THE CRASH ENVIRONMENT

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This paper attempts to define the crash environment for recent model cars in terms of specific accident circumstances such as the object struck, the area of impact, and the direction of force. For each accident situation, details for a number of specific impact types and resultant injuries are provided. Details include comparison of single-car and two-car accidents and comparisons of severe injury accidents with all accidents in the study population from which they are drawn. National Safety Council and police-reported data are examined and discussed. The remaining data used in this study are selected from cases investigated by Calspan personnel in a trilevel accident study. Approximately 8,000 police cases collected during 1972 and a subset of 360 in-depth cases are available for study. For perspective purposes, the population of injury and property damage accidents from which the latter cases are drawn is described.

•DEFINING the crash environment requires, first, some understanding of the data on which the definition is based. Today, the most common sources of highway accident data are

1. Police and involved drivers,
2. Multidisciplinary accident investigation teams,
3. Trilevel studies of the U.S. Department of Transportation, and
4. Special studies.

Police reports of accidents are available in huge volume but provide a limited amount of detail concerning each accident. Multidisciplinary team data provide the greatest amount of detail but are available in limited quantity. In addition, because of varying team objectives, these data do not provide an adequate statistical sample of accidents in the United States. Trilevel studies provide basic data from the police and other state agencies augmented by specially collected data and by in-depth investigations of a relatively small number of cases. Data from these studies also may not be representative of the entire United States but generally serve to adequately describe the region from which they are drawn. Special studies usually provide detailed information concerning a specific topic, such as accident type, highway situation, single-vehicle accidents, rollovers, intersection accidents, and accidents involving drinking drivers. In these studies, data volume varies considerably; it is difficult to place the data in perspective, and there is no study continuity so that trend analyses (ongoing comparisons of data) are impossible to conduct.

In this paper, the crash environment is described based on two sources of data, police reports and in-depth data. The influence of different data sources, injury indexes, and study criteria on study results also is discussed to emphasize the importance of understanding criteria used in data collection and analysis when data are reviewed.

DATA SOURCES

Data summarized by the National Safety Council (1) from police-reported information collected in a number of states are used to broadly define the extent of the highway accident problem. Data from the Calspan trilevel program then are used to provide more

detail concerning the broad accident types identified in the National Safety Council data and to compare results obtained by using police and in-depth data (both from the trilevel program).

Calspan Trilevel Program

The Calspan trilevel program is conducted in an eight-county area of western New York that encompasses approximately 6,000 miles^2 (15 540 km^2). Nearly 1 million vehicles are registered in this area, there are nearly 900,000 licensed drivers, and approximately 40,000 accidents occur annually. The three levels of data collection are briefly described below. In this paper, only data from study levels 2 and 3 are used.

Level 1

The level 1 accident file is produced through a merging process performed by the New York State Department of Motor Vehicles and contains data from accidents occurring in the eight-county area that are merged with the drivers' license files and vehicle registration files.

Level 2

The level 2 accident file contains all police-investigated accidents involving a current model automobile or a recent model truck in the study area. Calspan personnel obtain a copy of all police reports by personally visiting all the police stations regularly, and a copy of all driver reports is provided by New York State for the eight counties. Medical data are obtained from hospital records prepared by the attending physican for all injured occupants of all vehicles involved in the accident. Data from approximately 8,000 accidents are obtained annually.

Level 3

The level 3 file contains accidents that are investigated by the Calspan multidisciplinary team (approximately 350 accidents annually). Each accident involves a current model automobile or a recent model truck in which at least one occupant requires hospital treatment and thus represents a subset of the more serious injury accidents from the level 2 file. The major output of level 3 consists of detailed case reports in which descriptions of the accident sequences are provided and causal factors are enumerated. Drivers involved in these accidents are interviewed by Calspan personnel, and the interior and exterior of each case vehicle are examined and photographed extensively. Evidence at the scene is also measured and photographed. For each case, a 1974 annotated collision performance and injury report and supplementary forms are completed.

