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An Assessment of the Relationship Between Frontal Impact Speed and Fatalities

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16. Abstract

An assessment was made of the cumulative distributions of fatalities and injuries as a function of crash severity (Equivalent Barrier Speed and TAD damage extent) using the in-depth Collision Performance and Injury Report (CPIR) data and Texas police-reported data. The exact forms of the cumulative distributions are dependent upon the set of data used and upon the set of analytical techniques used. It was also demonstrated that fatalities are associated with other factors than speed alone. Further, the probability of being killed is the product of the risk of fatality for each set of crash factors times the chance that each combination of crash factors will occur. Consequently, vehicle safety design changes or a shift away from single-vehicle rural collisions can alter the distributions of fatalities.

Existing accident data are inadequate for the preparation of an accurate and representative fatality distribution by speed (or severity). CPIR data are detailed but unrepresentative and TAD lack sufficient resolution. An up-to-date national sample with sufficient data for preparation of a representative cumulative fatality curve by speed (or severity) is needed.

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1. INTRODUCTION

Several previous efforts to relate crash severity to injuries have resulted in cumulative distributions of fatalities—most of them in terms of speed. While the precise definition of speed of collision in the various analyses varies, it has generally been thought of as an equivalent barrier impact speed. In addition, these previously published curves have resulted from several different fatal accident populations, and it has not been clear how closely these represent the true population of fatal crashes in the nation.

This report presents information on those distributions from updated or new sources—one based on in-depth accident investigations, and one based on police-reported accidents. Finally, the cumulative distributions of injury (by abbreviated injury severity) from the on-going restraint systems evaluation study are given as an example of what might be expected from a more carefully controlled sample of accidents.

Particular attention in this report has been given to (a) the variations due to the source of the data, (b) factors other than speed which associate with fatality production, and (c) changes in time which will affect the form of the desired distribution.

1.1 Summary

Two efforts were made to prepare cumulative fatality curves as a function of derived Equivalent Barrier Speed (EBS), the first using the Collision Performance and Injury Report (CPIR) (1)* data (Section 2) and the

*Numbers in parentheses designate references at end of paper.

second using the Texas police-reported accident data (Section 3).

The CPIR file provides specific and relatively accurate impact data (compared to that reported by police), but with a relatively strong bias toward severe collisions (2). A derived EBS was computed and plotted from inches of front crush for each case. The distributions derived from the CPIR data differ from, for example, the presently published DOT curves, in that the 50 percent fatality point is about five mph higher in the CPIR data than in the NHTSA-published curves (3,4).

To provide a better sample of the real-world accident situation, police-reported Texas accident data were used. While police-reported accident data are less specific, they are more representative of the total accident population than the CPIR file. The Texas data were selected because they contain police-reported TAD (Traffic Accident Data) vehicle damage severity codes (5). The intent was to use the average number of inches of frontal crush for each TAD severity code (1 to 7) and to convert crush into EBS. Unfortunately, approximately two-thirds of the fatal cases were coded as TAD 7 (i.e., everything beyond TAD 6), so there was not sufficient resolution to plot a meaningful distribution in the region of most interest.

While the Texas data yield a cumulative distribution of uncertain structure at the upper end (because of the dominance of the level 7 crashes), the data do provide an opportunity to observe a change in the distribution over two time periods with markedly different traffic fatality characteristics. It is shown that, although calendar year 1974 exhibits a smaller total number of in-car fatalities, the proportion of fatalities occurring at a given severity was higher. This is taken as a demonstration that the distribution of interest does vary with time. This shift is indicative of the influence that changes in the total traffic environment can have on the production (occurrence) of traffic fatalities.

Much of the analysis in the literature has centered on the relationship between vehicle speed and the occurrence of a fatality, although it is clear that other factors (some of them quite independent of speed) also affect the chance of an occupant fatality. Among these are collision configuration, vehicle characteristics, or such occupant characteristics as age and sex. An analysis of variance was performed on several such factors in the Texas and in the CPIR data sets to identify the relative association of these factors.

Cumulative distributions of injuries have also been published, but the injury definitions have generally not been precise. Present CPIR data are too biased to be considered representative, and police injury codes have not been well defined or consistently applied. In this analysis, we have taken injury data from the on-going Restraint Systems Effectiveness Study (6) and have determined cumulative distribution at several levels of (AIS) injury. Although these data were acquired over a limited geographic area and for a specific subset of vehicles (1973-74 passenger cars), they exemplify the type of information that could be determined by an adequate national sample of accidents.

1.2 Conclusions and Recommendations

1. The exact form of a cumulative fatality by

impact speed distribution for frontal impacts is dependent upon the particular set of data used as well as on the methods used to determine speed. Further, the distribution varies with time when other factors are held constant.

The CPIR fatal distribution was significantly different from the earlier NHTSA distribution, evidently due to different biases in the data sets used and to different analytic techniques. A time dependence was also demonstrated in a comparison of 1973 and 1974 fatal accidents in Texas (Section 4).

2. Fatalities are associated with many factors other than speed alone. A distribution of fatalities by impact speed cannot be interpreted as if speed were the sole causative factor of death. The fact that many crash factors other than just impact speed affect fatality production can be seen in both the police-reported and the in-depth data (Section 5). Thirty-six CPIR crash factors were found to be significant, and these fell into seven general groupings (ranked by statistical significance):

1. Passenger Compartment Performance.
2. Speed/Crush.
3. Type of Collision (e.g., severe impact with solid object).
4. Driver Pre-Crash Condition (e.g., alcohol, stress).
5. Secondary Impacts.
6. Single-Vehicle, Ran-Off-Roadway, Rural Collisions.
7. Physical Characteristics of Occupant.

While these factors are not necessarily independent of speed, each plays a significant role in predicting fatalities. The point is that speed alone is not the sole predictor of fatalities. Instead, it is the specific set of all crash factors in a collision that predicts a fatality. Clearly, most of the crash factors that do influence the fatality rate are not under the control of the designer or rulemaker. On the other hand, the list of related crash factors suggests some possibilities—for example, in the area of passenger compartment performance. Note that the interaction of speed and compartment performance has not been analyzed (see item 4 below).

3. Fatality probabilities are a function of the causal factors and the occurrence of these factors. Given a crash, the probability of being killed [P(F)] is determined by the risk of fatality for each set of crash factors [$P(F|C_F)$] times the chance that each combination of crash factors will occur [$P(C_F)$], or:

$$P(F) = \Sigma\left[P(F|C_F) \cdot P(C_F)\right]$$

where the sum is over all possible sets C_F of crash factors. The C_F are mutually exclusive.

Consequently, both improved vehicle safety designs [$P(F|C_F)$] and a shift away from single-vehicle rural collisions [$P(C_F)$], for example, can affect the distribution of fatalities. Quite apart from safety improvements applied to specific crash factors, changes in the overall mix or combinations of crash factors also affect the probability of fatalities. For example, a change in the proportion of time during which particular combinations of crash factors occur produced a shift in the distributions of fatalities for 1973 and 1974 in Texas (Section 4).

4. The interactions between the many crash factors that contribute to the fatality rate were not determined in this analysis. Some of the factors may predict speed (e.g., vehicle damage extent). Some factors (e.g., driver age) may both predict speed (young drivers) and contribute to fatalities (old drivers). This suggests a need for a more complex model that would help in determining the interactions between crash factors.

5. Existing accident data (known to HSRI), are inadequate for the preparation of an accurate and representative fatality distribution by impact speed. An up-to-date national sample of collisions with sufficiently accurate and detailed data to properly prepare a defensible cumulative fatality curve by impact speed is needed. The CPIR data set contains detail but lacks representativeness. The TAD vehicle damage scale is of little utility in deriving a fatal distribution, since one-half to two-thirds of the cases fall into the open-ended TAD 7 category. The methods of determining impact speeds used in this paper and in previous efforts need improvement. As more sophisticated analytical techniques are developed, they should be applied in future efforts to determine fatality distributions.

6. The MVMA-sponsored Restraint System Evaluation Study (RSES) preliminary data exemplify what can be accomplished—high quality, good detail, and representative collision data. While the RSES data are not as detailed and comprehensive as the CPIR data, they are more representative of the geographical areas where they were collected. The family of cumulative injury curves (Section 6) serves to demonstrate the type of results that could be provided by a national sample. Such a set

of national data would provide cumulative distributions by level of injury (AIS) and would permit trend analyses for other crash factors (e.g., model year, car size).

2. CUMULATIVE FATALITY CURVE - CPIR DATA

Of the 862 fatal occupants reported by in-depth accident investigation teams in the CPIR (Collision Performance and Injury Report Revision 3) data file (7), 360 were killed in passenger cars that sustained a primary frontal impact. Damage for each case vehicle was recorded by the CDC/VDI (Collision Deformation Classification) (8) and by the inches of residual front crush.

The distribution of fatal occupants by the CDC/VDI damage extent zone code is displayed in Table 2.1* and Figure 2.1. The distribution is restricted to 281 unrestrained front-seat, adult (age 15 to 98 years) fatalities in passenger cars sustaining primary frontal impacts. This subset of fatals is more comparable to the previous NHTSA results. Note that fatalities occur even in cars that sustained very little damage (CDC-1), probably because of an occupant's state of health and other crash factors (e.g., fire).

Table 2.1 - CPIR Fatal-Car Occupants by Primary Frontal Damage Extent

Frontal Damage Extent	Unrestrained, Front Seat Adults (ages 15-98 years)	
	%	(N)
1		
2	3.6%	(10)
3	8.9%	(25)
4	16.0%	(45)
5	18.9%	(53)
6	14.2%	(40)
7	15.7%	(44)
8	9.3%	(26)
9	3.9%	(11)
	9.6%	(27)
	100%	(281)

*Due to rounding, all table percentages may not sum to exactly 100.0 percent.

