The Likelihood of Human Casualty in Highway Crashes

9th Briefing: Prediction of Compelling Injury

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

September 3, 1996
DeBlois Associates
Washington, D.C.

"The Likelihood of Casualty in Highway Crashes"

Introduction

This 9th briefing concerning the cited subject is entirely dedicated to the prediction of compelling injury occurrence. The briefing addresses, evaluates, and illustrates: incidence, perspective, predictive algorithm, numerical applications, sensitivity to predictors, and evaluation of predictive ability.

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.

"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.

"Harm"

For the purpose of this briefing, "Harm" is essentially a weighted sum of fatal outcomes, injured survivors, and other human losses incurred in crashes. The weights in this summation are scaled essentially in accordance with the comprehensive costs of human casualties, i.e. monetary plus "other costs". These "other costs" are based on a valuation of the less tangible costs of reduced functional capacity and diminished quality of life of survivors and their families.

As per NHTSA's recent publication, (see Appendix A, in "The Economic Costs of Motor Vehicle Crashes", NHTSA, July 1996) the following schedule of comprehensive costs is applicable.

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 Casualties, and Harm

There are about 1,850,000 cars involved each year in towaway crashes on U.S. roads. The incidence of occupant casualties and harm are summarized in Exhibits A1 and A2.

Perspective for Compelling Injuries

The perspective of injured car occupants with compelling v. noncompelling injuries is illustrated in Exhibits B1 and B2.

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. This briefing emphasizes the probability of a car occupant's incurring a compelling injury. For additional perspective, the probability of any injury irrespective of severity is addressed.

Programmable Algorithm

An optimal, but not necessarily optimum, algorithm for projecting the cited probability is modeled as follows:

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

$$w = A0 + A1*DVTOTAL + A2*SINGLE + A3*ROLL + A4*GADF + A5*GADS + A6*EXT1 + A7*EXT2 + A8*EXT3 + A9*EXT4 + A10*OCCRE + A11*AGE + A12*GENDER + A13*EJC + A14*EJP$$

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, A0 to A14, needed for an application are given below for the projection of occupants with compelling injury.

Coefficients for Compelling Injury

Predictor	A	Std Err	Probabil. of A=0
Intercept	-8.20	0.33	0.0000
TOTALDV	0.13	0.01	0.0000
SINGLE	0.42	0.14	0.0024
ROLL	0.84	0.37	0.0237
GADF	2.17	0.21	0.0000
GADS	2.80	0.21	0.0000
EXT1	-2.40	0.27	0.0000
EXT2	-1.44	0.17	0.0000
EXT3	-0.93	0.14	0.0000
EXT4	-0.25	0.18	0.1742
OCCRE	-0.62	0.10	0.0000
AGE	0.04	0.00	0.0000
GENDER	-0.23	0.10	0.0215
EJC	2.26	0.30	0.0000
EJP	1.26	0.29	0.0000

A similar schedule of coefficients may be derived for occupants injured at any specified severity or outcome.

Projected Probabilities

Applications of the cited algorithm for the probability of a compelling or any injury occurrence are illustrated in Exibit C. The probabilities, each accompanied by the 95% confidence bounds, are displayed here versus the most influential predictor, i.e the crash severity, delta V. All other predictors cited in the algorithm assume their mean values or portions in effect within the entire population of crash involved occupants. The following schedule is generally applicable in Exhibit C and elsewhere.

Single Car	20.8%
Multi-Vehicle	79.2
w Subseq. Rollover	2.6%
No Rollover	97.4
Frontal Crush	57.7%
Side Crush	31.9
Rear Crush	10.4

Crush Extent	1	35.5%
	2	35.4
	3	17.6
	4	5.0
	5+	6.5
Restrained Occ.		65.2%
Unrestrained		34.8
Male Occupant		50.1%
Female		49.9
Nonejected		98.9%
Partially Ejected		0.5
Completely Ejected		0.6
Mean Occupant Age		31.5 yrs
Mean Car Delta V		16.8 mph

Cumalative Frequency v. Probability of Occurrence

The relatively slow rise of the probability of occurrence of a car occupant's compelling injury, as observed in Exhibit C, should not diminish the serious concern that the majority of compelling injuries are compiled at relatively low values of delta V.

This is illustrated in Exhibit D, showing how rapidly the cumulative frequency of compelling injuries rises as crash severity increases: 50% of cumulative compelling injuries at about 20 mph delta V; nearly 80% at about 30 mph, notwithstanding the fact that the probability of individual occurrence is relatively small and rises slowly.

Other Factors Influencing the Probability of Compelling Injury

Exhibits C and D illustrate the effect of the strongest influence, i.e. crash severity, delta V. Other influences, that have been included as predictors in the cited algorithm, can have strong effects, as illustrated in the following exhibits.

The sensitivity of the probability of a car occupant's compelling injury to a car's type of crash is shown in Exhibit E. Exhibit F illustrates the sensitivity to a car's damage area location, while Exhibit G deals with the sensitivity to the extent of crash induced deformation.

Three more Exhibits: H, I, and J address the sensitivity to a car occupant's attributes: age, restraint use, and ejection

occurrence, respectively. In all Exhibits E to J the shown influencing factors are addressed in conjunction with the influence of crash severity, delta V.

