	30	5-7	15	Male	Small	8.0	1.4
43	30	5-7	15	Female	Large	7.6	1.5
44	30	5-7	15	Female	Small	9.7	1.7
45	30	5-7	75	Male	Large	18.1	3.0
46	30	5-7	75	Male	Small	22.4	3.6
47	30	5-7	75	Female	Large	21.4	3.5
48	30	5-7	75	Female	Small	26.3	4.0
49	40	8-10	15	Male	Large	51.2	4.2
50	40	8-10	15	Male	Small	57.9	3.2
51	40	8-10	15	Female	Large	56.5	4.0
52	40	8-10	15	Female	Small	62.9	3.0
53	40	8-10	75	Male	Large	77.7	3.0
54	40	8-10	75	Male	Small	82.1	2.3
55	40	8-10	75	Female	Large	81.2	2.6
56	40	8-10	75	Female	Small	84.9	1.9
57	40	5-7	15	Male	Large	15.3	2.7
58	40	5-7	15	Male	Small	19.2	3.0
59	40	5-7	15	Female	Large	18.2	3.1
60	40	5-7	15	Female	Small	22.6	3.5
61	40	5-7	75	Male	Large	37.5	5.0
62	40	5-7	75	Male	Small	44.0	5.2
63	40	5-7	75	Female	Large	42.6	5.2
64	40	5-7	75	Female	Small	49.3	5.3
65	50	8-10	15	Male	Large	74.1	3.7
66	50	8-10	15	Male	Small	78.9	2.6
67	50	8-10	15	Female	Large	77.9	3.2
68	50	8-10	15	Female	Small	82.2	2.3
69	50	8-10	75	Male	Large	90.5	1.7
70	50	8-10	75	Male	Small	92.6	1.3
71	50	8-10	75	Female	Large	92.1	1.4
72	50	8-10	75	Female	Small	93.9	1.0
73	50	5-7	15	Male	Large	33.0	4.9
74	50	5-7	15	Male	Small	39.2	4.9
75	50	5-7	15	Female	Large	37.8	5.2
76	50	5-7	15	Female	Small	44.3	5.2
77	50	5-7	75	Male	Large	62.0	5.3
78	50	5-7	75	Male	Small	68.1	4.8
79	50	5-7	75	Female	Large	66.8	5.0
80	50	5-7	75	Female	Small	72.5	4.5
81	60	8-10	15	Male	Large	88.6	2.2
82	60	8-10	15	Male	Small	91.1	1.5
83	60	8-10	15	Female	Large	90.6	1.8
84	60	8-10	15	Female	Small	92.6	1.3
85	60	8-10	75	Male	Large	96.3	0.8
86	60	8-10	75	Male	Small	97.1	0.6
87	60	8-10	75	Female	Large	97.0	0.7

Table XII. Concluded

88	60	8-10	75	Female	Small	97.7	0.5
89	60	5-7	15	Male	Large	57.2	5.8
90	60	5-7	15	Male	Small	63.6	5.1
91	60	5-7	15	Female	Large	62.2	5.6
92	60	5-7	15	Female	Small	68.4	4.9
93	60	5-7	75	Male	Large	81.6	3.6
94	60	5-7	75	Male	Small	85.3	3.0
95	60	5-7	75	Female	Large	84.6	3.2
96	60	5-7	75	Female	Small	87.8	2.6

Table XIII.

Results from Application of Algorithm for <u>Case</u> <u>III,</u> <u>Car</u> <u>Rollover</u>: Probability of Fatality or MAIS=2+.

Rollover with 4+ Quarter Turns

OCCAGE	GENDER	CAR	P	SEP
15	Male	Large	20.4	1.7
15	Male	Mid	23.0	1.6
15	Male	Small	24.2	1.6
15	Female	Large	21.9	1.8
15	Female	Mid	24.6	1.7
15	Female	Small	25.9	1.8
30	Male	Large	25.7	2.0
30	Male	Mid	28.7	1.9
30	Male	Small	30.2	1.9
30	Female	Large	27.5	2.1
30	Female	Mid	30.6	1.9
30	Female	Small	32.1	2.0
45	Male	Large	31.9	2.2
45	Male	Mid	35.2	2.1
45	Male	Small	36.8	2.1
45	Female	Large	33.8	2.3
45	Female	Mid	37.3	2.1
45	Female	Small	38.9	2.2
60	Male	Large	38.7	2.5
60	Male	Mid	42.3	2.4
60	Male	Small	44.0	2.4
60	Female	Large	40.9	2.6
60	Female	Mid	44.5	2.4
60	Female	Small	46.3	2.4
75	Male	Large	46.0	2.7
75	Male	Mid	49.8	2.6
75	Male	Small	51.5	2.6
75	Female	Large	48.3	2.8
75	Female	Mid	52.0	2.5
75	Female	Small	53.7	2.6

Rollover with 2-3 Quarter Turns

OCCAGE	GENDER	CAR	P	SEP
15	Male	Large	14.1	1.3
15	Male	Mid	16.0	1.3
15	Male	Small	16.9	1.3
15	Female	Large	15.2	1.4

Table XIII. Cont'd

15	Female	Mid	17.2	1.4
15	Female	Small	18.2	1.5
30	Male	Large	18.1	1.6
30	Male	Mid	20.4	1.6
30	Male	Small	21.6	1.6
30	Female	Large	19.5	1.7
30	Female	Mid	21.9	1.7
30	Female	Small	23.1	1.7
45	Male	Large	23.0	1.9
45	Male	Mid	25.7	1.9
45	Male	Small	27.1	1.9
45	Female	Large	24.6	2.0
45	Female	Mid	27.5	2.0
45	Female	Small	28.9	2.1
60	Male	Large	28.7	2.3
60	Male	Mid	31.9	2.2
60	Male	Small	33.4	2.3
60	Female	Large	30.6	2.4
60	Female	Mid	33.8	2.3
60	Female	Small	35.4	2.4
75	Male	Large	35.2	2.6
75	Male	Mid	38.7	2.6
75	Male	Small	40.4	2.6
75	Female	Large	37.3	2.7
75	Female	Mid	40.9	2.7
75	Female	Small	42.6	2.7