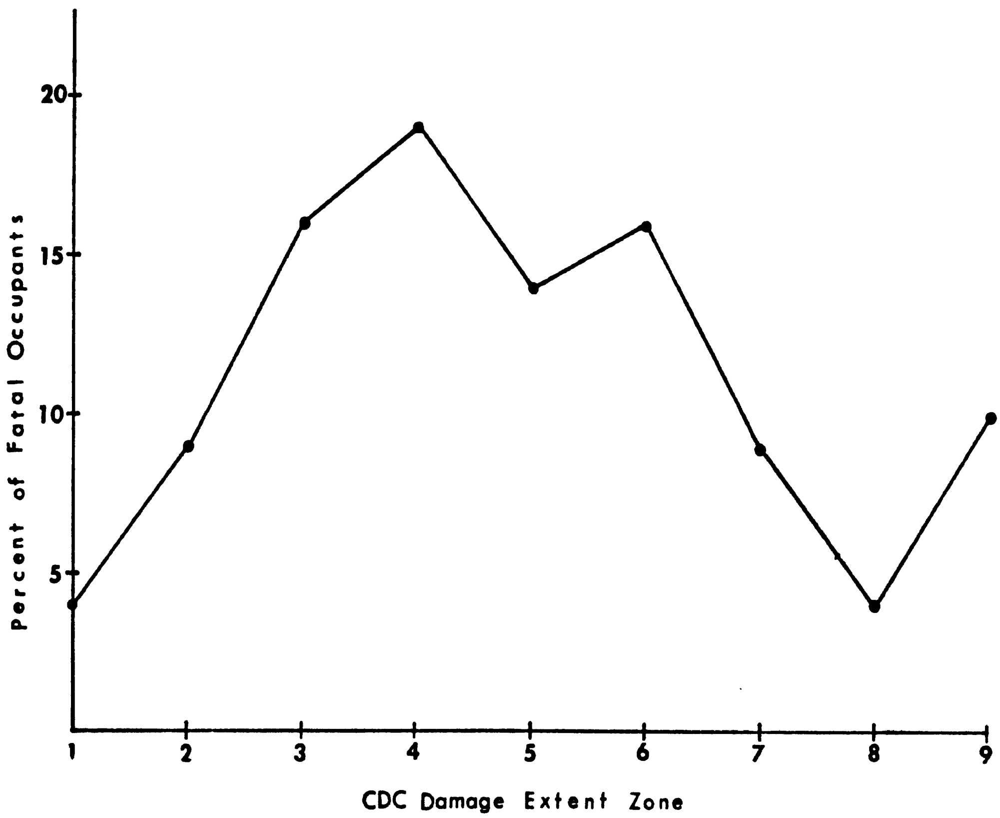

Figure 2.1 - CPIR Fatal-Car Occupants by Primary Frontal Damage Extent

The CPIR data file also contains the inches of residual front crush as a measure of damage severity for 213 of the 281 cases. Half of the remaining 68 cases of unknown crush inches had major CDC extent codes of 6-9, with many of these being underrides or overhanging structures for which crush measurements have little meaning. The other half of the unknown crush cases were distributed between 1 and 5 extent codes.

Campbell (9) has developed an energy basis for collision severity that permits the interpretation of residual crush damage in terms of energy, which, in turn, can be expressed, in its simplest terms, as a linear equation of the form

$$EBS = A + B \cdot \text{Crush (inches)}$$

This relationship was developed for recent-model General Motors standard, intermediate, and compact/sub-compact cars in frontal collisions. The relationship for intermediate cars

$$EBS = 7.5 + 0.90 \cdot \text{Crush (inches)}$$

was used to approximate the mix of CPIR vehicles used in this analysis. The specific transformation used inches of front crush bracketed into five-mile-per-hour increments of derived EBS.* The resultant distribution of fatal occupants is shown in Table 2.2 and Figure 2.2. This approximation does not specifically account for variations in vehicle size, crush characteristics, damage patterns (e.g., narrow/wide) or crash configurations.

Table 2.2 - CPIR Fatal-Car Occupants by Derived EBS

Derived EBS (mph)	Fatal Occupants %	(N)	Cum %	Derived EBS (mph)	Fatal Occupants %	(N)	Cum %
10	1.9%	(4)	1.9%	55	4.7%	(10)	75.2%
15	3.3	(7)	5.2	60	7.0	(15)	82.2
20	6.6	(14)	11.8	65	4.2	(9)	86.4
25	9.4	(20)	21.2	70	3.3	(7)	89.7
30	7.0	(15)	28.2	75	2.3	(10)	92.0
35	11.3	(24)	39.5	80	4.7	(10)	96.7
40	10.8	(23)	50.3	85	1.9	(4)	98.6
45	8.9	(19)	59.2	90	1.4	(3)	100%
50	11.3	(24)	70.5				
				Known	100%	(213)	
				Unknown		(68)	

RECODE V168 (00)=00,(01-05)=10,(06-11)=15,(12-16)=20, (17-22)=25,(23-27)=30,(28-33)=35,(34-38)=40,(39-44)=45, (45-50)=50,(51-55)=55,(56-61)=60,(62-66)=65,(67-72)=70, (73-77)=75,(78-83)=80,(84-89)=85,(90-96)=90,ELSE=99

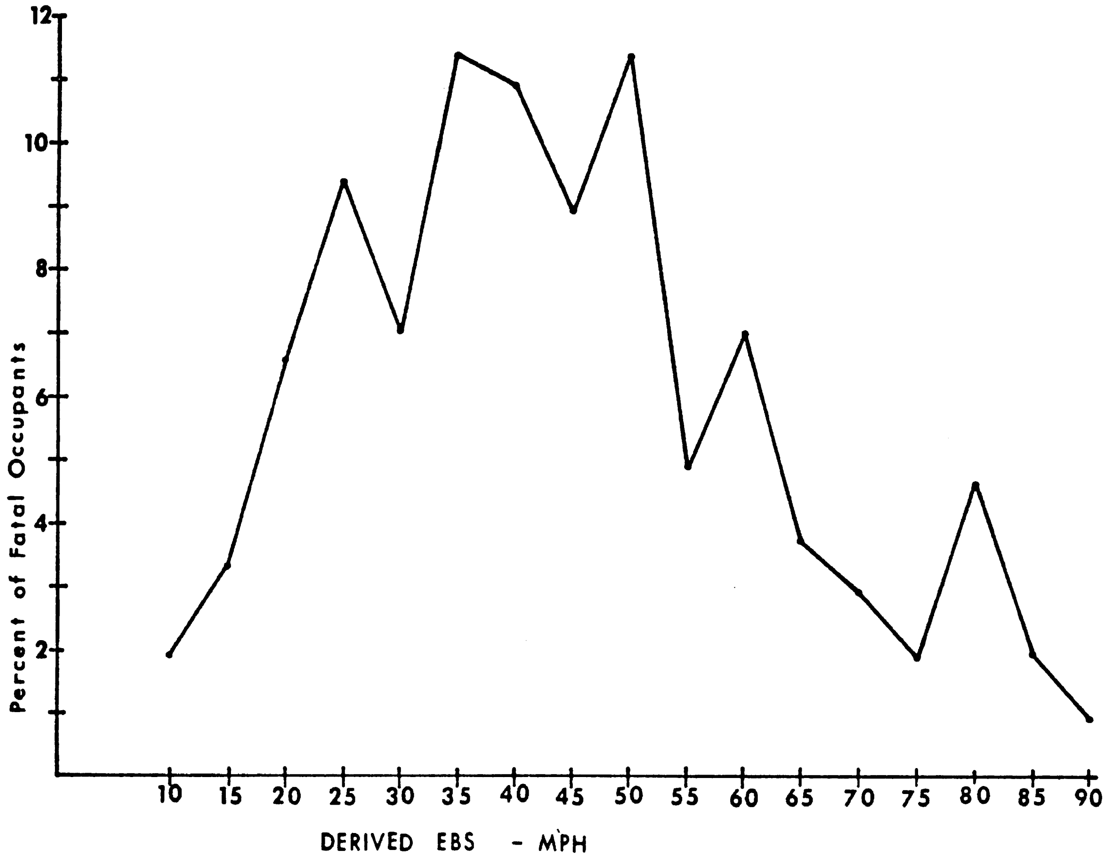

Figure 2.2 - CPIR Fatal-Car Occupants by Derived EBS

While the distribution in Figure 2.2 is not smooth, it does bear a rough resemblence to a bell-shaped normal probability distribution. A goodness of fit test with the normal distribution resulted in a chi-square of 33.3 (mean = 44.6 mph, standard deviation = 18.95 mph) which indicates that Figure 2.2 is statistically different than the normal distribution at the five percent level. In order to be comparable to the NHTSA normal cumulative fatality curve, the cumulative distribution of CPIR fatalities by derived EBS (Table 2.2) was graphically fitted to a normal distribution* to produce a cumulative

*Equivalent to graphically computing mean ($\overline{X}$) and standard deviation (SD) to produce plot.

percentage of fatalities by EBS ["CPIR (Normal)" distribution in Figure 2.3]. Note that the intercept at zero miles per hour is 1.3 percent, an artifact of extrapolating the normal probability curve from the derived data in Table 2.2. When a smooth curve (not a normal probability) is fitted to the cumulative data, the "CPIR (Smooth)" distribution is produced. The NHTSA also fitted their fatal data to a normal probability curve, and the "NHTSA (Normal)" distribution is replicated in Figure 2.3.

The observed difference between the NHTSA and CPIR curves seems to imply that the CPIR cars are "safer." For example, up to 50 mph, only 64 percent of the CPIR fatalities occurred, as compared to 94 percent of the NHTSA fatalities. This difference could be due to a newer, and hence stiffer, set of cars in the CPIR file, or due to a bias in the CPIR case selection towards fatal-car accidents with a higher damage severity than the average fatal accident. The difference in the curves might also be explained by differences in the assumptions and transformations used in deriving the curves. In particular, the transformation from crush to EBS assumed a uniform crush distribution. Thus, any narrow crush distributions were treated as if they were higher-severity uniform crush distributions with the same inches of crush. Consequently, the transformation biased the distribution towards higher-severity collisions. The point to be made is that the distribution is sensitive to the set (or sample) of fatal accidents analyzed and the analytic procedures used.