National Safety Council

Up to the present time, national highway accident statistics have been based largely on police reports collected and summarized by the National Safety Council. Information from all states is not available, and reporting is not always complete for all data items. Additional data also are obtained by the safety council from the National Center for Health Statistics, the Federal Highway Administration, the Federal Railroad Administration, and other sources, including special studies. Thus, the data are not homogenous but, rather, represent a best effort to provide useful information from a variety of sources.

The type of information available from police through the National Safety Council is

given in Table 1, in which accident types reported by police are summarized for fatal accidents and for all accidents in rural and urban areas. The data indicate that the pedestrian accident occurs primarily in urban areas in terms of both accident occurrence and fatality. In general, the only accident type that occurs more frequently in rural areas than in urban areas is the noncollision (rollovers, primarily). Except for pedestrian accidents, more fatal accidents of all types occur in rural areas than in urban areas.

Most accidents involve two vehicles, and the two-vehicle accidents result in more fatalities than any other accident type. Noncollisions and pedestrian accidents rank second and third respectively, in terms of numbers of fatalities.

In Table 1, two-vehicle accidents can be further subdivided as given. The categories shown, however, are not sufficiently detailed to provide useful research data for vehicle studies. Noncollision accidents and other collisions (largely single-vehicle impacts) generally cannot be further subdivided in terms of the accident type or the vehicle area impacted for use in vehicle studies. Data such as those in Table 1 are also subdivided in terms of the time of occurrence (day or night), directional analysis, improper driving, day of week, and a number of other factors. Additional details concerning the vehicle area impacted, direction of force, and injury are not available however.

Injury Indexes

National Safety Council data generally provide information concerning all accidents, injury accidents, and fatal accidents. The data collected by police also provide additional injury classifications that are not used by the safety council. Injury definitions are based on the 2nd edition of the Manual on Classification of Motor Vehicle Traffic Accidents. Perhaps the major shortcoming in police reporting involves these injury definitions. The police rating and the abbreviated injury scale (AIS) ratings (2), which are used in highway safety research, are as follows:

Police Rating		AIS Rating	
Notation	Definition	Notation	Definition
K	Killed	6	Fatal
A	Incapacitating injury	4, 5	Dangerous
B	Nonincapacitating evident injury	2, 3	Not dangerous
C	Possible injury	1	Minor
O	No injury	0	No injury

Individual police ratings of injuries were anticipated to compare reasonably well with the AIS ratings given; however, comparison of police-reported injury with injuries reported by physicians and classified according to AIS in a Calspan study (3) revealed a considerable number of discrepancies in rating injury. In general, the data revealed that police were unable to discriminate between injury levels and, consequently, the only reasonably reliable information from this source was deemed to be the occurrence of any injury to an occupant and the occurrence of fatality.

In the study, AIS and police ratings of injuries for the same occupants were compared. Data for a total of 1,618 occupants were analyzed. Table 2 gives the percentage distribution of AIS injury ratings for each police-rated injury to the 1,618 occupants of cars included in the study. Anticipated correlations between the two indexes are underscored.

The data indicate that 82.5 percent of the police C ratings were in the anticipated AIS 1 category and that all of the police K ratings were in the AIS fatal ratings. Of the B ratings, however, only 37.6 percent were in the anticipated AIS 2 and 3 categories. Almost all of the remaining B ratings appeared in the AIS 1 category, which indicated

Table 1. Number of accidents by type and area for 1972.

Accident Type	Fatal			All		
	Urban	Rural	Total	Urban	Rural	Total
Pedestrian	6,800	3,700	10,500	350,000	50,000	400,000
Two-vehicle collision	5,500	13,400	18,900	10,400,000	2,700,000	13,100,000
Angle	2,100	3,000	5,100	2,100,000	500,000	2,600,000
Head-on	1,200	6,600	7,800	400,000	400,000	800,000
Rear-end	600	1,600	2,200	3,300,000	700,000	4,000,000
Other two-vehicle	1,600	2,200	3,800	4,600,000	1,100,000	5,700,000
Other collision total	2,400	4,000	6,400	700,000	400,000	1,100,000
Noncollision total	2,400	10,600	13,000	750,000	1,650,000	2,400,000
Total	17,100	31,700	48,800	12,000,000	4,800,000	17,000,000

Table 2. Percentage distribution of abbreviated injury scale ratings for each police rating.