Rollover with 1 Quarter Turn

OCCAGE	GENDER	CAR	P	SEP
15	Male	Large	10.5	1.6
15	Male	Mid	12.0	1.8
15	Male	Small	12.8	1.8
15	Female	Large	11.4	1.8
15	Female	Mid	13.0	1.9
15	Female	Small	13.8	2.0
30	Male	Large	13.7	2.0
30	Male	Mid	15.6	2.2
30	Male	Small	16.5	2.3
30	Female	Large	14.8	2.2
30	Female	Mid	16.8	2.3
30	Female	Small	17.8	2.4
45	Male	Large	17.7	2.5
45	Male	Mid	19.9	2.7
45	Male	Small	21.1	2.8
45	Female	Large	19.0	2.7
45	Female	Mid	21.4	2.8

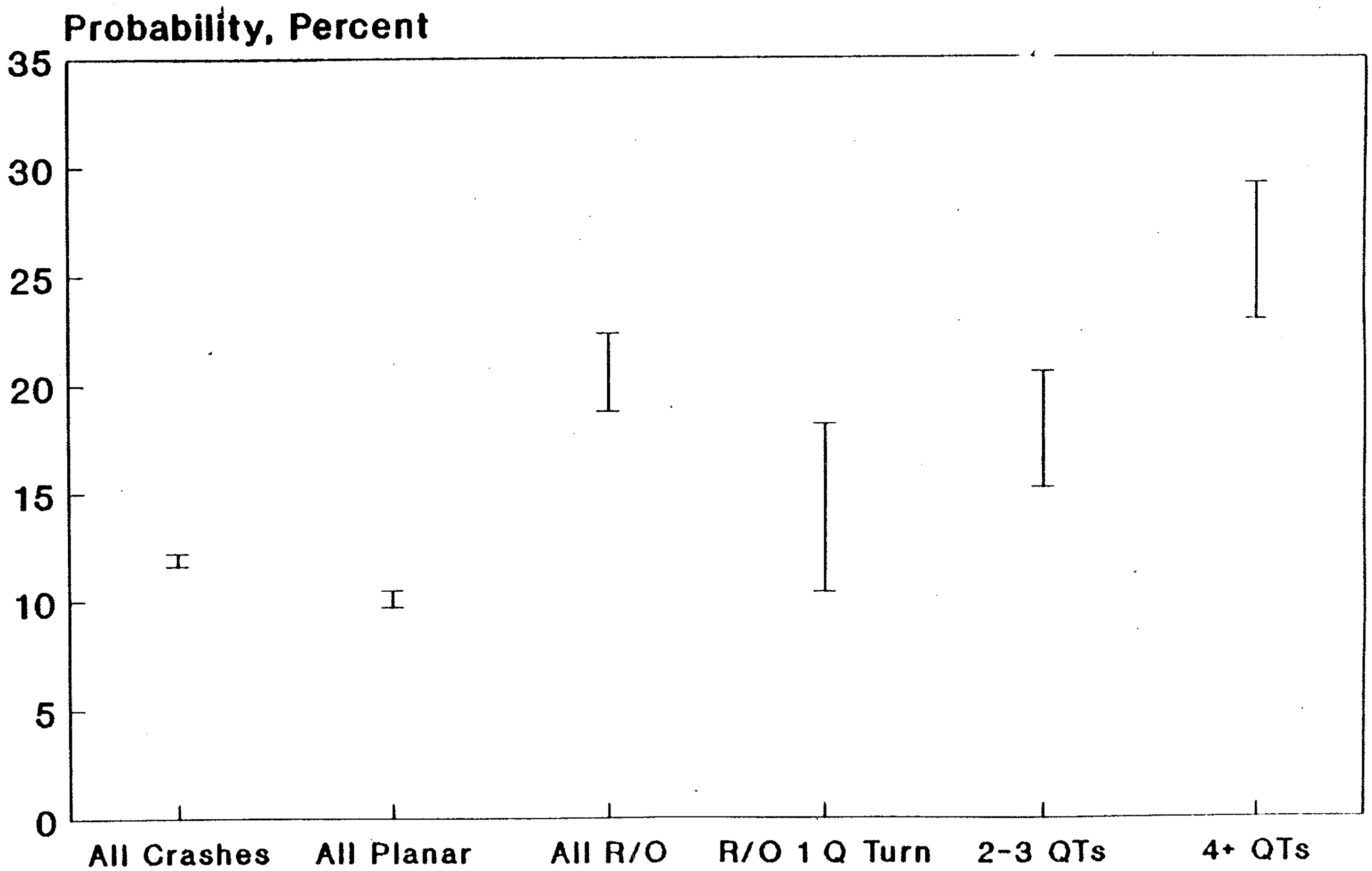
Table XIII. Cont'd

45	Female	Small	22.6	2.9
60	Male	Large	22.4	3.0
60	Male	Mid	25.2	3.2
60	Male	Small	26.5	3.3
60	Female	Large	24.0	3.2
60	Female	Mid	26.9	3.3
60	Female	Small	28.3	3.4
75	Male	Large	28.1	3.6
75	Male	Mid	31.2	3.7
75	Male	Small	32.7	3.8
75	Female	Large	29.9	3.7
75	Female	Mid	33.2	3.8
75	Female	Small	34.8	3.9

