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AN EVALUATION OF THE EFFECTIVENESS OF SIDE-DOOR BEAMS BASED ON ACCIDENT EXPOSURE

Fred Preston
Ray Shortridge

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Prepared by:

Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48105

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16. Abstract

This article reports on an evaluation of the injury reducing effects of side-guard door beams based on accident investigation reports. The evaluation considers two measures of effectiveness: (1) the mean injury severity recorded for the occupants, and (2) the degree of deformation in the door. In each case the analysis controls on contributing factors such as occupant seating location, restraint use, side of the car damaged, and the angle of the impact force. In both cases, results show that it cannot be concluded that side door beams produce an effect on injuries, or on door penetration.

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1. Introduction

Previous studies have indicated that the side-impact crash is a major injury producing accident configuration (1). This finding has led to serious efforts over the past several years to improve the design of passenger cars so as to help alleviate this problem (2,3). The principal approach adopted by the automobile manufacturers has been to install steel beams in the door structures of the vehicle (4,5). The stated purpose of these beams is to limit passenger compartment intrusion and thus reduce occupant injuries (4). Although not explicitly stated, the reasoning behind this is that anything that limits penetration into the passenger compartment, and the attendant reduction of compartment size, should decrease the probability of occupant contact with the interior of the car, thus lessening the chance of injury. To be sure, if a car is hit on the side there will be a force tending to push an occupant toward that side whether it is caved in or not. Nonetheless, the limitation of passenger compartment penetration can certainly not increase the probability of injury. Another possible injury reducing mechanism of side door beams (side-guards, side-guard beams) is based on the idea that the injuries to an occupant should be reduced if he is allowed to decelerate over an extended period of time. Thus a two-car accident like a side-swipe, in which the cars glance off each other and continue decelerating to a safe stop, should result in fewer or less severe injuries than if forward velocity is suddenly arrested. A device that would increase the probability of a glancing blow should therefore tend to reduce injuries, and it is reasonable to consider the side door beam as such a device.

The purpose of this report is an assessment of the effect of side-door beams on the injury level sustained by the driver and right front passenger of vehicles whose side doors have been struck. The data for this investigation stem from reports of automobile accidents. Two approaches to this assessment have been adopted. First, the injury severity levels of occupants in cars equipped with side beams are compared with those in cars without side-door beams. Because there may be some confounding factors such as seating location, and restraint use, the analysis explicitly controls on these factors. Second, a comparison is made between vehicles with side-guards and those without side-guard beams regarding the extent to which the striking vehicle penetrates the passenger compartment of the struck car. This analysis also imposes controls upon relevant factors such as angle of contact.

Three large accident data files provide the information used in the first analysis. First, the analysis draws upon the comprehensive data set for Denver County, Colorado, for the 1972 calendar year. This file consists of police accident reports. Second the Collision Performance and Injury Report, Revision 3, occupant file is used. This file contains Multi-Disciplinary Accident Investigation reports submitted by several teams across the country. Third, the analysis uses a 5% random sample of accidents occurring in the state of Texas for the 1972 calendar year. The information is derived from police accident investigations. Because none of these data sets comprise a sample of the total national accident population, each of them is analyzed in turn. That is, the report consists of parallel analyses of three discrete bodies of data. Presumably, if side-guard beams exercise an important injury reduction effect, a similar pattern would emerge in each of these three data files. The second analysis, of door penetration, uses only the CPIR file because it is the only one containing sufficient information for a systematic analysis.

2. Summary

Although each analysis is discussed thoroughly in the body of the report, a brief summary of the methods and results is presented here.

The first analysis attempts to determine if there is a direct relationship between side beams and occupant injuries. Three data files are consulted: Denver County 1972 accidents, a 5% sample of Texas 1972 accidents, and the Collision Performance and Injury Report (CPIR) file collected by various investigation teams around the country. For each file, a determination is made of what complicating factors would confound the analysis, and appropriate methods of controlling such factors are applied.

In the case of the Denver data, both seated position and side of impact have an effect on injuries and thus the comparisons of the distributions of injuries between occupants of side beam and non-side beam cars is made while holding the values of these other two factors constant. In no case can it be stated that the distributions are different, and thus we conclude that the Denver file does not show any side beam effect on injuries.