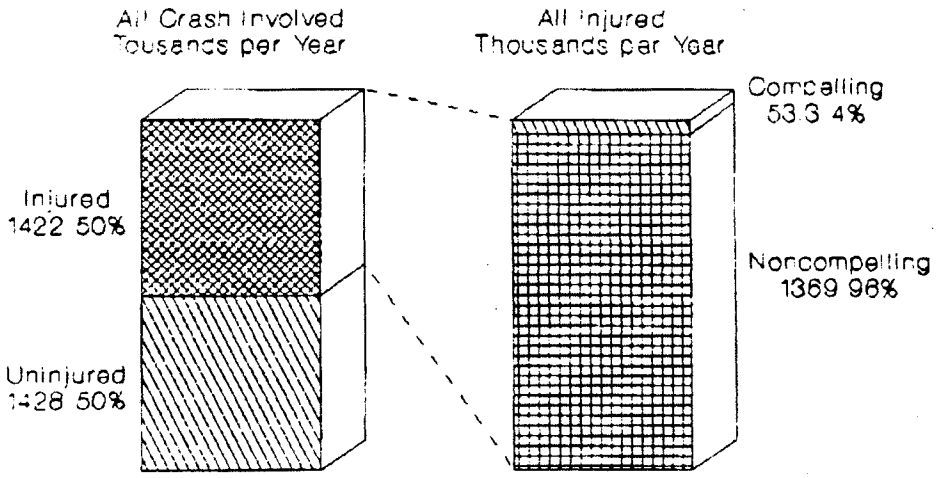
Evaluation of the Predictive Ability of the Algorithm

The predictive ability of the algorithm in effect is evaluated in terms of five pertinent yardsticks defined below, relevant to any selection of predicted probability:

Correct Prediction is the fraction of correct predictions (whether for compelling or noncompelling injury), made at a selected probability level, as a percent of all predictions. Correct is by reference to the car crash experience under consideration;
Sensitivity is the fraction of predicted compelling injuries, as a percentage of all compelling injuries in the population at stake;
Specificity is the fraction of predicted noncompelling injuries, as a percentage of all noncompelling injuries in the population at stake;
False Positives is the fraction of incorrectly predicted compelling injuries as a percentage of all predicted compelling injuries; and
False Negatives is the fraction of incorrectly predicted noncompelling injuries as a percentage of all predicted noncompelling injuries.

The evaluation of the five cited yardsticks is shown in Exhibit K, for any selected probability, from zero to 100%.

Exhibit A1. Towaway Car Occupants; Annual Incidence



The NASS/CDS 1988-1995

Exhibit A2. Towaway Car Occupants; Comprehensive Harm Distribution

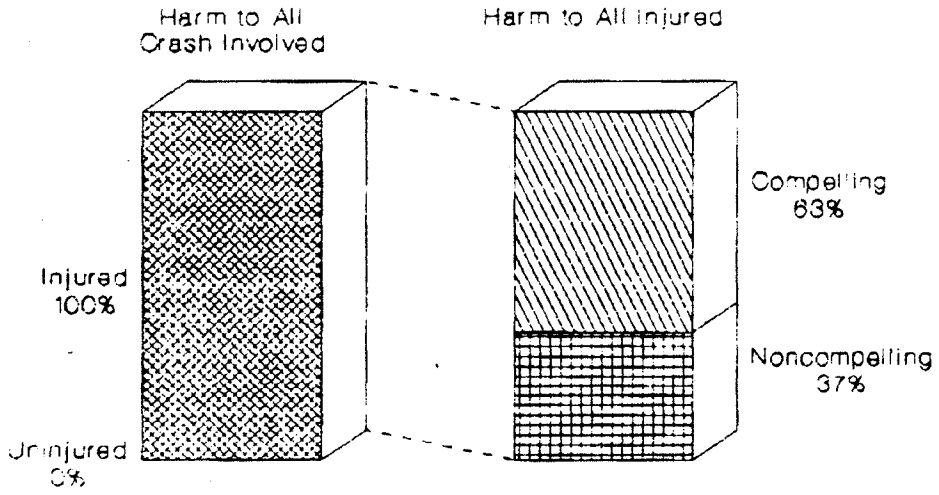


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Exhibit B1. Injured Car Occupants, by Max Injury Severity

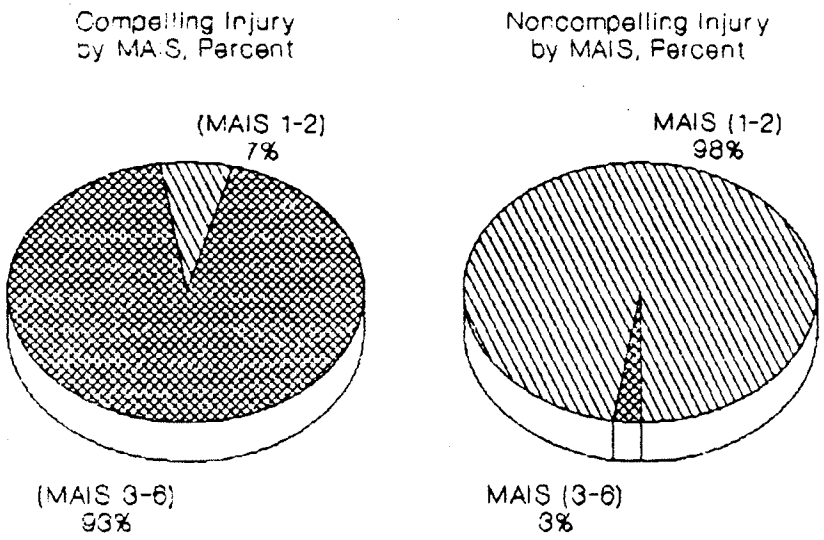

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Exhibit B2. Injured Car Occupants, by Severity of Outcome