No Rollover

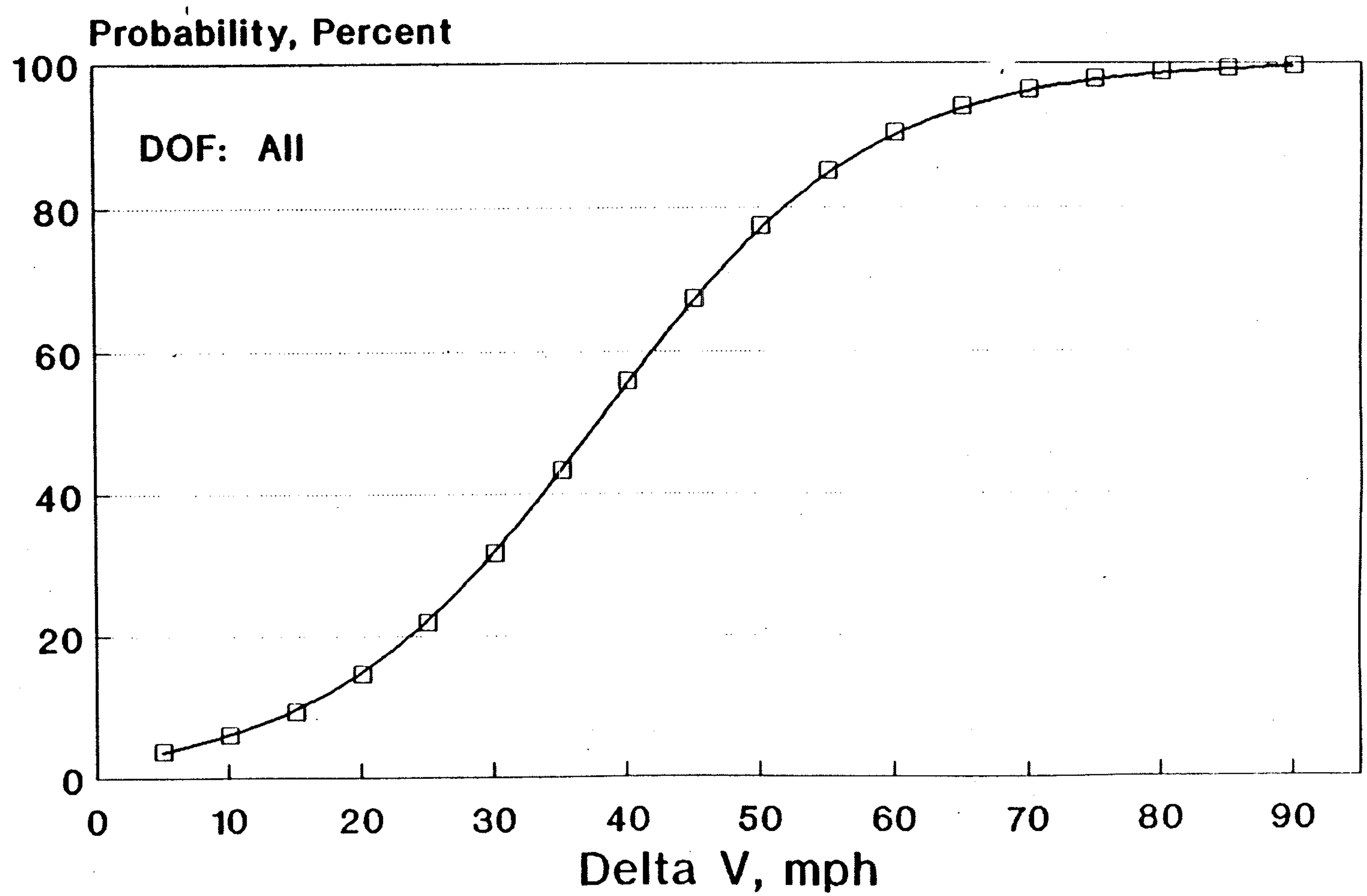
OCCAGE	GENDER	CAR	P	SEP
15	Male	Large	.	.
15	Male	Mid	.	.
15	Male	Small	8.6	0.3
15	Female	Large	.	.
15	Female	Mid	.	.
15	Female	Small	9.4	0.4
30	Male	Large	9.3	0.5
30	Male	Mid	10.6	0.3
30	Male	Small	11.3	0.4
30	Female	Large	10.1	0.5
30	Female	Mid	11.5	0.4
30	Female	Small	12.2	0.4
45	Male	Large	12.1	0.6
45	Male	Mid	13.8	0.4
45	Male	Small	14.7	0.5
45	Female	Large	13.1	0.6
45	Female	Mid	14.9	0.4
45	Female	Small	15.8	0.6
60	Male	Large	15.7	0.8
60	Male	Mid	17.8	0.7
60	Male	Small	18.8	0.8
60	Female	Large	16.9	0.8
60	Female	Mid	19.2	0.6
60	Female	Small	20.3	0.8
75	Male	Large	20.1	1.0
75	Male	Mid	22.6	1.0
75	Male	Small	23.9	1.1
75	Female	Large	21.6	1.1
75	Female	Mid	24.2	1.0
75	Female	Small	25.5	1.2

Fig. 37. 95% Confidence Bounds of Probability of Fatality or MAIS 2+, in Towaway Car Crashes: An Overview