For the CPIR file analysis, seated location and side of impact are again considered as complicating factors, but in addition restraint use and model year of the car are also controlled. The prime method of analysis used on this file is regression using categorical variables. The results are similar to the Denver results - there is no consistently significant side beam effect over and above the effects of the other variables.

Finally, the Texas file is consulted, and here the complicating factors are model year of car, restraint use, and seated location. As with the CPIR data, regression is the main method of analysis. The results are also similar--the Texas data do not support the contention that side beams exercise an important injury reducing effect.

The final part of the study evaluates the presence of a side beam effect on injuries indirectly, by considering the amount of crush sustained by the side door of a car as the measure of effectiveness. The CPIR file is used as the source of data, and the control variable is the angle of impact on the door. Comparisons of the distributions of side door crush between side beam and non-side beam cars reveal that at all angles of impact there is no difference in the amounts of crush sustained. This tends to confirm the findings of part one. Therefore we must conclude that there is no significant side beam effect on occupant injuries or on the amount of crush to the side doors.

3. Side-Impact and Injury

3.1 Denver County Data

3.1.1 Frequency and Severity of Side-Impact Accidents

The first part of the investigation draws upon the comprehensive accident data file for Denver County, Colorado, for 1972. This file contains information denoting the region of the occupant's vehicle which was damaged in the accident. However, because the data do not explicitly indicate the region actually contacted by the striking vehicle, it is not possible with this data set to analyze only those cases in which the striking vehicle contacted the door of the other car. Yet, by restricting the analysis only to those accidents with broadside and sideswipe configurations, one does obtain a set of cases which more closely approximate the desired door-contact population. The subsequent analyses performed on the Denver data employ this set of cases (n=7615). Table 1 contains the frequency and proportion with which vehicles involved in sideswipe and broadside configurations sustain damage to the front doors. The third column shows the percentage of such vehicles in the total accident population contained in the Denver 1972 file (n=33,166).

Table 1

Frequency and Percent of Passenger Cars Sustaining Front Door Damage in Broadside and Sideswipe Configurations, Denver

Denver 1970	Frequency	% of Broadside & Sideswipe Cases	% of Total Number Accidents
Left front door	1848	22.6	5.6
Right front door	1966	24.1	5.9
Total	3814	46.7	11.5

The table reveals that a front door is damaged in a sizeable proportion (11.5%) of the automobile accidents recorded in the Denver file and that there is not much difference between the incidence of right-front door and left-front door damage (5.9% to 5.6%). As one would expect, front doors are very likely to be damaged in sideswipe or broadside configurations (46.7%). The Denver 1972 data supports the view that direct impact with the passenger compartment comprises a frequently encountered collision configuration.

The Denver file was also used to assess the relative severity of injury produced by side-impact with the passenger compartment. The file records the severity levels for drivers and right front passengers who received an injury on a four value scale (pain--but no visible injury, minor visible injury, carried from the scene, and fatal). Table 2 presents the distribution of injuries across this scale for those passengers involved in side-swipe or broadside accidents in which the door sustained damage. For comparison purposes, the table presents the injury severity distribution for all injured drivers and right-front passengers in the file.

The tabulations indicate that a larger proportion of the injured drivers involved in a broadside or sideswipe accident in which a door is reportedly damaged sustain severe injuries ("fatal" or "carried from the scene") than the driving population reportedly involved in Denver accidents. The data indicate a similar injury severity pattern for right-front passengers--more of them reportedly sustain fatal or carried-away injuries in side-impact configurations with door damage than that reported for the total right-front passenger population. Consequently, the Denver mass accident file corroborates the suggestion that broadside or side-swipe accidents constitute an important injury-producing class of collisions (1).