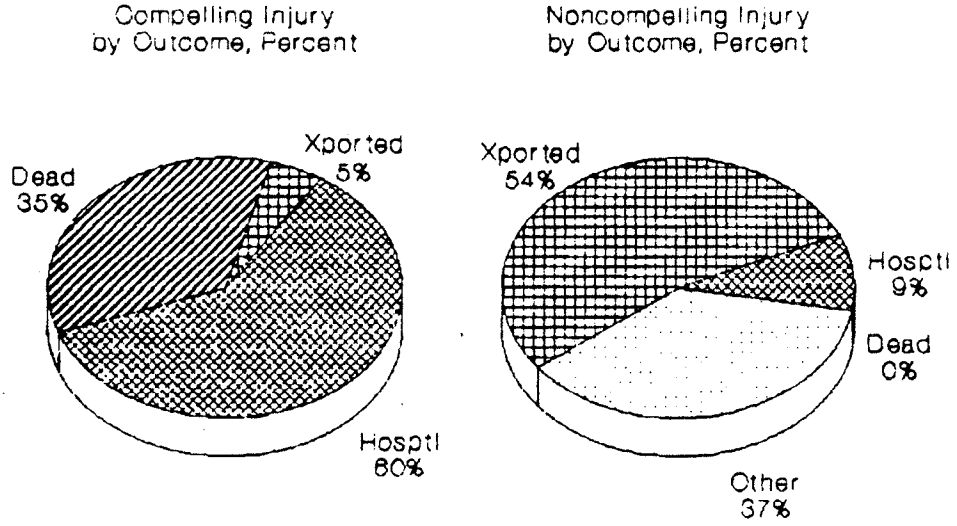

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Exhibit C. Probability and 95% Confid. Bounds for a Car Occupant Incurring a Shown Injury v. Crash Severity, Delta V

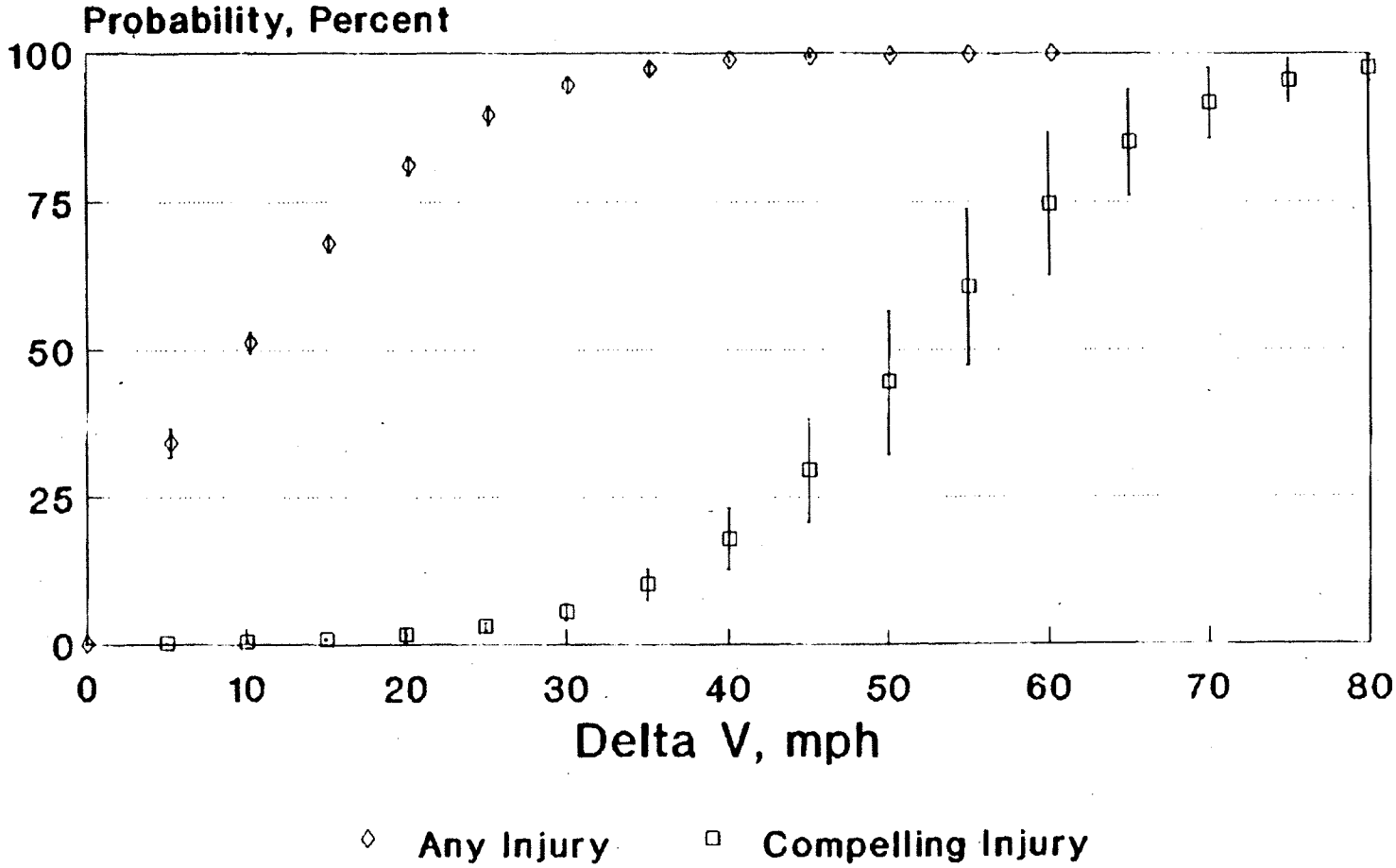

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Exhibit D. Probability of Occurrence and Cumulative Frequency of Compelling Injury v. Crash Severity, Delta V