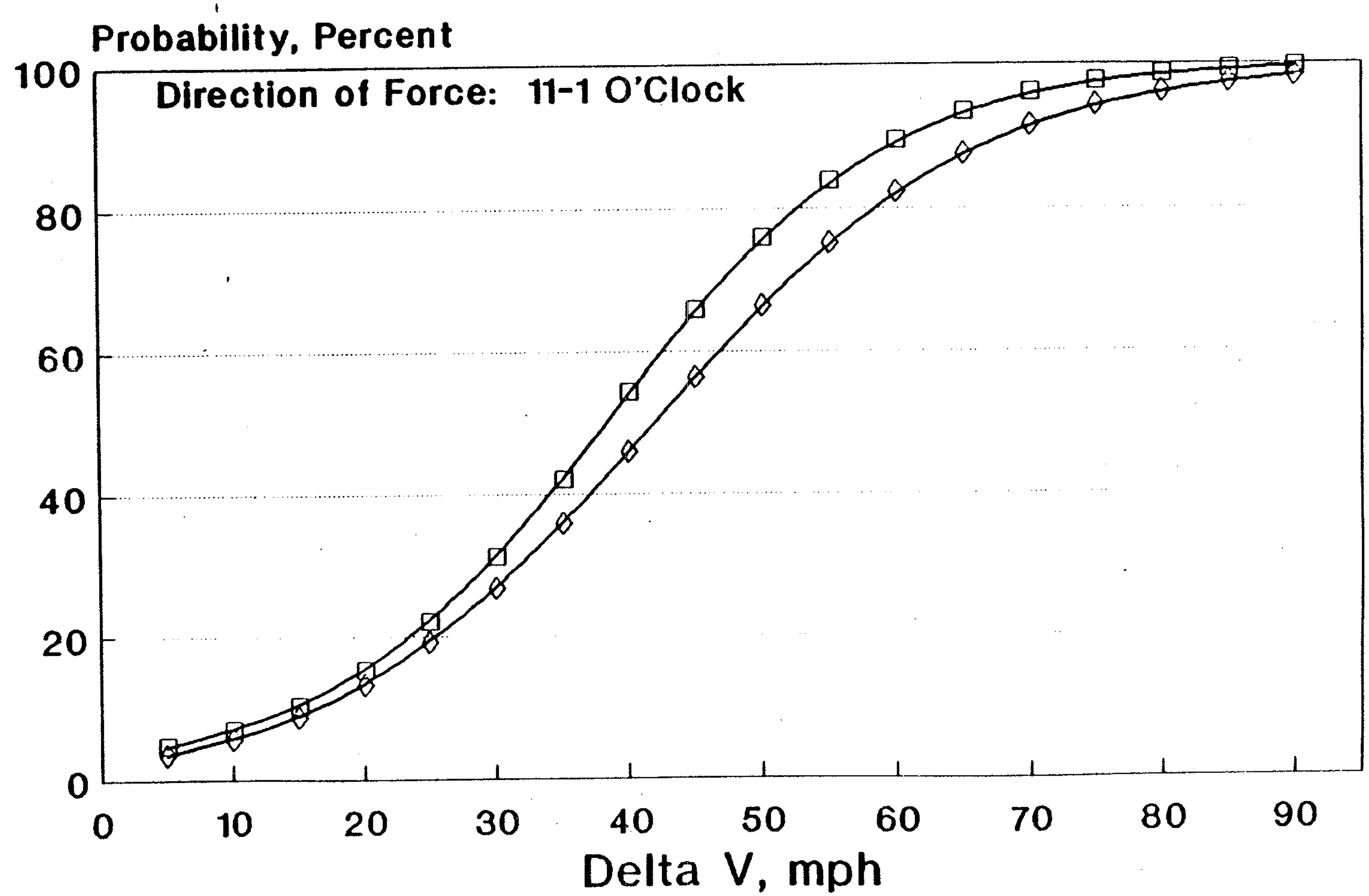
The NASS/CDS 1988-1995

Fig. 38. Variation of Probability of Fatality or MAIS 2+, v. Delta V, for All Planar Car Crashes