Table 2

Recorded Injury Code for Injured Occupants
Involved in Broadside or Sideswipe
Accidents in Vehicles with Door Damage, Denver

Drivers	Pain	Minor Injury	Carried from Scene	Fatal
% of drivers with Pain through Fatal Injury Severity Value (n=385)	40.8	34.8	24.2	0.3
Number of Cases	157	134	93	1
Right Front				
% of Right front with Injury values Pain through Fatal (n=132)	30.3	42.4	26.5	0.8
Number of Cases	40	56	35	1

Recorded Injury Code for All Injured Occupants, Denver

Driver	Pain	Minor Injury	Carried from Scene	Fatal
% Drivers with Injury Values Pain through Fatal (N=3193)	45.6	37.6	16.3	0.6
Number of Cases	1457	1199	519	18
Right Front				
% Right Front Occupants with Injury Severity Value Pain through Fatal (N=1132)	42.8	33.0	23.3	0.9
Number of Cases	484	374	264	10

3.1.2 Complicating Factors

A number of factors other than the presence or absence of side-guard beams conceivably could affect the injury level sustained by the occupants. In assessing the utility of side-guard beams, it is necessary to control for these other factors in order to measure the net effect of the side-guard on occupant injury. The first factor examined with the Denver data is whether the side of impact affects the injury patterns for the occupants. The following table presents the incidence rate for an injury occurring to drivers and right-front passengers according to the side which was damaged.

Table 3

Frequency of Side of Vehicle Damaged for Injured Occupants in Broadside and Sideswipe Accidents, Denver

Drivers	#	% Injured Occupants (Broadside/Sideswipe)
Left-front door damaged	208	54.0
Right-front door damaged	177	46.0
Right-Front Passengers		
Left-front door damaged	55	41.7
Right-front door damaged	77	58.3

The figures suggest that the incidence of injury to right-front passengers is a function of the side of impact to a slightly greater degree than that for drivers. That is, 58% of the injured right-front passengers are injured when their (right front) door is damaged compared with 54% of injured drivers when their (left front) door is damaged.

It should also be useful to know whether the side of impact affects the level of injury for those occupants who were hurt.

Table 4 displays the frequency of driver injury recorded for the four severity levels according to the side of the vehicle which was damaged. Again, the cases are only for broadside and sideswipe accidents.

Table 4

Distribution of Driver Injury by Door Damaged, Denver

Left Front Door	Pain	Minor	Carried Away	Fatal
N	94	69	45	0
%	45.2	33.2	21.6	0.0
Right Front Door				
N	63	65	48	1
%	35.6	36.7	27.1	0.6

The tabulations show that for injured drivers the more severe injury levels of carried away and fatal do not seem to be associated with the side of the vehicle which was damaged.

Comparable tabulations of injury level for the injured right-front passengers are presented in the following table.

Table 5

Distribution of Right-Front Passenger Injury by Door Damaged, Denver

Left Door Damaged	Pain	Minor	Carried Away	Fatal
N	19	29	7	0
%	34.5	52.7	12.7	0.0
Right Door Damaged				
N	21	27	28	1
%	27.3	35.1	36.4	1.3

The evidence suggests that injured right-front passengers in broadside and sideswipe configurations are more likely to be carried from the scene or killed when their vehicle's right front door is damaged (37.7%).

Comparing Tables 4 and 5, it is evident that right-front passengers are, as a group, more likely to suffer death or injuries requiring their being carried from the scene than are drivers. Moreover, the dependency of injuries of these levels of severity (killed or carried away) upon the side of the vehicle damaged is greater for right front passengers than for drivers (25.0% difference versus 6.1%, respectively). However, both drivers and right-front passengers are slightly more likely to sustain such injuries when their right-front door is damaged than when the left-front door is damaged. Therefore, both the side of impact and the seated location are important factors to control when assessing the effects of side door beams on injuries.

3.1.3 Side-Guard Beams and Injury Severity

Having established two factors which influence injury and therefore should be controlled, we turn to an assessment of side-door beams. The procedure is to partition the Denver cases into two groups: those cars without side beams, and those cars with side beams. A comparison is then made of the percentage and distribution of injuries to each seat position occurring in the cars of each group. Table 6 presents this comparison.

Table 6

Distribution of Injuries to Occupants of Side Beam and Non-Side Beam Cars by Seated Position (Denver 1972 Broadside and Sideswipes)

	No Side Beam				Side Beam			
	Driver		Rt. Front		Driver		Rt. Front	
Injury Level	N	%	N	%	N	%	N	%
Fatal	1	0.3	1	1.1	0	0.0	0	0.0
Carried	79	24.9	28	30.1	14	20.6	7	17.9
Minor	115	36.3	41	44.1	19	27.9	15	38.5
Pain	122	38.5	23	24.7	35	51.5	17	43.6
Total	317	100.0	93	100.0	68	100.0	39	100.0

A statistical test of the hypothesis that the distributions of injuries are the same between side beam and non-side beam cars reveals that there is no real difference in the frequency of each type of injury to occupants in each seated position.