The apparent difference between the NHTSA curve and the CPIR empirical data (Figure 2.4) may be tested for

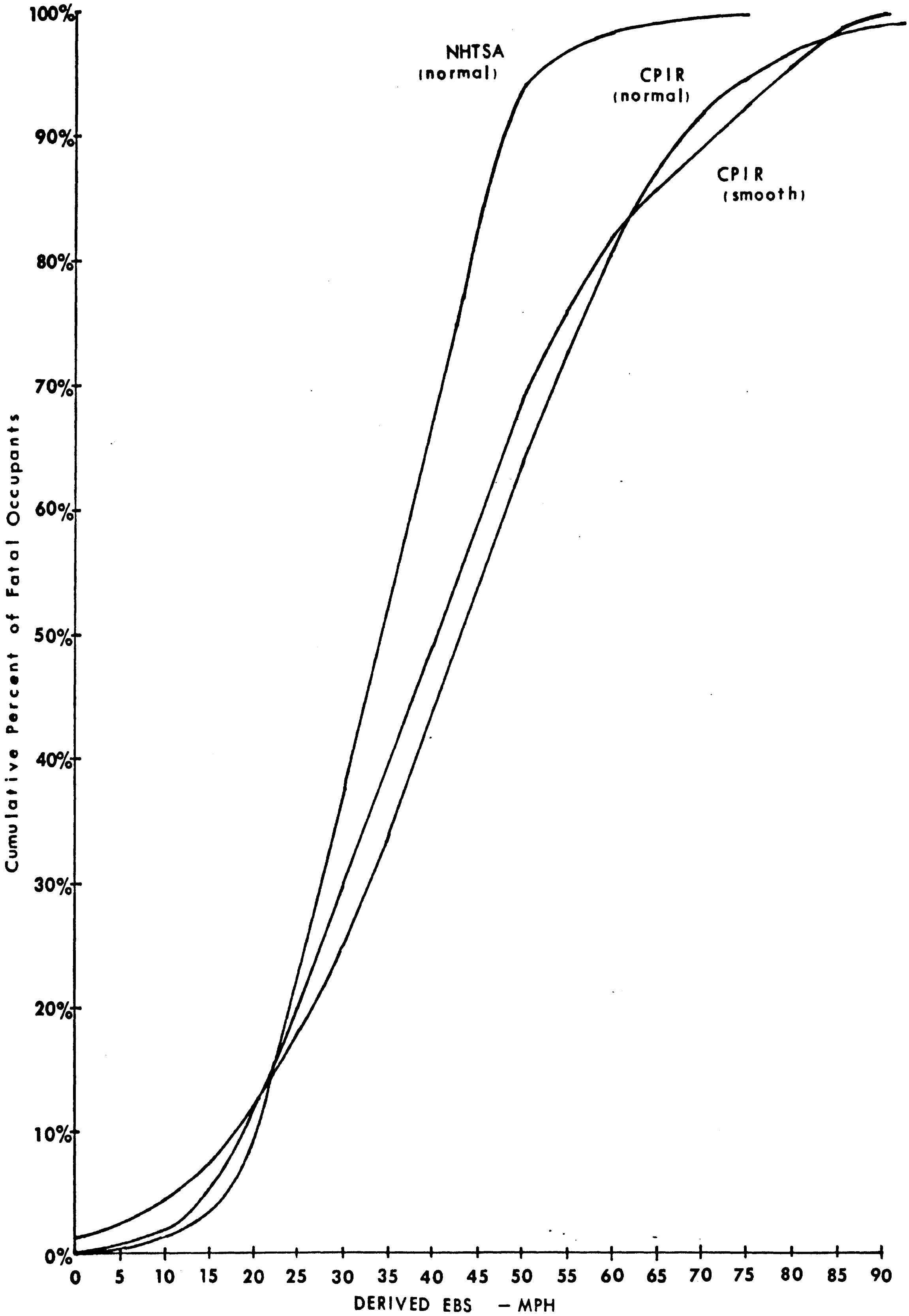

Figure 2.3 - Cumulative NHTSA and CPIR Fatalities
by Derived EBS

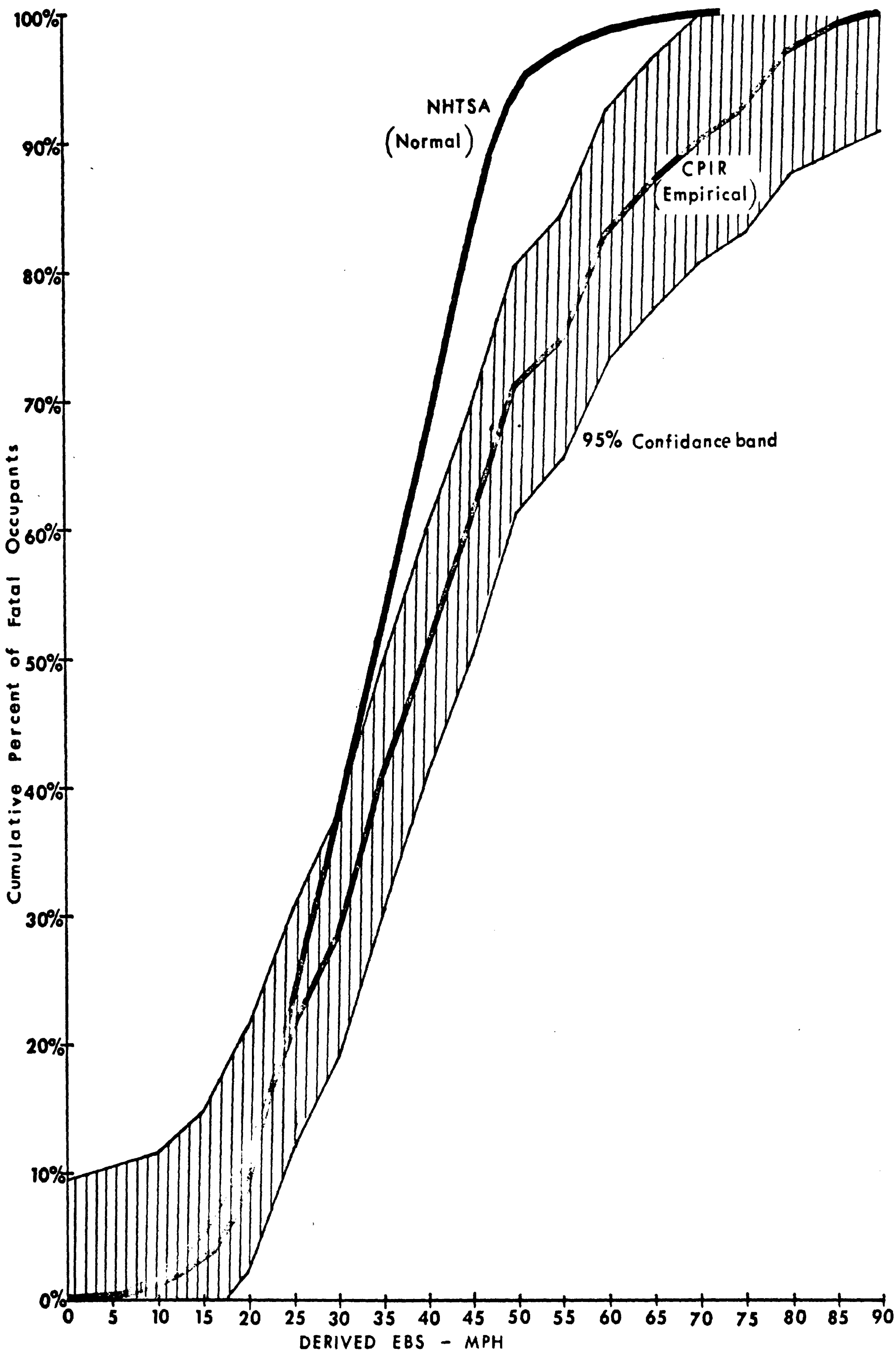

Figure 2.4 - Cumulative Distribution of CPIR
Empirical Fatality Data

statistical significance by the use of the Kolmogorov-Smirnov test (K-S test). We assume that the NHTSA curve is a known cumulative distribution function, and that the data used to construct the CPIR curve are a random sample from some other population. The test is then based on the maximum vertical distance between the two curves, rejecting if this distance exceeds a critical value which is dependent upon the significance level and the sample size for the CPIR curve.

The maximum deviation is 0.29, which occurs at 45 mph. For a sample size of 213, and an $\alpha = 0.05$, the critical value is 0.093. Hence the hypothesis that the two curves came from the same population (are equal) is rejected.

Inspection of the two curves reveals that they are quite similar for speeds of 25 mph or less. If one calculates a joint 95 percent confidence band from the CPIR curve, then this band no longer includes the NHTSA curve, beginning at 30 mph. Thus the two may be viewed as similar up to 30 mph and different thereafter. The confidence band again begins to include the NHTSA curve for speeds above 70 mph, because both curves approach 1.0 at high speeds.

3. CUMULATIVE FATALITY CURVE - TEXAS DATA

To gain a more representative sample of fatalities, an attempt was made to derive the cumulative fatality distribution from Texas police-reported traffic fatalities. While impact speeds and inches of crush are not recorded, the Texas data do provide the TAD Vehicle Damage Scale (3) as a rough measure of damage severity.

The first portion of this section provides a derivation of impact speeds from the TAD vehicle damage scale codes (1-7). In the second portion, a cumulative distribution of the 828 Texas passenger car frontal-impact fatalities reported in 1973 are plotted. Due to the fact that the majority of the fatalities fell into TAD category 7 (i.e., anything over TAD 6) and an uncertain TAD to EBS derivation, no representative cumulative fatality curve could be plotted from the Texas police-reported data. The same problems exist for any fatal accident base using the TAD scale.