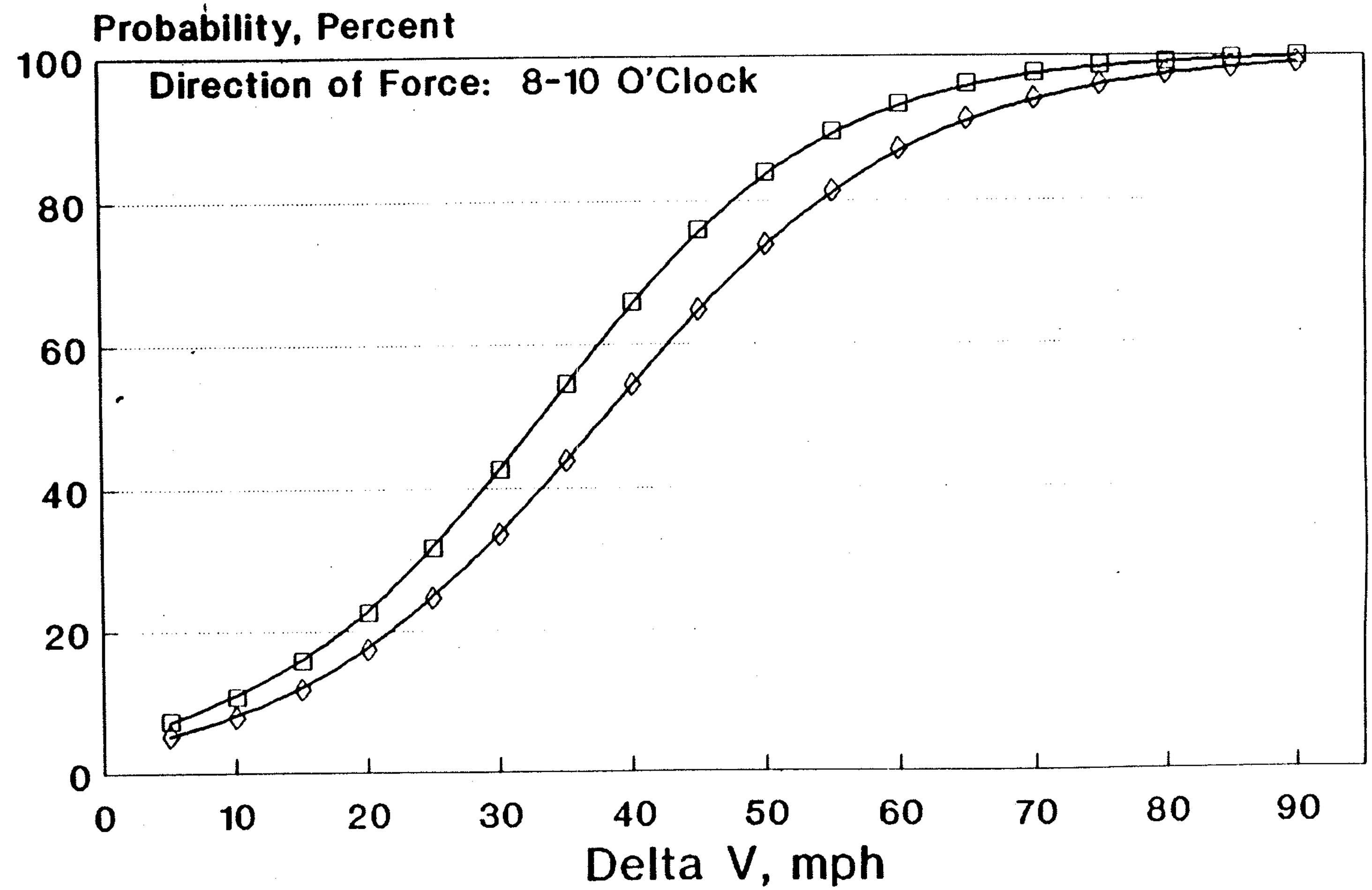
The NASS/CDS 1988-1995

Fig. 39. 95% Confidence Bounds for Probability of Fatality or MAIS 2+, v. Delta V, in Frontal Towaway Crashes



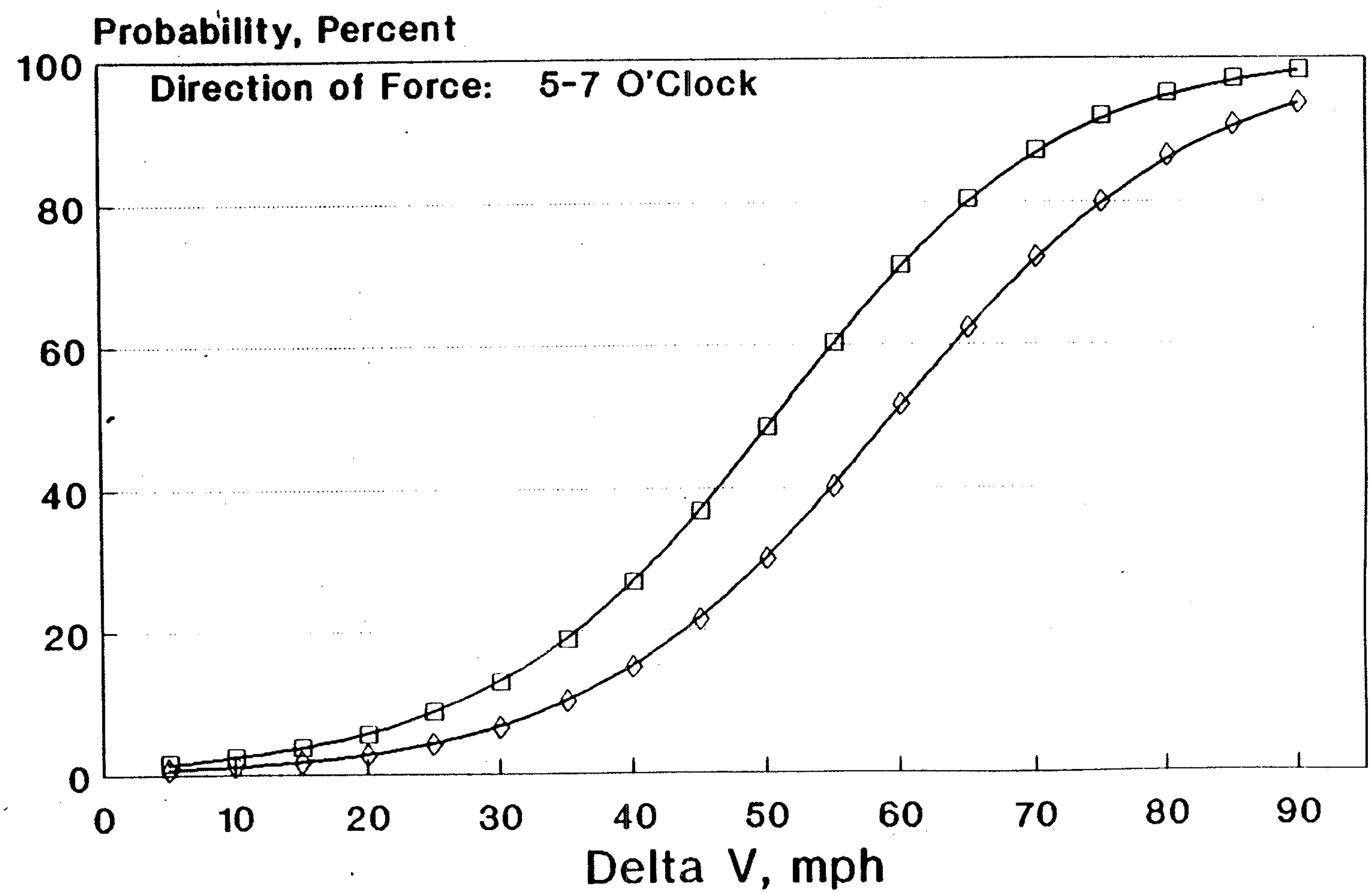
The NASS/CDS 1988-1995

Fig. 40. 95% Confidence Bounds for Probability of Fatality or MAIS 2+, v. Delta V for Left Planar Car Cras