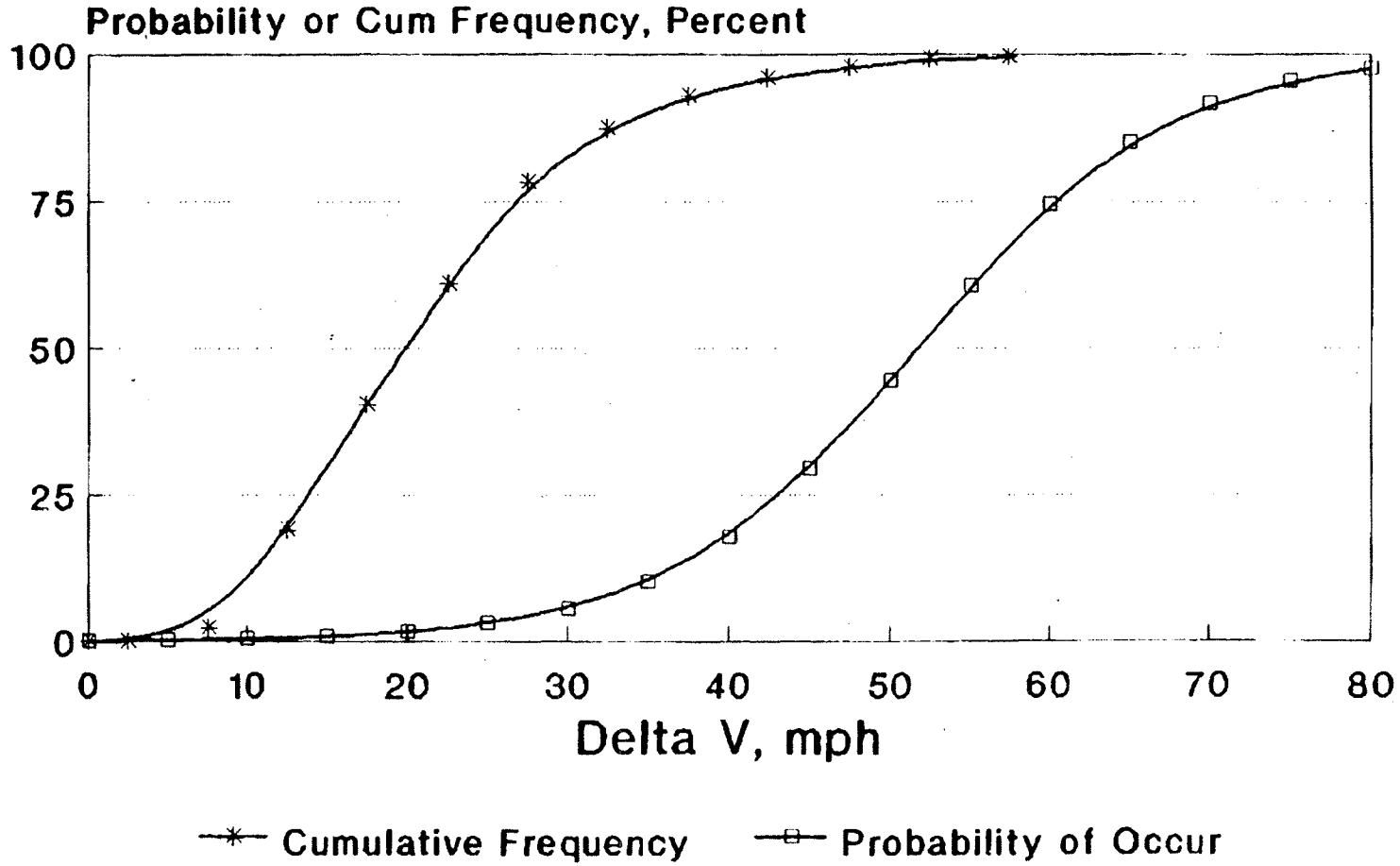

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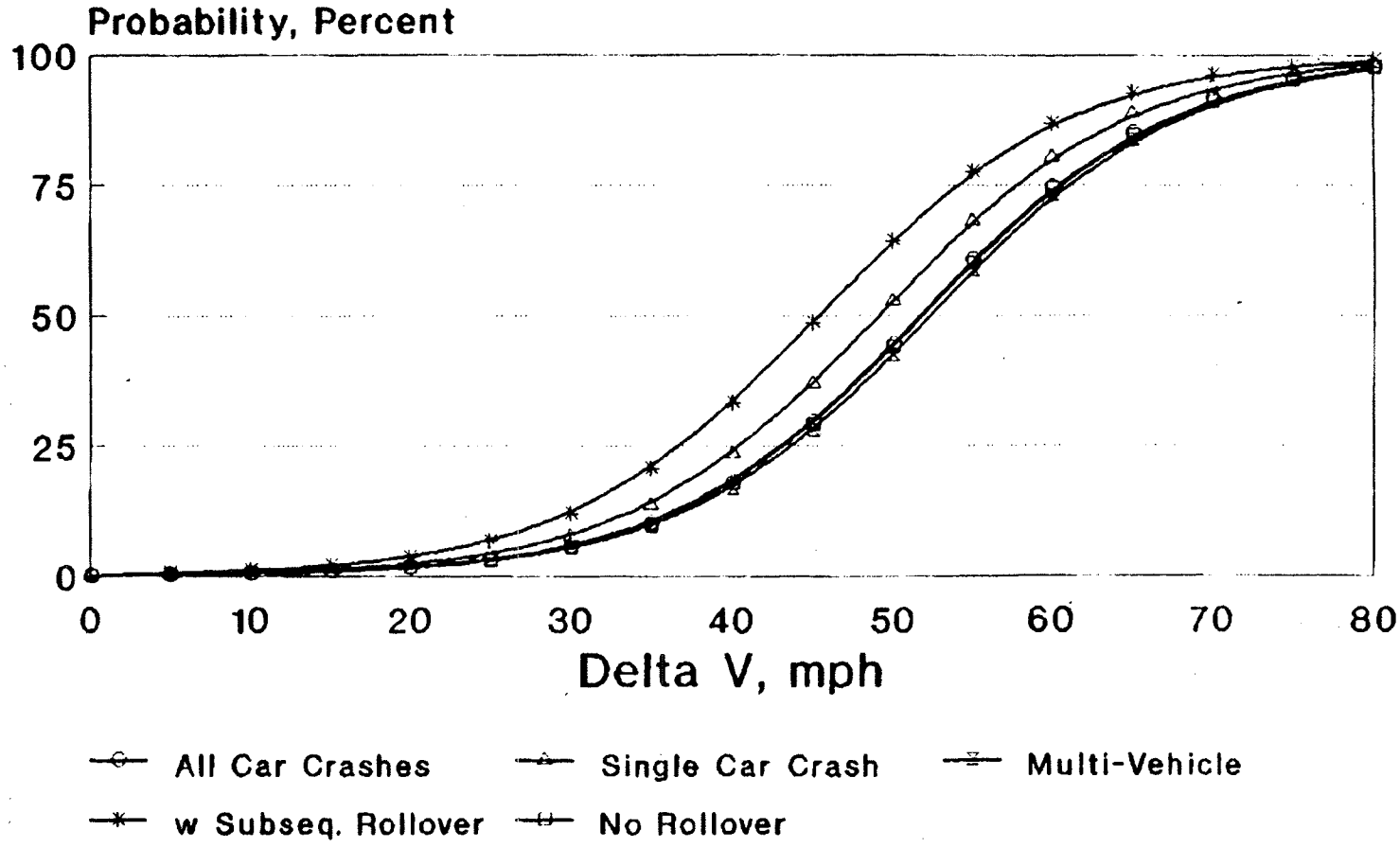