3.1 EBS Derived From TAD Vehicle Damage Scale

The derivation of EBS from Texas police-reported TAD vehicle damage scale codes involves two separate operations. First, the relationship of inches of frontal crush is developed for each frontal TAD damage scale code; and second, this indirect crush measurement is used to determine the corresponding EBS by the linear approximation used in Section 2. Fortunately, the Southwest Research Institute (SwRI) has completed a special study of police-reported TAD and SwRI-investigated TAD, VDI, and inches of crush.*

*"MDAI, Volume 3, Special Studies," SwRI, August 1974, DOT-HS-801182.

The Southwest Research Institute (SwRI) studied 5,481 traffic accidents (10,371 vehicles) in the San Antonio (Bexar County) area from December 1, 1972 through May 1973 (six months). The study included all accidents that had a police TAD severity rating of three or higher or one of its occupants had been injured or killed. Of the 10,371 accident vehicles, 3,436 were inspected by SwRI investigators and coded with SwRI-determined VDI and TAD damage ratings. Therefore, only one-third of the study vehicles have SwRI TAD and VDI ratings.

Of the 3,436 cases inspected by both the police and SwRI, 62.40 percent were reported as having identical TAD alphabetic characters (area of damage). A closer look at the original study data by HSRI revealed that the police and SwRI agreed on the occurrence of primary frontal damage 90 percent of the time for passenger cars when only the first TAD letter (F) was used for comparison. In an additional two percent of the cases of police-coded primary frontal TAD damage location, SwRI coded frontal damage, but as secondary, not primary. Thus, there was consistency between the police and SwRI TAD in the identification of frontal impacts.

Of those 90 percent of the cases where the police and SwRI agree that the primary car damage was frontal, the TAD damage codes were identical 45 percent of the time and were within one code 84 percent of the time. Thus, there does seem to be sufficient agreement on the general area damaged and extent of damage to permit the following analysis of police-reported TAD damage scale codes and SwRI-investigated inches of crush for cars with frontal damage.

The mean inches of primary frontal crush was computed using an analysis of variance on the 1,605 cases where the police and SwRI agreed on the existence of primary frontal crush. The results are displayed in Table 3.1. Each mean level of crush was then converted to equivalent barrier speed by the equation used in Section 2 (i.e., EBS (mph) = 7.5 + 0.90 • Crush Inches).

Table 3.1 - Police TAD Damage Scale vs. Average Crush

Police TAD Damage Scale	Mean Crush (inches)	Standard Deviation	(N)	Derived EBS (mph)
1	5.9	5.5	(29)	12.8
2	10.6	6.0	(92)	17.0
3	13.8	7.0	(816)	19.9
4	19.0	8.4	(404)	24.6
5	23.2	8.4	(145)	28.5
6	27.3	11.7	(83)	32.1
7	32.0	12.5	(36)	36.3
Total	16.7	9.3	(1605)	22.5

$F(6,1598) = 106.19$

Significance = 0.0

Due to the substantial deviation of crush for each level of TAD damage extent and the questionable appropriateness of the EBS derivation from crush in this instance, the resultant EBS derived from TAD must be viewed with considerable uncertainty.

3.2 Cumulative Fatality Curve

Table 3.2 tabulates the 946 Texas fatalities that occurred during 1973 in passenger cars with frontal damage. Figure 3.1 graphically displays the same data.

Table 3.2 - 1973 Texas Fatal Occupants by TAD Frontal Damage Scale

TAD Vehicle Damage Scale	N	Percent	Cumulative Percent
1	1	0.1%	0.1%
2	7	0.7	0.8
3	23	2.4	3.2
4	47	5.0	8.2
5	84	8.9	17.1
6	169	17.9	35.0
7	615	65.0	100%
	946	100%	

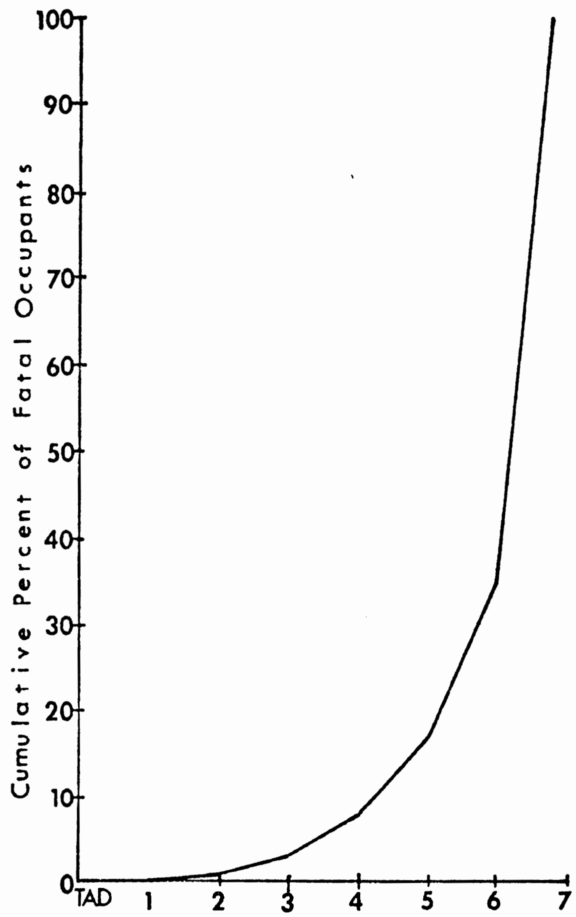

Figure 3.1 - 1973 Texas Fatalities by TAD Frontal Damage Scale

4. TEMPORAL CHANGES IN THE PROBABILITY OF FATALITY

A data file containing all 2,697 Texas fatal accidents from the first half of 1973 and the first half of 1974 was analyzed by Golomb and O'Day (10) to detect "before" and "during" energy crisis factors. Lowered speed limits and intensified interest in fuel conservation were followed by a noticeable reduction in traffic accidents, injuries, and fatalities in late 1973 and early 1974.

Such noticeable changes in traffic patterns could have a significant effect on the distribution of speeds at which fatalities occur, and, consequently, on the benefits (in lives saved) derived from the distribution of cumulative fatalities by speed. For example, a reduction in traffic volume (miles traveled) might be expected to reduce all accidents, and might produce a disproportionate reduction in multi-vehicle collisions by lessening the average traffic density. Conversely, a reduction in speed without a reduction in total mileage (that is, a possible increase in total hours of travel), could increase traffic density and thus tend to increase multi-vehicle collisions. (10)

In order to review changes in accident patterns, a data file containing the first six months of both 1973 and 1974 Texas fatal accident data was used. This Texas comparison file contains 1,505 passenger cars with at least one fatal occupant. Of these, 58 percent (871) were involved in 1973 accidents and 42 percent (634) were involved in 1974 accidents. The number of fatal passenger cars dropped 27 percent between the two six-month periods. The temporal changes were analyzed in terms of accident type, occupancy rate, damage extent, and cumulative fatalities.

Accident Type

Multiple-vehicle accident involvement dropped 41 percent (219/529) for early 1974 Texas fatal-cars (passenger cars with one or more fatal occupants), while the number of single-vehicle involvements remained about the same (Table 4.1). In other words, there was a shift from a 2-to-3 ratio to a 1-to-1 ratio of single- to multiple-vehicle accidents.

Table 4.1 - Texas Fatal-Car Accidents by Number of Vehicles

	First Half 1973		First Half 1974	
	%	N	%	N
Single-Vehicle	39%	(342)	51%	(324)
Multiple-Vehicle	61%	(529)	49%	(310)
	100%	(871)	100%	(634)

There also was a shift in 1974 accident types from collisions-with-other-motor-vehicles to ran-off-the-roadway and other noncollision accidents (Table 4.2). While the frequency of fixed-object collisions was lower in 1974, the proportion of fixed-object collisions remained the same (18 percent).

Table 4.2 - Texas Fatal-Car Accidents by Object Struck

	First Half 1973		First Half 1974	
Accident Type	%	N	%	N
Other Motor Vehicle	59%	(512)	48%	(302)
Fixed-Object	18%	(157)	18%	(113)
Other Collisions	5%	(49)	7%	(44)
Ran-Off-Road	15%	(131)	24%	(149)
Other Noncollisions	3%	(22)	4%	(26)
	100%	(871)	100%	(634)

While the number of cars with occupant fatalities dropped, the proportion of cars with frontal damage remained at about 40 percent (Table 4.3).

Table 4.3 - Texas Fatal Car Accidents by Damage Area

	First Half 1973		First Half 1974	
	%	N	%	N
Frontal	40%	(351)	43%	(277)
Other	56%	(491)	52%	(328)
Unknown	4%	(29)	5%	(29)
	100%	(871)	100%	(634)

Occupancy

While a higher occupancy rate per vehicle might have been expected during the early 1974 energy crisis, the percentage of cars with multiple fatalities dropped 41 percent (53/130) from 1973 to 1974. The proportion of multiple casualties (fatals and injured) in this set of "fatal cars" dropped from 51 percent to 47 percent in 1974 (Table 4.4). Thus, the early 1974 Texas fatal car accidents tend to involve fewer multiple in-car fatalities and injuries.

Table 4.4 - Texas Fatal-Car Occupants by Injury Severity

	First Half 1973				First Half 1974			
	Single		Multiple		Single		Multiple	
	%	N	%	N	%	N	%	N
Fatal (K)	85%	(741)	15%	(130)	88%	(557)	12%	(77)
Injury (A+B+C)	58%	(504)	42%	(367)	60%	(383)	40%	(251)
Fatal + Injury (K+A+B+C)	49%	(430)	51%	(441)	53%	(338)	47%	(296)

Texas police accident reports do not routinely record all the non-injured occupants in each vehicle. Consequently, there is no direct measure of occupancy rate in accident-involved cars. As an approximation, one can assume that if one car occupant is killed that the other occupants of the fatal car will sustain at least a "C" injury and therefore be reported. Using the number of K+A+B+C occupants as a measure of occupancy it looks as if there were fewer occupants per "fatal car" in early 1974 (Table 4.4).

A comparison of seated locations for injured occupants demonstrates a higher percentage of drivers, a slightly higher percentage of right-front passengers, and a lower percentage of rear and other seated positions (Table 4.5). This shift is consistent with a lower occupancy rate in 1974 fatal cars.