Police Scale	AIS Scale						
	0	1	2	3	4	5	6
C	1.2	82.5	14.1	2.2			
B	0.5	61.3	32.2	5.4	0.3	0.2	0.2
A		34.8	33.0	26.5	2.9	1.4	1.4
K							100.0

rather mild injuries. Only 4.3 percent of the police A ratings appeared in the anticipated AIS 4 and 5 categories. Even if the 1.4 percent of A rated injuries that later resulted in death were added to this, approximately 94 percent of the A rated injuries would not be included in the anticipated AIS categories.

Essentially, the foregoing information means that death and the lowest level injury C as rated by police were more consistent with anticipated AIS ratings than other categories. The more serious injury ratings B and A generally were not consistent with anticipated AIS ratings. Note that 98.9 percent of the B ratings and 94.3 percent of the A ratings were distributed among the 1, 2, and 3 AIS categories. Perhaps the least discrimination is evidenced in the A category, where roughly 33 percent of the injuries fall into each of the 1, 2, and 3 AIS categories, although an A rating is intended to indicate serious injury.

These data indicate that the anticipated correlation between AIS ratings and police ratings is poor except for fatalities and reflect the fact that definitions provided the police do not permit them to discriminate between injury severities. As an example, a minor AIS injury (rating 1) is generally a laceration, abrasion, contusion, or bruise without extensive bleeding. A bleeding injury may well be classified as an A, B, or C injury depending on the officer's interpretation of the extent of bleeding. The AIS scale does not permit discrimination among specific types of injuries.

Comparison of Levels 2 and 3 From Calspan Program

Accident data collected by the Calspan program and by other teams throughout the country provide more detailed information than police data provide for the study of accidents. With respect to accident type, vehicle damage, and occupant injury, for example, the use of the vehicle deformation index (VDI) (4) and the AIS can clarify the relationship between site and extent of vehicle damage and associated occupant injuries. If necessary, further damage details may be obtained by using the actual crash measurements that are available, as well, in level 3 data.

Level 2 data are based on police reports of accidents involving all current model cars and recent model trucks in the eight-county study area. Medical reports for injured occupants in all vehicles are obtained. Level 3 data represent a subset of these

data, investigated by Calspan personnel, in which at least one occupant was injured seriously enough to require hospital treatment. Thus, the latter accidents represent the most serious injury accidents found in the combined injury and property damage data from level 2.

Comparison of these data sets should reveal how the more serious accidents differ from all accidents with respect to a number of accident, vehicle, and occupant variables. Since the crash environment of the more serious injury accidents is the target in most highway safety studies, it should be useful to provide additional details concerning the general accident types shown in police and National Safety Council data.

Accidents and Vehicles

During 1972, there were 8,145 level 2 accidents and 358 level 3 accidents in the Calspan study area. Selected accident-vehicle data from these collisions are discussed in this section, and related occupant information is presented later.

The following table gives the percentage of level 2 and level 3 accidents according to the number of vehicles involved.

No. of Vehicles	Level 2	Level 3
1	16.4	36.9
2	74.7	52.8
3 or more	9.0	10.3

It is evident that there are more single-vehicle accidents and fewer two-vehicle accidents in level 3 data. This confirms earlier findings of Calspan and other researchers that single-vehicle accidents are generally more serious than multivehicle accidents. There were 15,866 vehicles involved in the 8,145 accidents from level 2 or 1.95 vehicles/accident. There were 626 vehicles in the 358 accidents from level 3 or 1.75 vehicles/accident. This reflects the larger proportion of single-vehicle accidents in level 3 data. (Note that numbers in the tables may vary because not reported categories are omitted most of the time.)

The percentage of level 2 and level 3 accidents according to the number of occupants in those vehicles is given below. There were 12,633 level 2 accidents and 615 level 3 accidents.