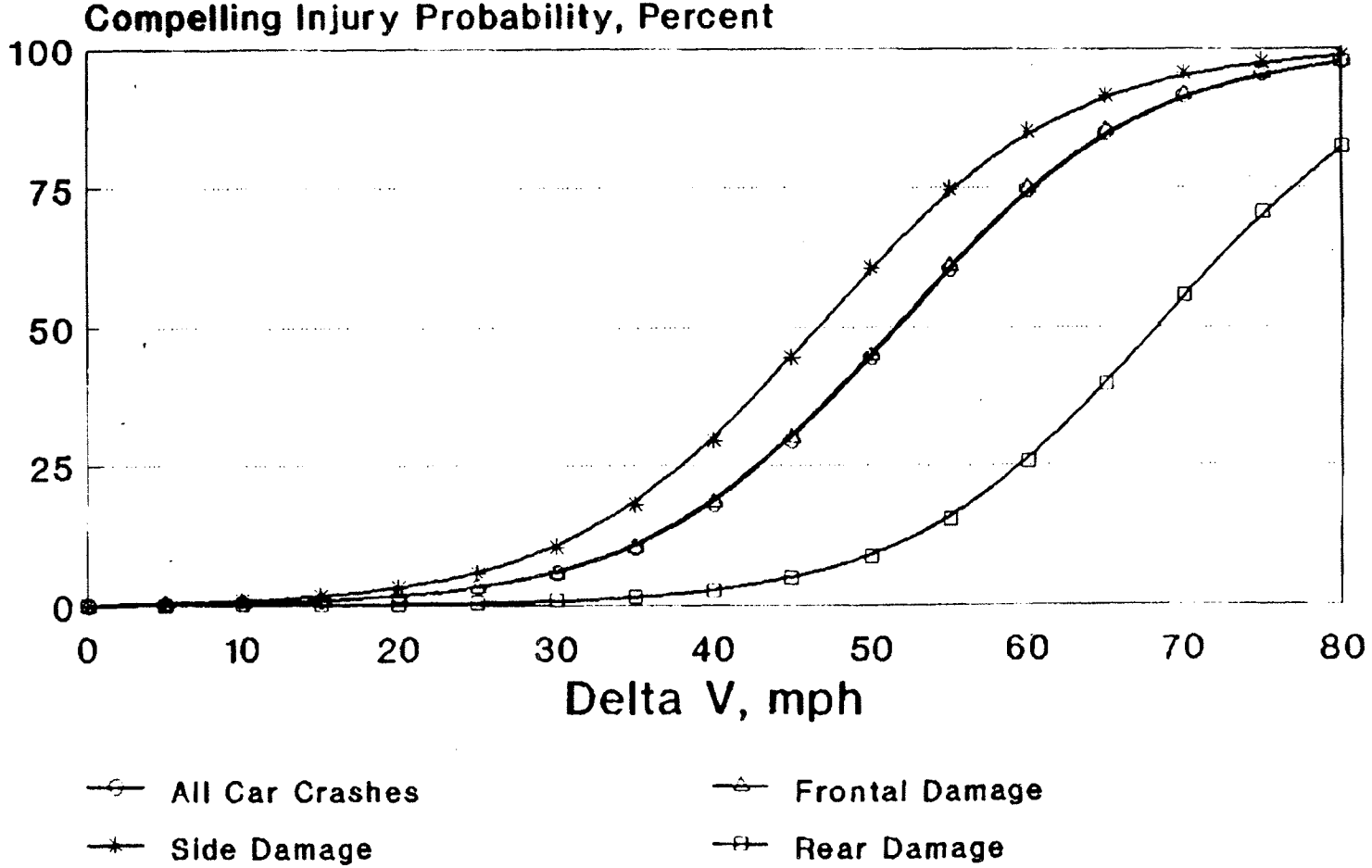
Exhibit E. Sensitivity of an Occupant's Probability of Compelling Injury to the Car's Crash Type