Table 4.5 - Texas Fatal-Car Occupant Seated Locations

	First Half 1973		First Half 1974	
	%	N	%	N
Front Left	50%	(871)	53%	(634)
Front Right	24%	(425)	25%	(302)
Other	26%	(464)	22%	(255)
	100%	(1760)	100%	(1191)

Damage Extent

In early 1974, the number of fatal cars with severe TAD damage extent code 7 dropped 37 percent (176/471) as compared to early 1973, and there was a 36-percent (240/671) drop for TAD 6 and 7 (Table 4.6). When restricted to the 628 frontal impacts, a similar drop (32 percent) in severe damage extents is observed. This one-third reduction of severe collisions can be reasonably explained by the effect of the reduction of vehicles speed during the energy crisis months.

Table 4.6 - TAD Damage Extent by Vehicle

	All Car Fatals				Front Fatals Only			
	First Half of:				First Half of:			
	1973		1974		1973		1974	
TAD	%	(N)	%	(N)	%	(N)	%	(N)
7	56%	(471)	49%	(295)	61%	(215)	53%	(146)
6	24	(200)	22	(136)	21	(74)	22	(60)
1-5	20	(171)	29	(174)	18	(62)	25	(71)
Unk	--	(29)	--	(29)	--		--	
	100%	(871)	100%	(634)	100%	(351)	100%	(277)

The same results are repeated in Table 4.7, except that this time the number of fatalities is tabulated.

Table 4.7 - TAD Damage Extent by Fatal Occupants

	All Car Fatals				Front Fatals Only			
	First Half of:				First Half of:			
	1973		1974		1973		1974	
TAD	%	(N)	%	(N)	%	(N)	%	(N)
7	60%	(626)	53%	(370)	66%	(294)	59%	(193)
6	21	(218)	21	(151)	19	(82)	19	(63)
1-5	19	(194)	26	(180)	15	(68)	22	(72)
Unk	--	(33)	--	(33)	--		--	
	100%	(1071)	100%	(734)	100%	(444)	100%	(328)

When the proportion of fatal-car occupants are considered, an even more dramatic shift towards less severe (TAD 1-5) fatal car accidents is seen. While the total number of fatal accidents and even the number of less severe fatal accidents dropped (e.g., 194 to 180), the proportion of less severe fatal accidents increased (e.g., 19 percent to 26 percent). Conversely, the proportion of more severe cases decreased. There was an absolute drop in TAD 7 or 41 percent (256/626) for all accidents and 34 percent (101/294) when only frontal car impacts were considered.

Cumulative Fatalities

To observe the shift in the cumulative fatality distribution due to changes in the traffic environment and, hence, exposure to the risk of fatality, cumulative distributions for early 1973 and 1974 data were derived and displayed in Table 4.8 and Figure 4.1. All passenger-car occupant fatalities involved in frontal impacts during the two six-month periods are included. It is clear that the cumulative number of fatalities in 1974 was lower for TAD extents 6 and 7, while the distribution across TAD 1-5 is similar for both periods.

Table 4.8 - Cumulative Texas Fatalities by TAD Frontal Damage Extent

TAD	First Half 1973			First Half 1974		
Extent	N	Cum. N	Cum. %	N	Cum. N	Cum. %
1	0	0	0.0%	2	2	0.6%
2	3	3	0.7	4	6	1.8
3	13	16	3.6	8	14	4.2
4	20	36	8.1	29	43	13.0
5	32	68	15.3	29	72	21.8
6	82	150	33.8	63	135	41.0
7	294	444	100%	193	328	99.8%

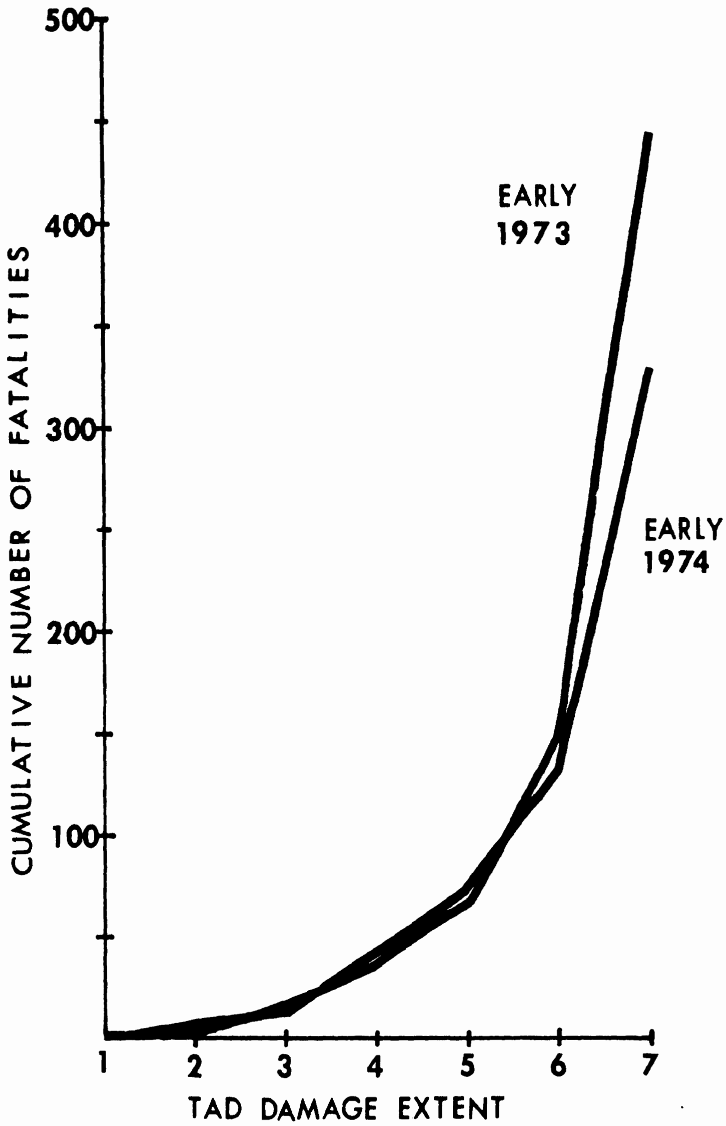

Figure 4.1 - Cumulative Number of Fatalities
by TAD Frontal Damage Extent

Any shift in the distribution of accident severity results in a temporal change in the probability that a particular set of crash factors will occur [$P(C_F)$]. The probability of fatality [P(F)] is a function of both the risk of fatality for each set of crash factors $[P(F|C_F)]$ and the chance that each combination of factors will occur $[P(C_F)]$, or:

$$P(F) = \Sigma P(F|C_F) \cdot P(C_F),$$

summed over all possible sets C_F of crash factors. Consequently, any change in $P(C_F)$ will alter the distribution of P(F) without any change in $P(F|C_F)$.

Figure 4.2 demonstrates the sensitivity of the cumulative fatality distribution to shifts in the mix of crash factors, particularly the mix or distribution of crash severities. These curves were developed from the early 1973 and 1974 cumulative percentage distributions by frontal TAD damage extent in Table 4.1. For purposes of comparison both years of data were assumed to have a normal probability distribution. This approach permitted extrapolating the TAD 1 through TAD 6 data over the remainder of the probability distribution. TAD 7 data was not used because TAD 7 is an open-ended category (i.e., everything over TAD 6) as discussed in Section 3.2.

Obviously, such a rough extrapolation may not represent the true distribution of fatalities. It does serve to demonstrate an observable temporal shift. Since it is unlikely that there was a given set of crash factors in a crash $[P(F|C_F)]$ this shift can reasonably be attributed to a shift in the probability that certain combinations of crash factors occur in a crash $[P(C_F)]$. In other words, the reduction in fatalities is more likely due to a change in the mix of crash factors