Occupants	Level 2	Level 3	Occupants	Level 2	Level 3
0	9.9	1.9	4	3.7	4.1
1	55.5	62.0	5	1.2	0.3
2	22.3	26.0	6 or more	1.2	1.5
3	6.2	4.2			

Fewer unoccupied cars were struck in level 3, however.

The percentage of accidents according to the area of the car impacted is given below.

Area	Level 2	Level 3	Area	Level 2	Level 3
Front	42.4	56.1	Top	0.7	4.6
Left	16.2	13.4	Undercarriage	0.2	1.0
Right	13.4	15.5	Unclassified	6.2	0.3
Back	20.9	9.1			

The level 3 accidents include more front, right side, top, and undercarriage impacts than level 2 accidents (all). There are twice as many rear impacts in level 2 as in level 3. These accidents usually produce fewer serious injuries than the impact areas mentioned for level 3.

Occupant Seat Position

The percentage of accidents according to occupant seat position indicates that for level 3 the proportion of drivers is smaller and the proportion of occupants in other seats is larger than for level 2:

Seated Position	Level 2	Level 3	Seated Position	Level 2	Level 3
Driver	66.4	62.4	Center rear	0.9	1.5
Center front	1.7	2.7	Right rear	1.9	3.5
Right front	9.3	18.6	Third seat	0.1	0.1
Left rear	1.6	3.2	Not reported	18.1	8.0

The number of accidents was 21,920 and 984 respectively for levels 2 and 3.

The percentage of level 2 (N = 21,892) and level 3 (N = 983) accidents according to whether the occupant was ejected is as follows:

Ejection	Level 2	Level 3
Ejected	0.2	1.3
Not ejected	99.2	98.5
Not reported	0.6	0.2

Ejection occurs about five times more frequently in the level 3 cases than in level 2 cases. This reflects the fact that ejection is a major source of serious injury in accidents.

Restraint use was not reported in about half of the level 2 cases. The percentage of accidents according to known restraint use by occupants is given below:

Restraint Use	Level 2	Level 3
None	71.2	79.7
Lap belt	6.1	15.5
Shoulder belt	0.1	0.1
Lap and shoulder belt	0.1	1.1
Restraint used (not specific)	22.5	3.6

A higher percentage of level 2 accidents (N = 10,627) involved seat-belted occupants, altogether 28.8 percent, than did level 3 accidents (N = 871), altogether 20.3 percent. Level 2 data are based on police reporting, and level 3 data are based on Calspan investigation and interviews. This finding tends to support a thesis developed by Mela (5) that there may be overreporting of restraint use in police data. It could also suggest, however, that those involved in serious accidents are less likely to be using restraints than others.

The percentage of accidents according to the apparent physical conditions of drivers is given below:

Condition	Level 2	Level 3
Felt normal	91.9	82.3
Felt ill	0.4	1.1
Had physical defect	0.1	0.4
Fell asleep	0.4	1.1
Had been drinking	7.0	14.2
Had taken drugs	0.05	0
Other	0.1	0.9

Level 3 data (N = 542) indicate a higher proportion of abnormal driver conditions than level 2 data (N = 9,357). The largest category, had been drinking, is twice as large in the more serious level 3 accidents as in the level 2 accidents. Other categories also tend to be larger in the level 3 data.

Accident Type, Accident Severity, and Injury for Level 3

A more detailed examination of the relationship between vehicle damage and injury may be made by using VDI and AIS. The data used are from the Calspan level 3 in-depth file. Data were collected for about 3 years and included 1,185 cases. Only single- and two-car accidents are presented. There were 238 single-car accidents and 386 two-car accidents or a total of 624 cases. Before these data are discussed, VDI codes are shown in Figure 1. A detailed description of VDI appears elsewhere (4). For simplification of discussion of the data in this section, the vertical area of damage (code 5) and the type of damage distribution (code 6) are omitted. Also, various categories are combined as necessary to illustrate certain points.