The NASS/CDS 1988-1996

Exhibit F. Sensitivity to a Car's Damage Area Location



The NASS/CDS 1988-1995

Exhibit G. Sensitivity to a Car's Deformation (as per SAE/CDC Standard)

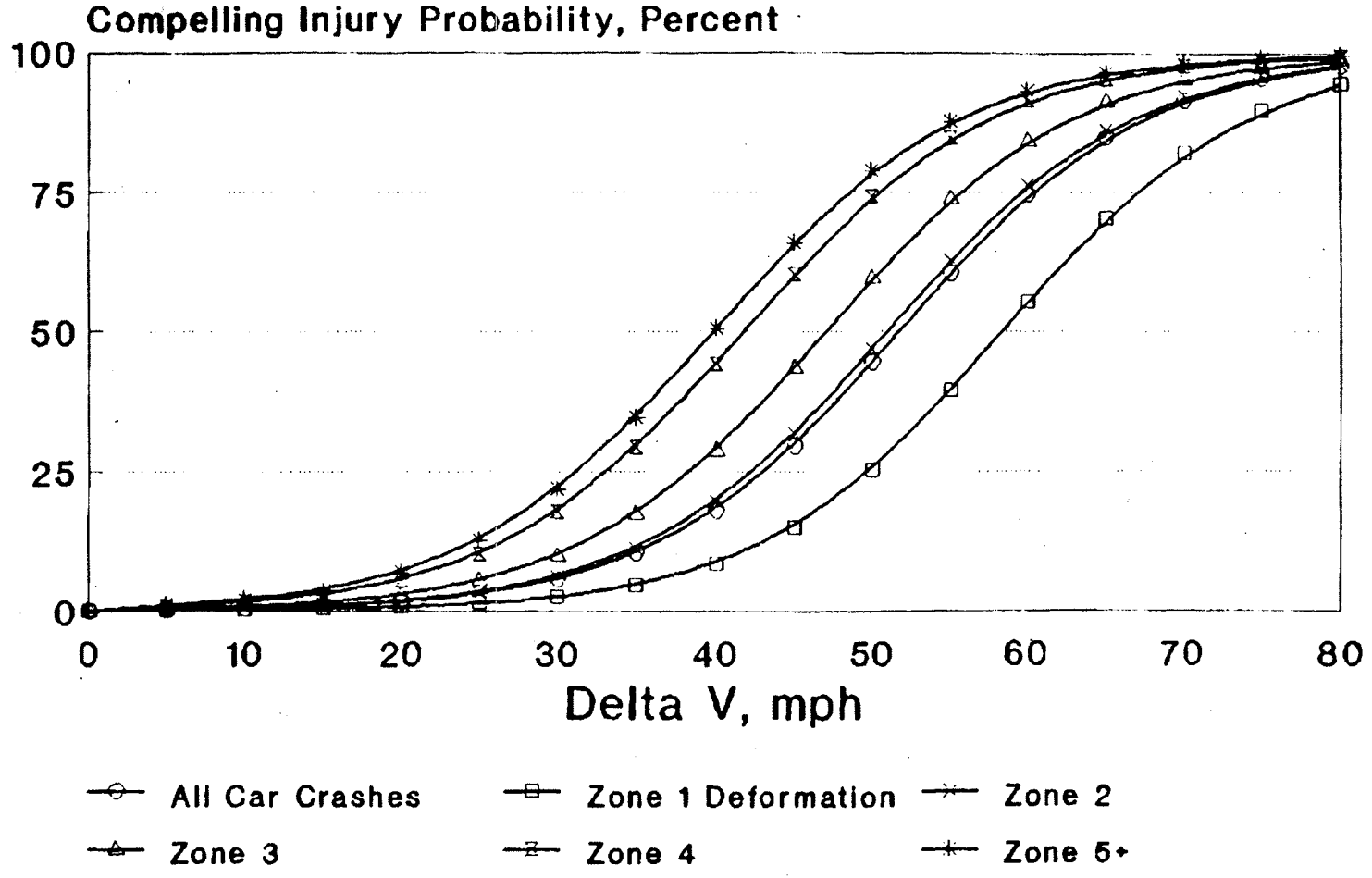


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Exhibit H. Sensitivity to an Occupant's Age