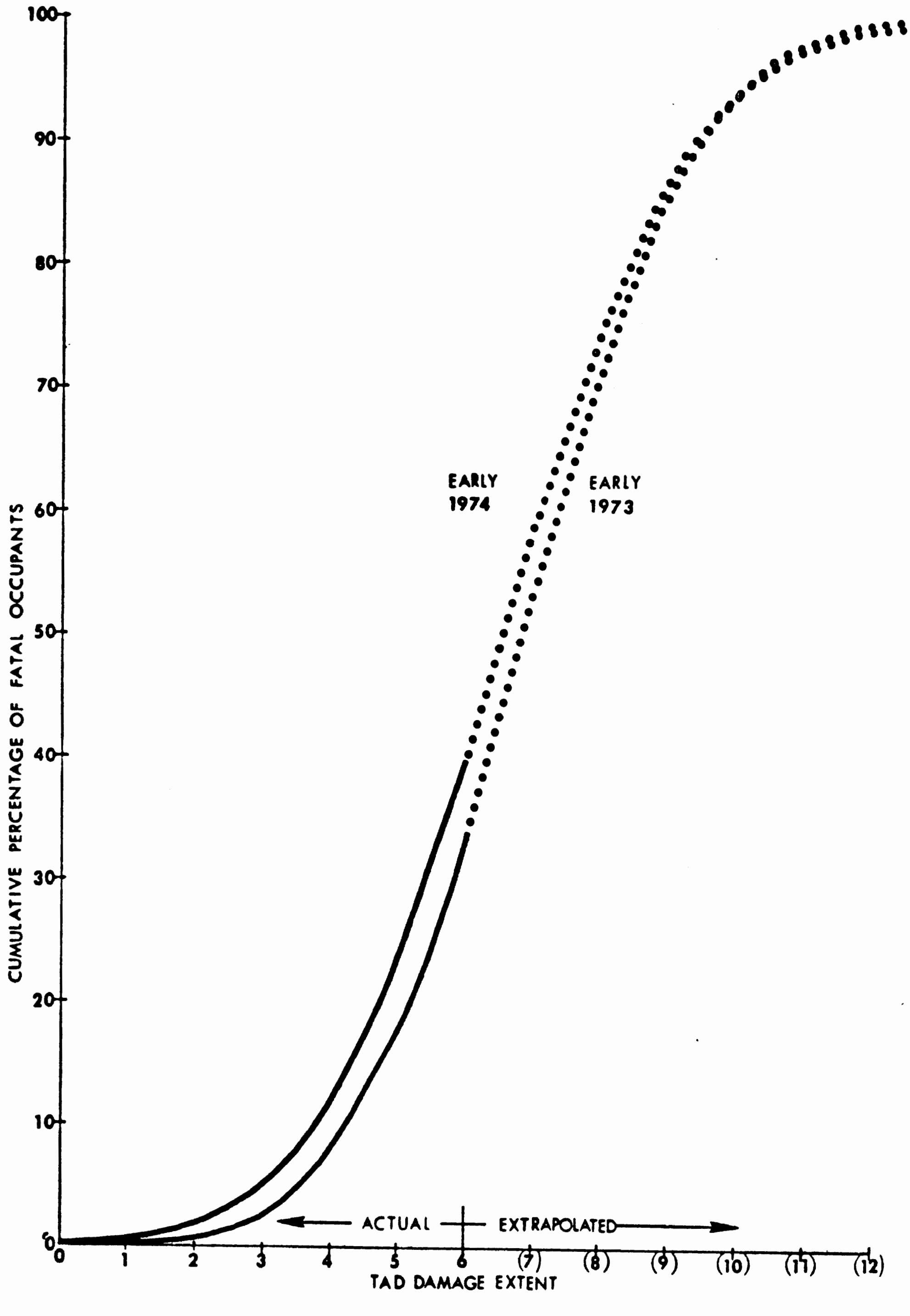

Figure 4.2 - Extrapolated Cumulative Fatalities by TAD Damage Extent

(e.g., less high-speed impacts), rather than to a reduction in fatality risk for any crash factors (e.g., fewer fatalities in identical 30 mph impacts).

Note that the early 1974 curve shifted to the left of the early 1973 curve. The shift is a reflection of the lower overall collision severity and speeds. Since all fatalities are represented in a cumulative distribution, a larger proportion of fatalities occur at lower speeds. For example there was a 53 percent (8 percent/ 15 percent) increase in the cumulative percentage of fatalities at TAD 5. The rise was from 15 percent in early 1973 to 22 percent in early 1974. Clearly, such real-world shifts can significantly influence the expected benefits of any occupant protection safety measures.

5. ROLE OF OTHER CRASH FACTORS IN PREDICTING FATALITIES

Fatality is not solely a function of impact speed, although that assumption is usually made in interpreting or reading cumulative fatality curves like Figure 2.3. Other factors also determine whether an occupant is killed. No one safety measure (e.g., restraint system) can prevent all the fatalities up to a certain speed (e.g., 50 mph-EBS). As noted by General Motors (11) in their comments on the NHTSA August MVSS208 analysis (3), "whether a person becomes fatal in a crash is a function of EBS, direction of impact, height, weight, sex, physical condition, presence of external object intrusion, geometry of struck object, ejection, seating position, presence of other occupants, restraint usage, etc."

To test this hypothesis, several analysis of variance tests were made on Texas accident data and the CPIR file. While the Texas data are more representative, they lack sufficient detail. The CPIR data, on the other hand, have the detail but lack representativeness. Consequently, the following should not be construed quantitatively but should be considered as a demonstration that other accident factors play a significant role in fatality causation.

5.1 Analysis of Texas Data

For consistency with the previous Section 4, the same set of Texas accident data from the first half of 1973 and 1974 was used for this analysis. Two sets of data from these periods were combined. The first set contained 1,505 passenger cars with at least one occupant fatality (fatal-cars). To test for differences between fatal-car accidents and nonfatal-car accidents, a systematic 0.5 percent sample was created, containing 2,789 cars in which no occupants were killed (nonfatal-cars). The set of all fatal cars and the sample set of nonfatal cars were combined into one file to permit an analysis of variance of collision factors that may be related to fatalities.

Because a half-percent sample of nonfatal cars was used, the "Percent of Fatal-Cars" column has been reconstructed for each code level. For example, Table 5.1 displays for each Damage Scale code the reconstructed "percentage of fatal cars" that results from inserting the half-percent sample ratio. The number of fatal cars is noted as "(Fatal N)" after each percentage. Thus, in the first six months of 1973 and 1974, 0.3 percent (3,844) of the passenger cars in reported traffic accidents involved at least one occupant fatality.

Table 5.1 - Texas Fatal-Cars by TAD Damage Extent

Damage Scale	Percentage of Fatal-Cars	(Fatal N)
0	0.00%	(46)
1	0.00%	(943)
2	0.01%	(712)
3	0.05%	(519)
4	0.45%	(267)
5	1.50%	(196)
6	4.46%	(372)
7	14.28%	(789)
	0.30%	(3844)

The remaining tables in this section are restricted to the 1,607 cars that sustained frontal damage. Table 5.2 contains a list of factors that demonstrated a strong statistical relationship with fatal cars (cars that had at least one fatal occupant). The factors have all been restricted to one degree of freedom $[F(1,\infty)]$ and ranked by the F-ratio.*

Table 5.2 - Factors for Fatal-Cars with Frontal Damage

Rank	Factor	Percentage of Fatal Cars Present	Absent (Non-)
1	Rural--under 10,000 (vs. Urban)	1.42%	0.11%
2	Car-Fixed Object (vs. Car-Car)	.68	.16
3	Driver Age Over 39	.46	.27
4	Driver Sex, Male	.37	.22
5	Old Cars, Pre-1967	.40	.29
6	Unlicensed Driver	.46	.31

Clearly, several factors, other than just speed, play a significant role in the probability of fatality, such as location of accident, collision type, driver characteristics, and vehicle characteristics.

A few factors, not limited to one degree of freedom, are presented separately. The most important of these is the TAD damage scale presented in Table 5.3, which is similar to Table 5.1 except that the case selection was restricted to frontal damage for comparability to the other results in this section.

The risk of fatality is somewhat less in front-left or right-corner impacts relative to front-center and front-distributed damage (Table 5.4). Thus, the distribution and area of frontal damage is also an important fatality factor.

*Equivalent to chi-square statistic as dichotomous variable was used (fatal=1, non-fatal=0). (12)

Table 5.3 - Texas Fatal-Cars by TAD Frontal Damage Extent

TAD Damage Scale	Percentage of Fatal Cars	Fatal N
0	0.00%	20
1	0.00	362
2	0.01	270
3	0.05	220
4	0.29	130
5	1.15	83
6	3.24	154
7	20.52	368
Total	0.32	1607

Table 5.4 - Texas Fatal-Cars by Area of Frontal Damage

Area of Frontal Damage	Percentage of Fatal Cars	Fatal N
Front Center	0.40	192
Front Distributed	0.40	723
Front Left	0.29	366
Front Right	0.18	326
Total	0.32	1607

Within the class of single-vehicle accidents, the specific crash event is a good predictor of the chance of fatality (Table 5.5). The high-energy and solid-object collisions (e.g., trains and trees) have a higher fatality rate than do the softer collisions (e.g., parked cars).

Table 5.5 - Texas Fatal-Cars by Single-Vehicle Crash Event

Crash Event	Percentage of Fatal Cars	Fatal N
Car-Non-Traffic Vehicle e.g., Parked car	0.37%	7
Car-Sign, Signal, Pole	0.42	126
Rollover	0.99	3
Car-Culvert, Guard Rail Tree, Abutment, Pier	2.71	184
Car-Train	100.0	7
TOTAL	1.11	327

5.2 Analysis of CPIR Data

The analysis of variance technique* was also used to review the more detailed CPIR collision data. While the case sampling biases result in an overrepresentation of serious and fatal accidents, analysis of the CPIR data elements does provide some insight into fatality causation factors. While the overall ranking of factors (Table 5.6) may be instructive, it must be recognized that the specific ranking of any one factor and the quantitative percentages of fatal occupants are strictly representative of the CPIR file and are not a representative national accident profile.

Several of these factors are obviously related to impact speed—either as predictors of speed (e.g., urban/rural, street/expressway) or as consequences of speed (e.g., vehicle deformation factors). Some of the driver physiological factors (e.g., license suspensions, stress that day) may also tend to predict impact speed.

Table 5.6 - CPIR Fatal Occupant Factors Ranked by Statistical Significance

Rank*	Factor**	Factor Present %	of (N)	Factor Absent (Non-) %	of (N)
1	External Object Intrusion	27.3%	(565)	3.0%	(4405)
2	Passenger Compartment Size Reduction	18.0	(1376)	1.2	(3558)
3	Primary CDC Extent Zone Over 6 (CDC=7-9)	42.0	(174)	4.6	(4826)
4	Front Crush Over 24"	15.1	(1053)	1.3	(3593)
5	Derived EBS Over 30 mph.	14.8	(1203)	1.3	(3407)
6	Coded Impact Speed, Over 30 mph.	15.1	(1375)	1.5	(3228)
7	Fuel Leakage	35.6	(146)	4.6	(4809)
8	Vehicle-to-Vehicle, Head-on (vs. Other)	10.9	(1161)	2.1	(3849)
9	Non-Intersection Collision (e.g., street, expressway)	9.1	(2793)	1.6	(2026)
10	First Object Impacted - Substantial (vs. Soft; e.g., tree vs. car)	12.0	(1243)	3.8	(3767)
11	Vehicle Fire	39.6	(53)	5.4	(4950)
12	Pharmacological Agents Involved	11.6	(1005)	3.5	(3362)
13	Limited Access Roadway	14.0	(662)	4.6	(4347)
14	Driver Stress That Day	20.7	(270)	5.7	(1297)
15	Secondary CDC Extent, Over 2 (CDC=3-9)	23.2	(128)	4.9	(1112)
16	Vehicle-to-Object	9.2	(1443)	4.5	(3567)
17	Vehicle Rollover	20.4	(93)	5.6	(4917)
18	Secondary Roof Crush, Over 1"	19.0	(84)	5.6	(4893)
19	Occupant Age, Over 39	9.0	(1362)	4.7	(3648)
20	Single Vehicle	9.4	(1164)	4.8	(3842)
21	Internal Loose Object	9.8	(776)	4.7	(3991)
22	Vehicle Final Location - Off-road (vs. on-road)	9.5	(1061)	4.9	(3715)
23	Ran-Off-Roadway	9.0	(1258)	4.8	(3752)
24	Occupant Sex, Male (vs. Female)	7.2	(3097)	3.7	(1906)
25	Vehicle Final Attitude, Rotated (vs. upright)	19.7	(71)	5.6	(4744)
26	Rural (vs. Urban)	7.9	(1814)	4.6	(3177)
27	Any Second Object Contacted	8.4	(1422)	4.9	(3581)
28	Occupant Weight, Over 174 lb.	8.5	(1272)	5.0	(2968)
29	Area of Secondary Damage, Top+Undercarriage (vs. F, R, L. B)	16.2	(130)	6.0	(1137)
30	Secondary Rear Crush Over 11"	33.3	(12)	5.7	(4969)
31	Driver Responsible for Crash	7.0	(2810)	4.2	(1753)
32	Vehicle Structure, Body Frame or Integral Stub	6.8	(2817)	4.4	(1986)
33	Previous License Suspension	16.1	(174)	8.9	(1536)
34	Occupant Height, Over 65"	6.2	(3061)	4.6	(1207)
35	Secondary Left Side Crush Over 5"	8.8	(159)	5.5	(4737)
36	Single Occupant (vs. Multiple Occupant)	6.5	(2309)	5.3	(2699)