The NASS/CDS 1988-1995

Fig. 41. 95% Confidence Bounds for Probability of Fatality or MAIS 2+, v. Delta V for Rear Planar Car Crashes



The NASS/CDS 1988-1995

Fig. 42. 95% Confidence Bounds for Probability of Fatality or MAIS 2+, v. Delta V in Crashes of Shown Direction

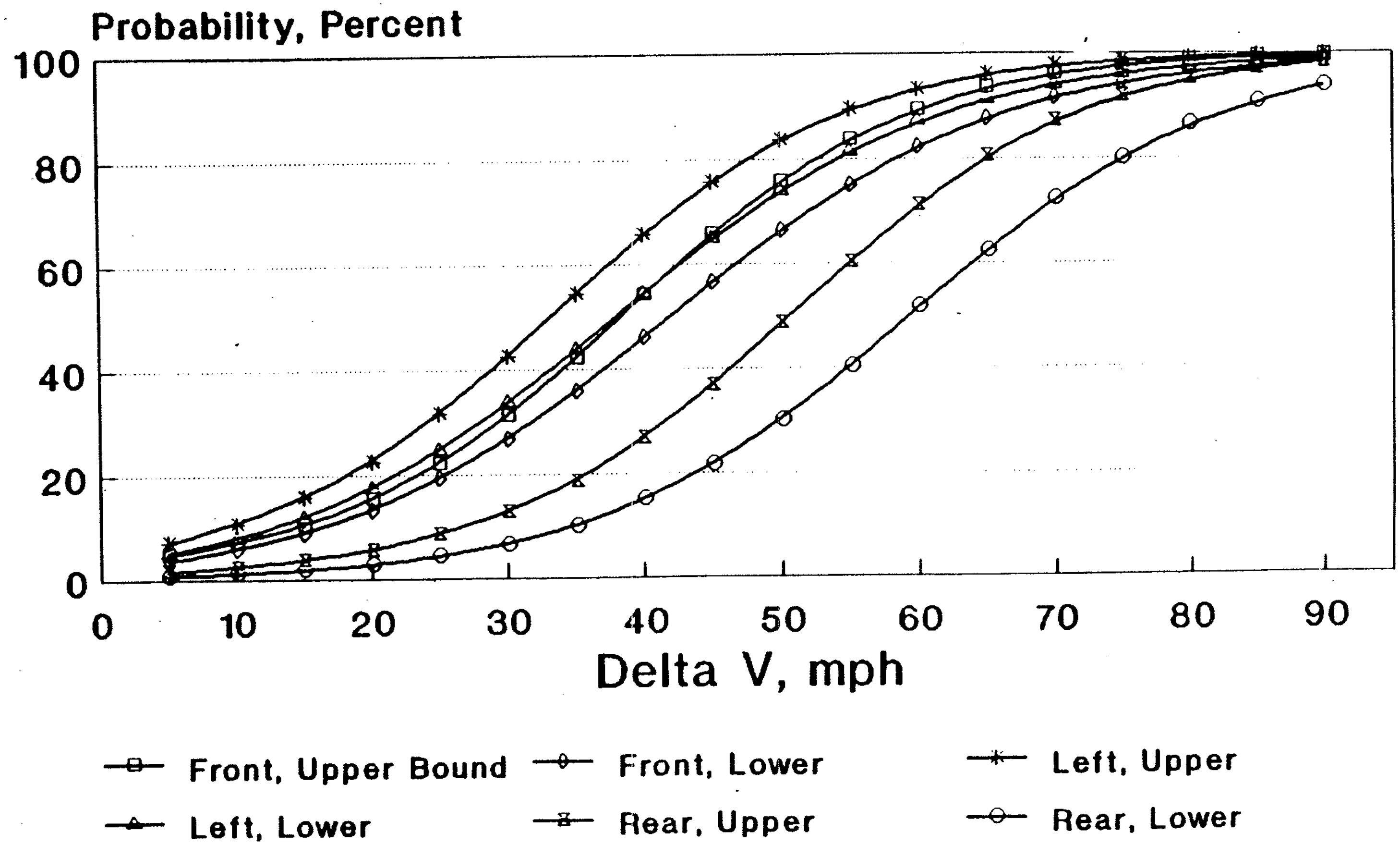


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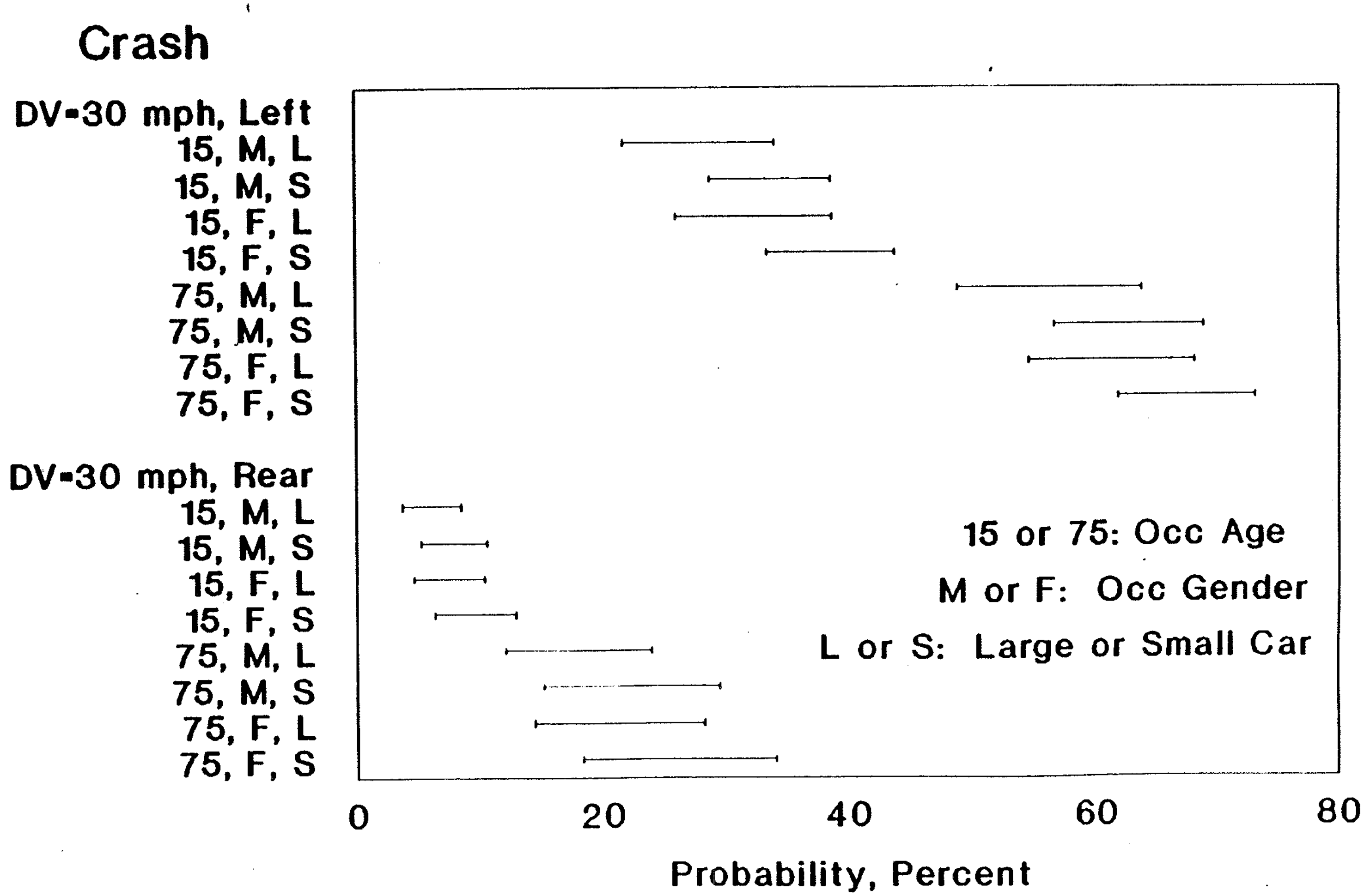
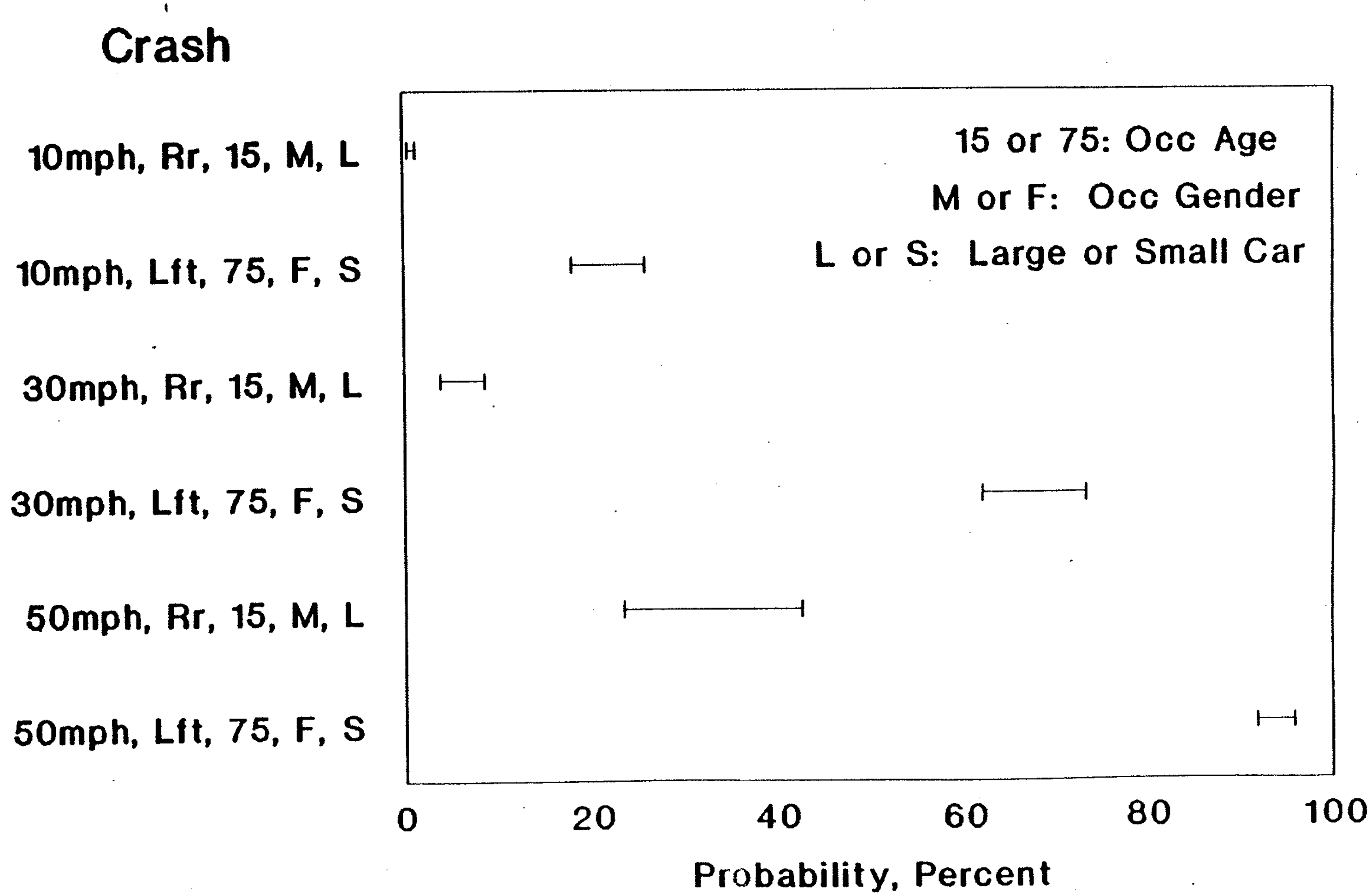
Fig. 43. 95% Confidence Bounds of Probability of Fatality or MAIS 2+, in Shown Towaway Car Crashes