Single-Car Accidents

The area of the car impacted and the direction of force for single-car accidents have been combined in Figure 2 to show well-defined accident types. Omission of other directions of force and unusual impacts reduced the number of single-vehicle accidents available from 238 to the 191 shown in Figure 2. The data reveal that front impacts and rollovers are the predominant types of single-car accidents. The center front is the front area most commonly impacted, and impacts to both sides are about equally distributed. In side collisions, front fenders or compartment impacts are most frequent.

The following table gives the percentage of severe or worse injury (AIS ≥ 3) for each general area of impact and for vehicle damage ratings of ≤3 and ≥4:

Car Area	≤3	≥4	Total
Front	16.3	46.4	24.6
Left	6.7	60.0	20.0
Right	30.0	83.3	50.0
Back	50.0	66.7	60.0
Rollover	19.0	44.4	30.8
Total	17.2	52.6	27.7

Overall, slightly more than half of the occupants (52.6 percent) sustained AIS ≥ 3 in-

juries when the damage rating was 4 or greater compared with 17.2 percent when AIS ≤ 3. Limited data volume precludes precise interpretation of many categories, but it is clear that the frequency of severe or worse injury is much higher as damage increases.

Two-Car Accidents

Two-car accidents are presented in a format similar to that for single-car accidents. Throughout this section it should be kept in mind that the level 3 data represent current model car accidents in which at least one occupant was injured sufficiently to warrant hospital treatment. Thus, the other car in a two-car accident appears in the data only because it was in a collision with a car meeting the above criteria. Logically, it can be hypothesized that, if an impact to any car area is more likely to produce serious injury than an impact to another area, that area should appear more frequently for the late model car than for the car it impacts. (The converse should also be true.) As an example, if a front to rear impact results in more serious injury to occupants of the striking vehicle than to those in the struck vehicle, one would expect more front impacts among current model cars in the level 3 data and fewer rear impacts (because the current model car determines which accidents enter level 3). This is a useful point to keep in mind because it illustrates the importance of understanding data collection criteria when data are reviewed or analyzed.

Data for both the case car and the other car (N = 652) in the accident are given independently in Table 3. Single-car accidents are also shown for perspective purposes. The data indicate that there are indeed more front impacts and fewer rear impacts for the current model car than for the other car, as hypothesized previously. Single-car accidents produced fewer side and back area impacts than two-car accidents, but, effectively, these collisions were replaced by rollovers.

Figure 3 shows the area of impact and direction of force information for the current model cars involved in two-car accidents. In front impacts, cars impacted the left front far more frequently than the right. This contrasts markedly with single-vehicle accidents in which there were more center front impacts and other front impacts were equally distributed on either side. Front impacts in single-vehicle accidents also involved a smaller front area, LCR, than that in two-car accidents, YZD. Back impacts generally involved a large area of the back, YZD. Back impacts were relatively infrequent in single-car accidents (Table 3). Side impacts for cars in two-car accidents were generally similar in frequency for both sides and involved a wide area, YZD.

The percentages of vehicles (current model car only) with severe or worse injury (AIS ≥ 3) to an occupant are shown in Figure 3 for each general area of impact. The data indicate that, as in single-car accidents, the percentage of occupants with AIS ≥ 3 is far greater in the more severe accidents. Comparison with data for single-car accidents, however, shows that AIS ≥ 3 injuries is far more frequent in single-car accidents than in two-car accidents, regardless of severity. The percentage of AIS ≥ 3 injuries for each general area of impact and for vehicle damage ratings of ≤3 and ≥4 is as follows:

Car Area	≤3	≥4	Total
Front	9.0	39.0	15.0
Left	6.9	33.3	11.4
Right	7.7	20.0	9.1
Back	—	—	—
Total	7.8	31.7	12.3

Figure 1. Vehicle deformation index.