*The CPIR file is not a statistical sample, contains strong biases, and overrepresents serious and fatal accidents.

**Statistically related factors, not necessarily direct injury or accident causation factors.

On the other hand, each of these factors may be an important fatality causation factor in its own right. Consequently, each factor was permitted to "stand on its own" in predicting the fatalities in CPIR passenger car impacts. Factors with the highest F-ratio are ranked first. (All factors have one degree of freedom in the numerator and most have large denominators, so F-ratios can be compared.) The F-ratio is only an indicator of statistical significance. It is not a measure of the absolute strength or importance of any one factor, nor does it provide any indication of how much higher, for example, factor 1 is over factor 2. Note that the fatal percentages are based on a count of the number of fatal occupants (not vehicles). For example, the 7.9 percent of fatalities for rural accidents (Rank 26, Table 5.6) indicates that 7.9 percent of the 1,814 CPIR case vehicle occupants in rural collisions are fatalities.

The three highest-ranked factors (Table 5.6) are directly related to vehicle passenger compartment damage. The first two factors are direct measures of the loss of passenger compartment integrity. A primary CDC/VDI damage extent zone (Rank 3) larger than 6 also records direct passenger compartment size reduction. Thus, the probability of fatality is significantly increased with direct damage to the passenger compartment.

The next three factors (Rank 4-6) are related to speed and/or crush. The EBS (Rank 5) was analytically derived from inches of crush, and the determination of the field-coded impact speeds (Rank 6) is, to a large extent, dependent on crush. Consequently, these three speed/crush factors can generally be interpreted as impact speed indicators. The presence of fuel leakage (Rank 7) might also be considered as an indicator of the extent of crush, and therefore, be included in the general class of speed/crush factors. While the speed/crush factors ranked high (Rank 4-7), they were secondary to passenger-compartment direct-damage factors (Rank 1-3).

The next three factors (Rank 8-10) are related to the type of collision. When only vehicle-to-vehicle collisions were included (Rank 8), the fatality rate for head-on collisions was significantly higher than other vehicle-to-vehicle configurations (i.e., front-to-rear, front-to-side, sideswipe, and other), probably because, of these configurations, head-on's involve a higher level of energy dissipation. Intersection collisions (Rank 9) had a lower fatality rate than other accident locations (e.g., streets, expressway), probably for the same reason, i.e., less energy involved. Similar reasoning could also be applied to the higher fatality rate for limited-access roadway factors in Rank 13 and the vehicle-to-object factor in Rank 16. The list of first objects contacted (Rank 10) was reclassified as either soft and small (e.g., other car, pedestrian, motorcycle, ground-ditch, embankment, and breakaway fixtures) or as solid and substantial (e.g., guardrail, bridge rail, pole, tree, trunk, train, pier, pillar, abutment). The "soft" objects tend to dissipate the impact energies over a longer time period than do the "substantial" objects. As expected, the "substantial" objects did indeed demonstrate a higher fatality rate than the "soft" objects.

The general class of collision type (Rank 8-10, 13, 16) ranked third in importance, just behind the speed/crush factors. Consequently, any changes or shifts in the mix of collision types (due to an energy crisis, for example) could have a major impact on the distribution of fatalities.

The occurrence of fire in the case vehicle (Rank 11) increased the chance for fatalities.

The importance of driver precrash factors is apparent in Ranks 12 and 14, "pharmacological agents involved" and "driver stress that day." The lower-ranked factors "driver responsible for crash" (Rank 31) and "any previous license suspensions" (Rank 33) could also be included in this general class. These factors may tend to predict higher-speed collisions, and, hence, a higher fatality rate. Changes in driver precrash factors due to sociological shifts could indeed influence the distribution of fatalities.

The role of secondary impacts is revealed by the ranking of secondary CDC/VDI extent over 2 (Rank 15), vehicle rollover and secondary roof crush (Rank 17, 18), any second object contacted (Rank 27), area of secondary damage (Rank 29), and secondary rear crush over 11 inches (Rank 30). The secondary CDC/VDI damage extent zone of 3 to 9 (Rank 15) may be to any region of the car, and is primarily an indicator of a significant secondary impact—something beyond a minor dent. The rollover/roof crush factors ranked at 17 and 18 are probably synonymous and indicative of the importance of rollover/roof crush in primary frontal impacts. Factors 27, 29, and 30, while receiving a lower ranking, still belong in this general class. Secondary damage

(Rank 29) to the top, undercarriage, or entire vehicle incurred a higher fatality rate than other secondary damage to the front, side, or rear of the car.

The effectiveness of occupant-protection measures in frontal impacts is clearly diluted by the extent to which secondary impacts play a fatality-causation role. Consequently, the distribution of fatalities by impact speed should not be interpreted as if there were only one impact per accident.

Collision factors show up again in the factors ranked as 20, 22, 23, 25, and 26. The general group is typified by the single-vehicle (Rank 20), ran-off-roadway (Rank 22, 23), rural (Rank 26) accident. While these factors are not as directly related to collision severity or energy as the earlier group-collision-type factors, these factors are usually indicative of higher severity collisions. Thus, a change in the proportion of any of these factors could also affect the overall fatality distribution.

The physical characteristics of the front-seat occupants played a lesser but significant role in predicting fatality rates. Occupant age over 39 (Rank 19), male sex (Rank 24), weight over 174 pounds (Rank 28), and height over 65 inches (Rank 34) were all statistically significant factors. Whether these factors are speed predictors (e.g., short young males) or fatality contributors (e.g., thin old males) is not clear. It is clear that occupant physical characteristics do play a significant role in the production of fatalities.

The remaining factors (Rank 32, 35, 36) are of minor, if any, importance. Cars with body and frame, or integral-stub structures, demonstrated a higher fatality rate than unitized and other structures. This difference could be due to biases in the selection of cases (e.g., oversampling of body and frame cars) and not a real effect. On the other hand, recall that the performance of the passenger compartment structure rated as the most important group of factors (Rank 1-3). The last two factors (Rank 35, 36) were significant at the 0.14 and 0.18 level respectively. Secondary side crush (Rank 35) is similar to other secondary damage in pointing to multiple-impact collisions. The single-occupant vehicle factor (Rank 36) may be a speed predictor of possibly an indication that drivers are less likely to kill themselves with other passengers in the car.

In summary, each of 36 CPIR factors was tested independently as a predictor of occupant fatalities. The positions or rankings of individual factors may be the result of CPIR case sampling biases. The broad grouping of factors does provide an overview of major fatality factors. Seven general factor groupings were identified:

1. Passenger Compartment Performance Factors
2. Speed/Crush Factors
3. Type of Collision (e.g., severe impact with solid objects)
4. Driver Precrash Factors (e.g., pharmacological agents, driver stress)
5. Secondary Impact Factors
6. Single-vehicle, Ran-off-roadway, Rural Collisions
7. Physical Characteristics of Occupant Factors

Again, each of these factors is not independent of speed. Some may predict speed (e.g., driver stress) and others may be the consequences of speed (e.g., vehicle damage). The point is that speed alone is not the sole predictor of fatalities.

6. DISTRIBUTION OF INJURY PROBABILITY

The derivation of injury distribution curves is fraught with the same problems of causality (e.g., speed vs. crush environment or occupant physical condition) and proper sampling as the derivation of a cumulative fatality curve. Because the threshold of "What is an injury?" is not clear, these problems are greatly magnified. Consequently, it is difficult to derive a cumulative injury curve that is well-defined, representative, and useful for decision-making and comparison with other results.

6.1 The Approach

The approach taken here is relatively well-defined and representative of the area and accidents sampled. On the other hand, the results may not be directly applicable to the nation because of the restricted set of accidents sampled, or may not be directly comparable with earlier results because of differences in definitions (e.g., EBS derivation) and sampling. The results in this section, then, are only exemplary of what might be obtained from a properly defined and sampled set of national accident data. This approach could be even more valuable if representative cost figures were determined for each level of injury.

During 1974 and 1975, the Motor Vehicle Manufacturers Association has sponsored a Restraint System Effectiveness Study (RSES) of 1973 and 1974 model year American-manufactured passenger cars. Three teams (Calspan, Highway Safety Research Institute, and Southwest Research Institute) have been investigating and reporting on a proper statistical sample of tow-aways. Scott and O'Day have documented the sample design elsewhere (6). While each team uses a slightly different sampling protocol, the resultant data set is a representation of the towed 1973 and 1974 cars in each area, from data available to date.