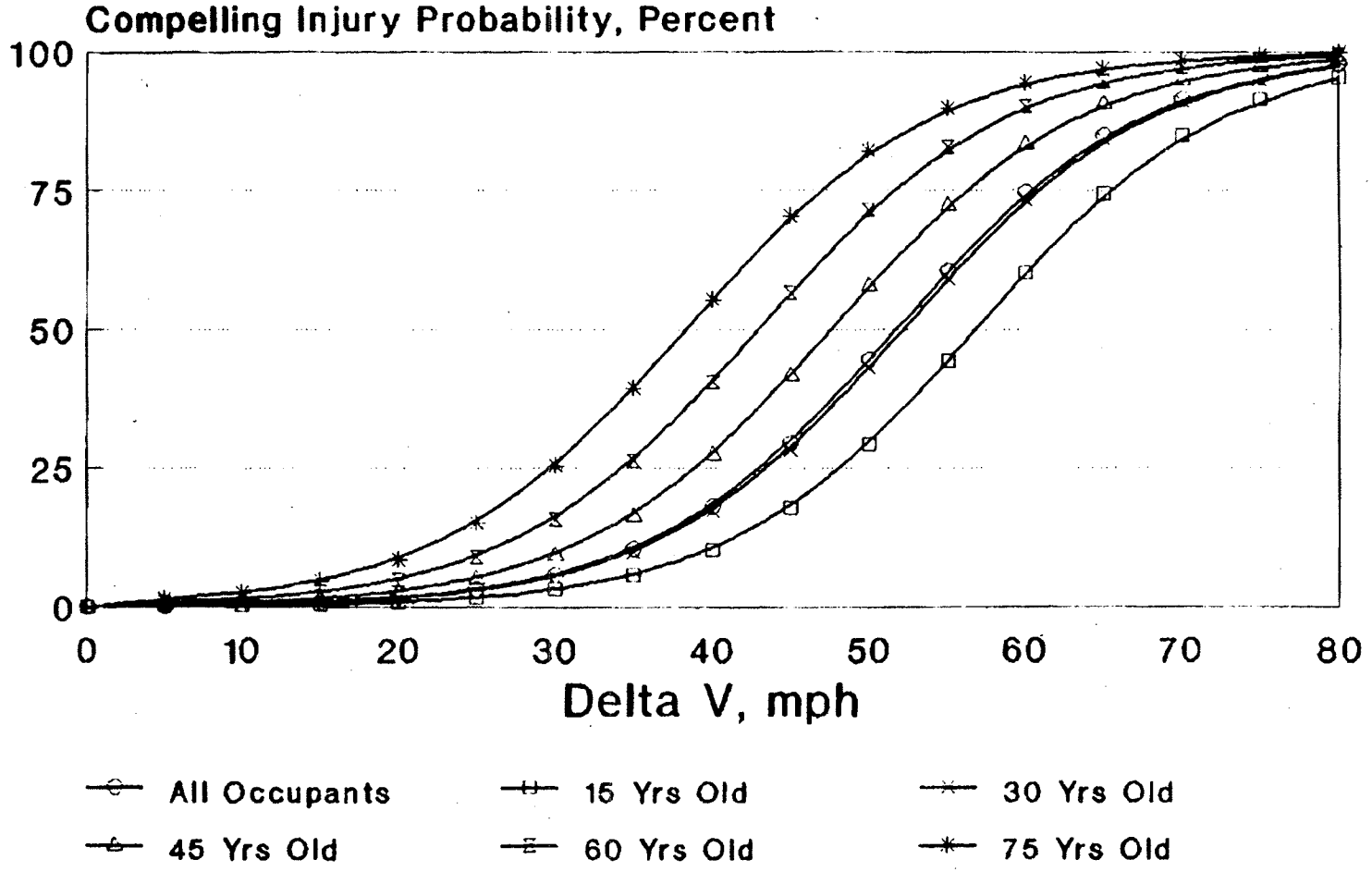

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Exhibit I. Sensitivity to an Occupant's Restraint Use