Tables 7 and 8 introduce the second factor, side of car contacted.

Table 7

Distribution of Injuries to Occupants of Non-Side Beam Cars by Seated Location and Side of Impact (Denver 1972 Broadside and Sideswipe)

	Left Impact				Right Impact			
	Driver		Rt. Front		Driver		Rt. Front	
Injury Level	N	%	N	%	N	%	N	%
Killed	0	0.0	0	0.0	1	0.7	1	1.9
Carried	40	22.5	7	17.9	39	28.1	21	38.9
Minor	59	33.1	21	53.8	56	40.3	20	37.0
Pain	79	44.4	11	28.2	43	30.9	12	22.2
Total	178	100.0	39	99.9	139	100.0	54	100.0

Table 8

Distribution of Injuries to Occupants of Side Beam Cases by Seated Location and Side of Impact (Denver 1972 Broadside and Sideswipe)

	Left Impact				Right Impact			
	Driver		Rt. Front		Driver		Rt. Front	
Injury Level	N	%	N	%	N	%	N	%
Killed	0	0.0	0	0.0	0	0.0	0	0.0
Carried	5	16.7	0	0.0	9	23.7	7	30.4
Minor	10	33.3	8	50.0	9	23.7	7	30.4
Pain	15	50.0	8	50.0	20	52.6	9	39.1
Total	30	100.0	16	100.0	38	100.0	23	99.9

Again, statistical tests are made of the hypotheses that there are no differences in the distributions of injuries between side beam and no side-beam cars in each of the four situations. They show no significant differences. Therefore the Denver data do not allow us to conclude that side beams have an effect on injury.

3.2 CPIR Data

3.2.1 Frequency and Severity of Side-Impact Accidents

More refined information regarding the area of the vehicle damaged, descriptions of salient characteristics of the accident, and severity of injury sustained by the occupants is available in the Collision Performance and Injury Report data file. The CPIR data are obtained from Multi-Disciplinary Accident Investigation reports obtained from government and industry sponsored investigation teams. However, the CPIR file does not constitute a random sample of the accident population--a primary bias in the file lies in the overrepresentation of accidents in which the occupants sustained severe or fatal injuries. Yet it is believed that the accident universe of which the CPIR is a useful sample is quite large.

Throughout this section only those occupants who were drivers or right-front passengers are included in the analyses. Moreover, to avoid possible sampling problems introduced by certain case selection criteria employed by the crash investigation teams, only those drivers and right-front passengers whose accidents were investigated in the 1970-1973 period are included in the analyses. The passenger compartment as defined for this study consists of the region from the "A" pillar to the "C" pillar. This definition does not allow one to differentiate between front and rear door area impacts--an inherent defect in the character of vehicle deformation information contained in the file. The damage resulted directly from collision contact with either another vehicle or with a "pole". (6)

Table 9 presents the number of drivers, right-front passengers, and case vehicles in the file in which the passenger compartment of the case vehicle sustained direct damage. The relative frequency for right- and left-side direct damage is about the same for both seating locations. For drivers, 50.8% of their cars were struck on the right-side as compared with 54.7% of the right-front passengers.

Table 9

Number of Cases in Which the Passenger Compartment Sustained Direct Damage

	Drivers	Right Front Passengers	Case Vehicles
Right Side	96	35	96
Left Side	93	29	93
Total	189	64	189

The CPIR file records the overall injury severity sustained by the occupants in terms of the Abbreviated Injury Scale (9). Eleven severity values comprise the scale (none, minor, non-dangerous--moderate, non-dangerous--severe, dangerous--serious, dangerous--critical, fatal lesions in one region, fatal lesions in one region and dangerous injuries in other regions, fatal lesions in two regions, fatal lesions in three or more regions, fatal with details unknown.) Throughout this analysis, the five values denoting fatal are collapsed into one category. Table 10 shows the overall injury severity distribution for the 253 occupants of vehicles incurring direct damage to the passenger compartment. By way of comparison, the same information for the other drivers and right-front passengers in the CPIR file whose accidents were investigated in the 1970-1973 period is also displayed.