Each team will transmit data collected through August, 1975 in digital form to HSRI for construction of statistical analysis files. The analysis presented here is based on twelve months of data from each team starting with March, 1974 for HSRI, and April, 1974 for both Calspan and SwRI. Investigations conducted during this period included a total of 5,465 outboard front seat occupants (2,151 Calspan, 1,464 HSRI, 1,850 SwRI). This sample represents a total population of approximately 7,700 occupants of 1973 and 1974 American passenger cars towed from the scene of an accident. This total population was estimated by weighting on the inverse of the respective sampling fractions.

6.2 Injury Distributions

To provide some comparability to the December NHTSA cumulative injury distribution curve (4), the inches of front crush were used to plot equivalent barrier speed (EBS) according to the transformation 7.5 + 0.9 • crush (in.) used in Section 2. Clearly, this transformation is a rough approximation, as it does not, specifically, take into account the vehicle mix or different damage patterns (e.g., narrow/wide) or crash configurations. Since distributed damage is assumed, the resultant derived EBS tends to be high.

The distribution of each AIS level (13) across derived EBS is displayed in Table 6.1. The cumulative injury distribution by EBS is displayed in Figure 6.1 with curves for occupants with AIS-1 or more, 2 or more, 3 or more, and 4 or more. A cumulative curve for all occupants (AIS-0 or more) is also displayed.

Note that the cumulative injury curves are not probability of injury curves. They are based upon the total number of occupants at-and-above each AIS category. The cumulative distribution of each injury class is displayed by derived EBS. Thus, for example, 60 percent of the AIS-4+ occupant injuries occurred between the derived EBS speeds of 0 and 45 mph. The probability of an AIS-4+ injury is not 60 percent at 45 mph.

The probability of injury at-or-above each injury level is displayed in Figure 6.2. These curves are based upon the total number of occupants at each level of derived EBS (10, 15, 20, etc.). Of all the occupants in 40 mph derived EBS crashes, 17 percent sustained an injury severity of AIS-3 or more. Thus, the (computed) probability of an AIS-3+ injury at a derived EBS of 40 mph is 0.17.

As with fatalities, these distributions should not be interpreted as if speed were the only cause of injury. Also, recall that these distributions were derived from recent-model American passenger car "tow-aways." Consequently, there is a smaller percentage of injury accidents. This is demonstrated by the small difference in the distribution of all occupants (AIS-0+) in Figure 6.1.

Table 6.1 - Overall Occupant Injury Severity by Derived EBS

EBS	AIS=0 %	AIS=0 N	AIS=1 %	AIS=1 N	AIS=2 %	AIS=2 N	AIS=3 %	AIS=3 N	AIS=4-10 %	AIS=4-10 N	Total %	Total N
0	0.0	0	0.0	0	0.5	1	0.0	0	0.0	0	0.1	1
10	24.2	195	15.3	142	7.8	16	6.4	3	0.0	0	17.8	356
15	41.4	333	32.9	305	18.9	39	19.1	9	0.0	0	34.2	686
20	19.1	154	22.9	212	24.3	50	6.4	3	10.5	2	21.0	421
25	8.4	68	12.8	119	12.6	26	21.3	10	5.3	1	11.2	224
30	3.5	28	7.1	66	13.6	28	8.5	4	5.3	1	6.3	127
35	1.2	10	5.4	50	8.7	18	6.4	3	10.5	2	4.1	83
40	0.9	7	0.6	6	5.3	11	6.4	3	10.5	2	1.5	29
45	0.2	2	0.9	8	3.4	7	6.4	3	15.8	3	1.1	23
50	0.5	4	1.4	13	2.9	6	6.4	3	10.5	2	1.4	28
55	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
60	0.4	3	0.2	2	0.0	0	2.1	1	0.0	0	0.3	6
65	0.0	0	0.0	0	1.0	2	4.3	2	5.3	1	0.2	5
70	0.1	1	0.1	1	1.0	2	4.3	2	15.8	3	0.4	9
75	0.0	0	0.0	0	0.0	0	2.1	1	0.0	0	0.1	1
80	0.0	0	0.3	3	0.0	0	0.0	0	10.3	2	0.2	5
Total	99.9	805	99.9	927	100.0	206	100.1	47	99.8	19	99.9	2004

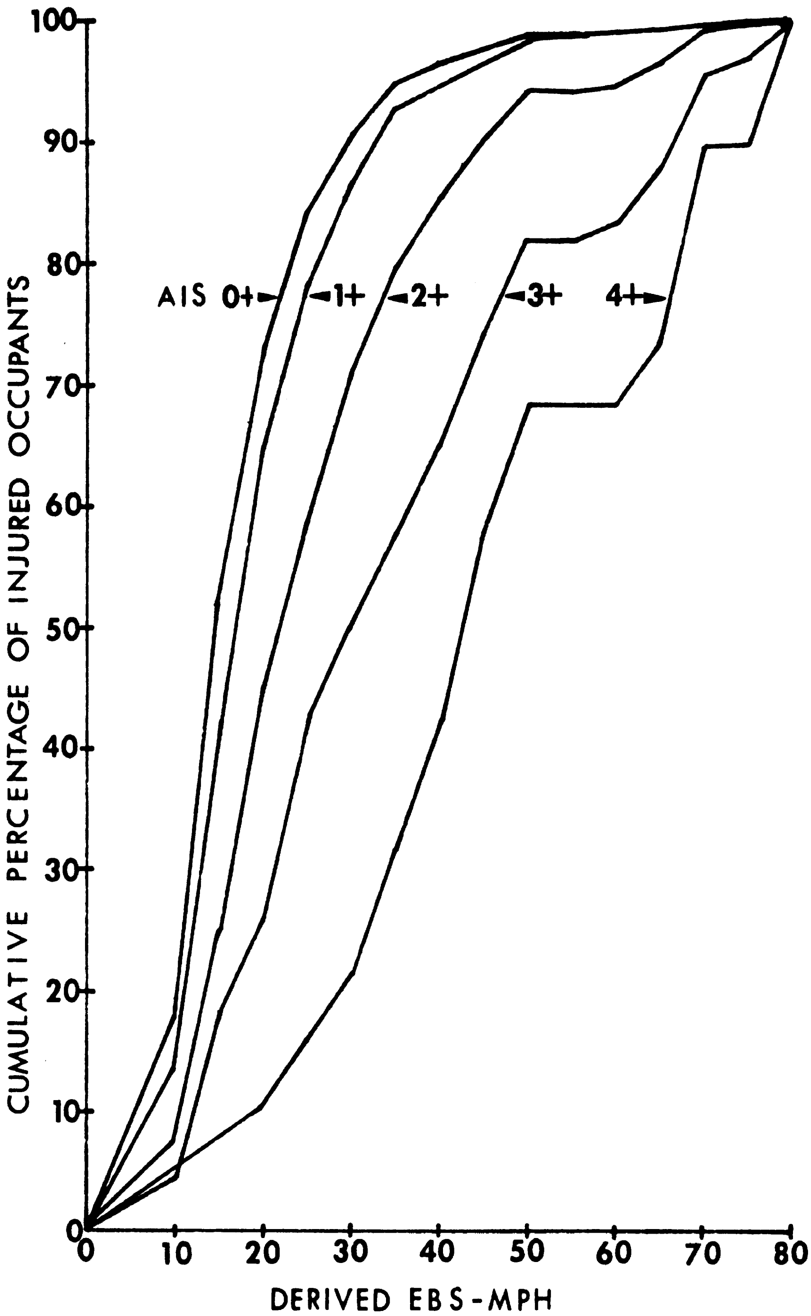

Figure 6.1 - Cumulative Occupant Injury
by Derived EBS

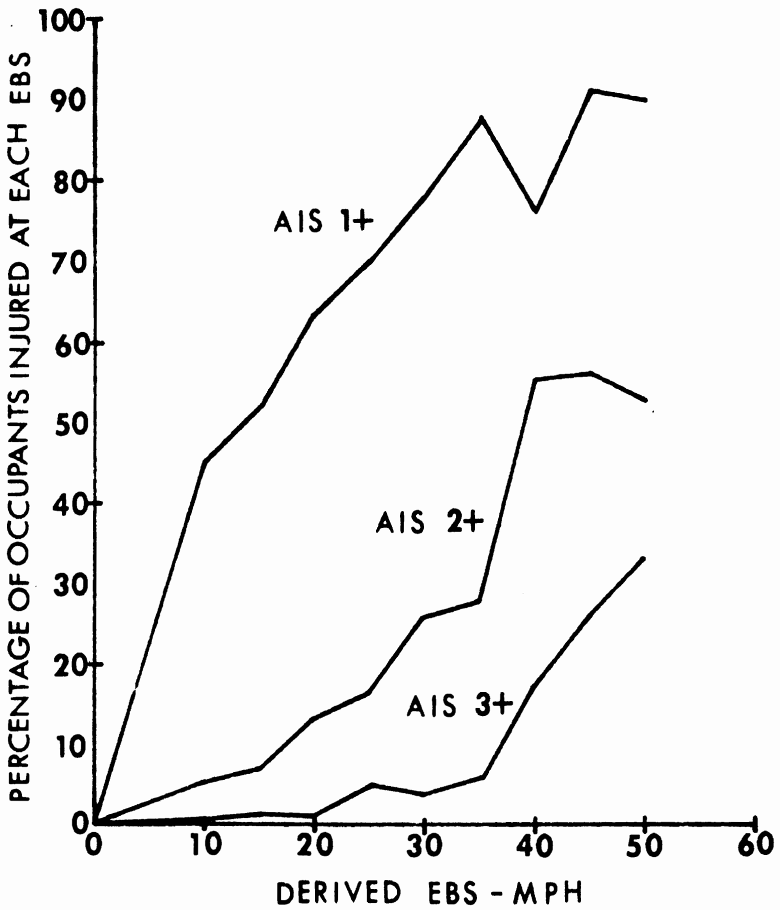

Figure 6.2 - Probability of Occupant Injury
by Derived EBS

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