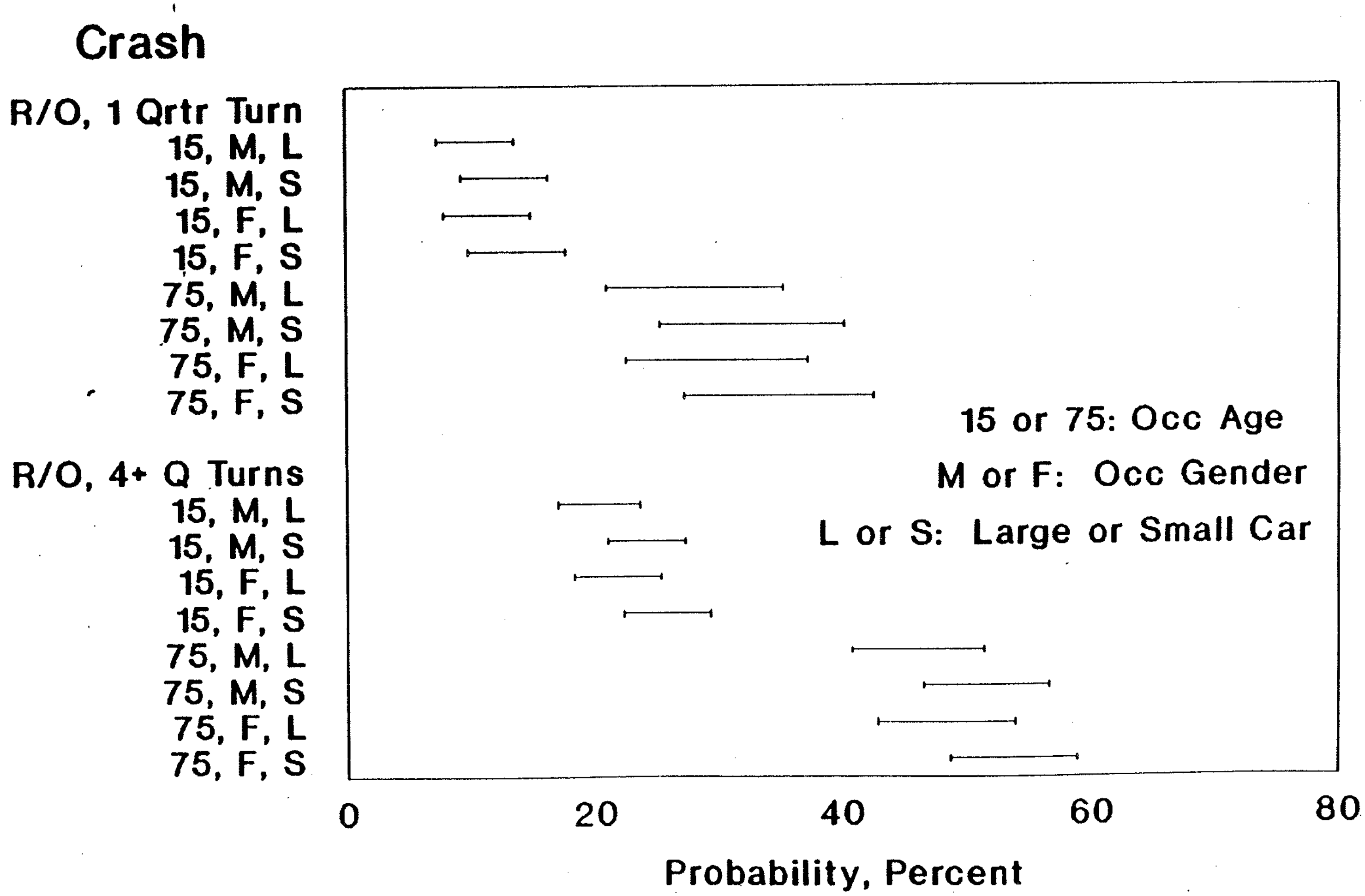
The NASS/CDS 1988-1995

Fig. 44. 95% Confidence Bounds of Probability of Fatality or MAIS 2+; an Illustration of Extremes



The NASS/CDS 1988-1995

Fig. 45. 95% Confidence Bounds of Probability of Fatality or MAIS 2+, in Shown Towaway Car Rollovers



The NASS/CDS 1988-1995