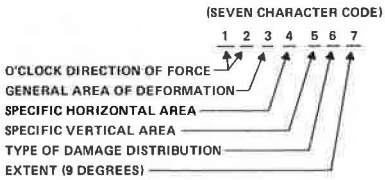
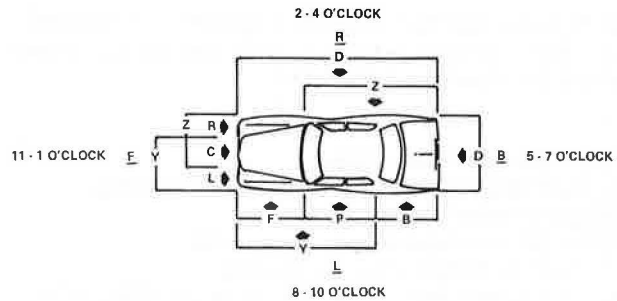


Table 3. Accident data for area of impact.

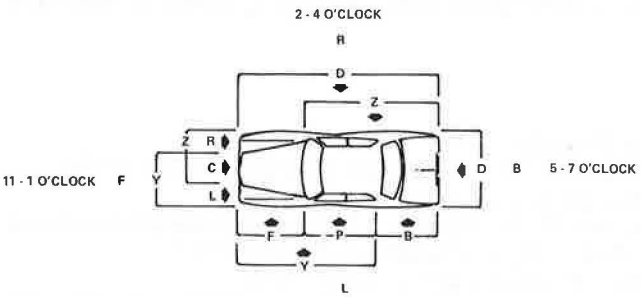
Accident	Front	Back	Left	Right	Rollover
Single-car	59.7	2.1	9.4	8.4	20.4
Two-car					
New car	65.3	9.8	11.0	13.9	–
Other car	54.9	16.0	12.5	16.7	–

Figure 2. Area of impact and direction of force for single-car accidents.



FRONT		BACK		LEFT		RIGHT			
L	22	L	1	F	6	F	5		
C	30	C	2	P	5	P	8		
R	21	R	0	B	2	B	1		
Y	12	Y	0	Y	2	Y	1		
Z	15	Z	1	Z	1	Z	1		
D	14	D	0	D	2	D	0		
F =	114	B =	4	L =	18	R =	16	ROLLOVER 39	TOTAL 191
%	59.7		2.1		9.4		8.4	20.4	100.0

Figure 3. Area of impact and direction of force for two-car accidents.



CURRENT MODEL CAR

FRONT		BACK		LEFT		RIGHT			
L	45		1	F	8		9		
C	2		3	P	5		2		
R	16		1	B	0		2		
Y	34		5	Y	11		13		
Z	40		7	Z	8		14		
D	70		14	D	3		4		
F =	207	B =	31	L =	35	R =	44	TOTAL	317
%	65.3		9.8		11.0		13.9		100.0

SUMMARY

Currently, data summarized by the National Safety Council provide an overview of accidents on a national scale. In a trilevel program, additional details may be obtained by improved analysis of police reports and collection of additional medical data from attending physicians (level 2 data). In-depth investigations by trained teams provide the required detail and accuracy for detailed analysis, and supplement data from level 2. In this paper, National Safety Council data indicate that two-vehicle accidents are more frequent and result in more fatal accidents than other types of accidents. The single-vehicle noncollision accident ranks second, but the proportion resulting in fatal injury is higher than that in two-vehicle accidents. Police ratings of injuries cannot discriminate among injury levels and appear to be adequate only to identify the occurrence of injury or fatality.

From Calspan data, level 3 accidents that required hospital treatment for at least one occupant were selected from the police-reported population of injury and property damage accidents. The level 3 accidents involved the following:

1. More single-car accidents;
2. More impacts from the front and fewer from the rear;
3. More impacts to the front, top, and undercarriage and fewer to the rear;
4. More right front occupants and fewer drivers;
5. More occupant ejection (about five times greater than in level 2);
6. Less restraint use (possibly because of better reporting); and
7. More drivers who had been drinking (about twice as many as in level 2), who were ill, or who fell asleep.

Two-car accidents involving severe or worse injuries (AIS ≥ 3) differed from single-car accidents and involved the following:

1. More impacts to the left front area,
2. Larger impact areas,
3. More rear impacts, and
4. Fewer severe (AIS ≥ 3) injuries.

Perhaps the most important point in this paper is the need for the influence of the data selection process on results to be understood when data are analyzed or reviewed.

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