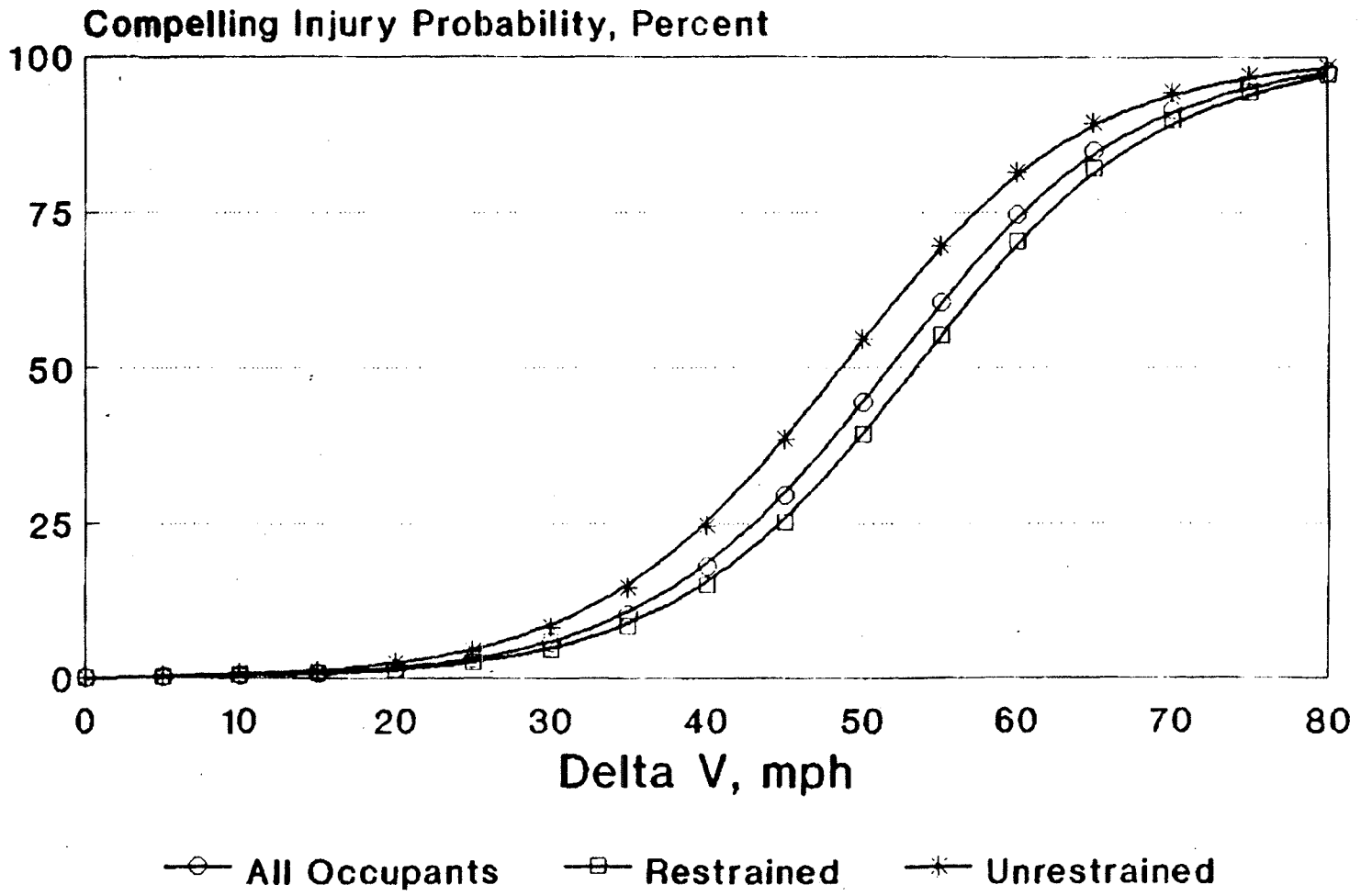

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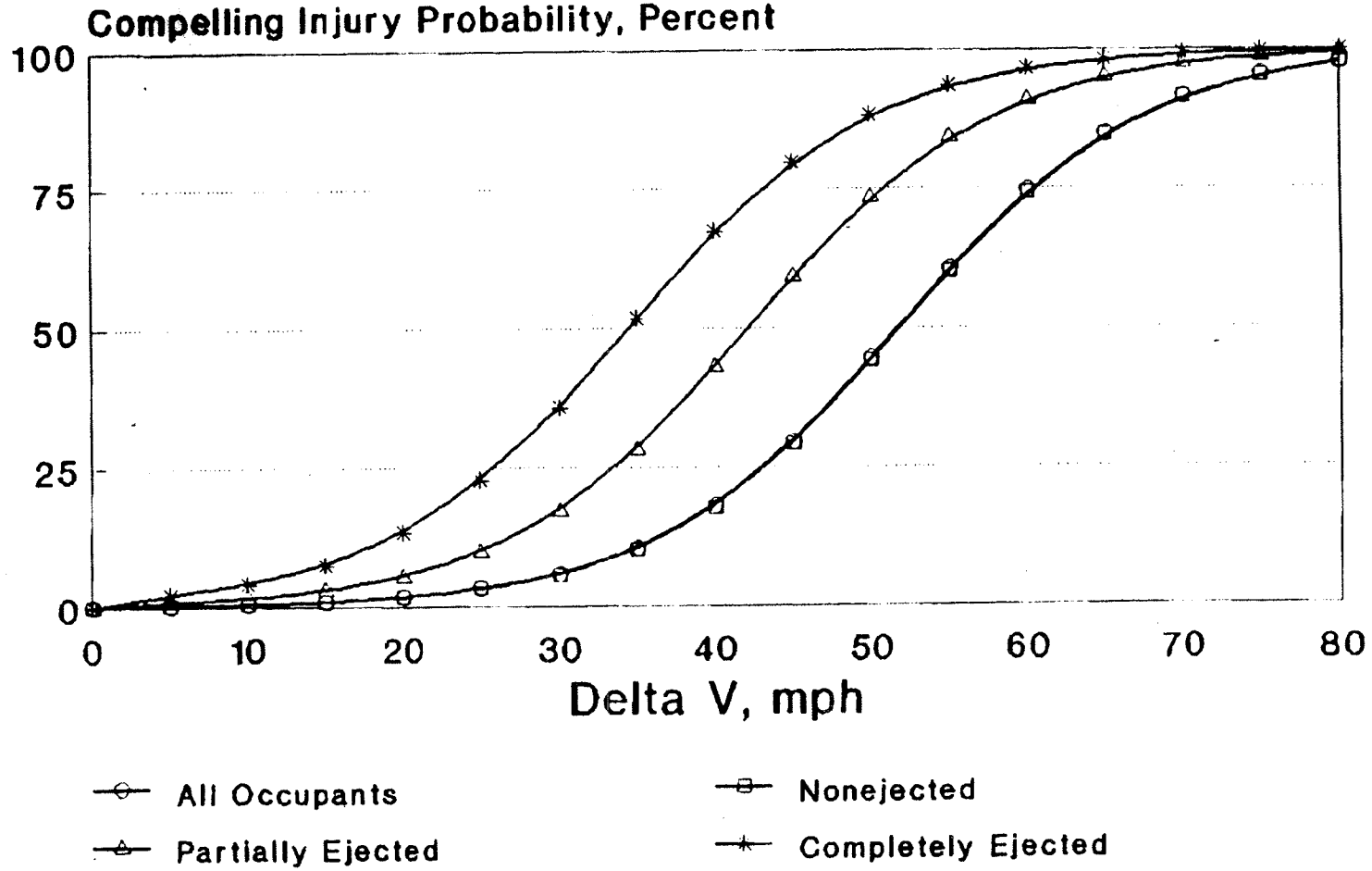
Exhibit J. Sensitivity to an Occupant's Ejection Occurrence



The NASS/CDS 1988-1995

Exhibit K. Evaluation of the Predictive Ability of the Algorithm for Compelling Injury