Table 10

Overall Injury Severity for CPIR Drivers and Right-Front Occupants

Side-Contact Cases

	0	1	2	3	4	5	6+	MD	N
#	44	116	44	21	3	6	18	1	253
%	17.4	45.8	17.4	8.3	1.2	2.4	7.1	0.4	

Non-Side-Contact Cases

	0	1	2	3	4	5	6+	MD	N
#	838	1789	433	213	65	40	177	34	3589
%	23.3	49.8	12.1	5.9	1.8	1.1	4.9	0.9	

These data indicate that occupants injured in accidents in which the passenger compartment of the vehicle was contacted tended to sustain more severe injuries than the other injured occupants contained in the file. This observation is particularly noticeable in the relative proportion of fatalities where 7.1% of side-contact occupants were killed as compared with 4.9% for the other occupants in the file. The side-contact configuration emerges as an important producer of severe injuries to the occupants in the CPIR data set.

3.2.2 Complicating Factors

A number of factors conceivably could affect the severity of the injury sustained by the occupants in their accidents. In drawing conclusions regarding the effect on injury attributable to the presence of side-guard beams, it is desirable to control on these other factors. This section assesses the association between side of impact, seating location, and restraint usage and injury severity to see whether these factors must be controlled in the subsequent analyses which measure the effect of side-guard beams on injury severity.

The first factor considered is whether the side of impact affects the injury level sustained by the occupants. In answering this question, the occupants were divided into two groups--drivers and right-front passengers. Table 11 presents the frequency and percent of the injury severity scale values recorded for drivers in side-contact accidents according to whether the impact occurred on the right or left side. The table indicates that the drivers tended to sustain a greater proportion of fatalities when their vehicle was struck on the left side than when it was struck on the right. The mean injury severity for right-side contact is 1.40 AIS units as compared with the mean of 1.87 AIS units obtained with left-side contact.

Comparable injury severity data for the right-front passengers are contained in Table 12.

Table 11

AIS(0-6+) for Side-Contact Drivers, by Side of Impact

	0	1	2	3	4	5	6+	MD	N
#Right	23	44	15	6	1	3	4	0	96
Left	9	45	18	10	0	3	8	0	93

	0	1	2	3	4	5	6+	MD
%Right	24.0	45.8	15.6	6.2	1.0	3.1	4.2	0.0
Left	9.7	48.4	19.4	10.8	0.0	3.2	8.6	0.0

Mean Injury Level

Right Impact = 1.40

Left Impact = 1.87

Table 12

AIS (0-6+) for Side-Contact Right-Front Passengers, by Side of Impact

	0	1	2	3	4	5	6+	MD	N
#Right	5	13	7	3	2	0	5	0	35
Left	7	14	4	2	0	0	1	1	29

	0	1	2	3	4	5	6+	MD
%Right	14.3	37.1	20.0	8.6	5.7	0.0	14.3	0.0
Left	24.1	48.3	13.8	6.9	0.0	0.0	3.4	3.4

Mean Injury Level

Right Impact = 2.11

Left Impact = 1.21

The right-front passengers in the CPIR file tended to sustain more severe injuries when the impact occurred on the right side of their vehicle than when struck on the left. The mean injury severity for right-front occupants in vehicles struck on the right is 2.11 AIS units and 1.21 AIS units when in vehicles struck on the left side. Not surprisingly, the findings from this table and Table 11 indicate that the occupant tends to be injured more severely when the vehicle is struck on the side on which he is seated, than when it is struck on the opposite side. Hence, side of impact must be controlled upon in the later analyses.

The second factor which could potentially affect the injury level sustained by the occupant to be considered is seating location. Table 13 presents the frequency and proportion of injury severity values for drivers and right-front passengers.

Table 13

AIS (0-6+) for Side Contact Cases for Drivers and Right Front Occupants

#	0	1	2	3	4	5	6+	MD	N
RF	12	27	11	5	2	0	6	1	64
D	32	89	33	16	1	6	12	0	189

%	0	1	2	3	4	5	6+	MD
RF	18.8	42.2	17.2	7.8	3.1	0.0	9.4	1.6
D	16.9	47.1	17.5	8.5	0.5	3.2	6.3	0.0

Mean Injury Level

Right Front Passengers = 1.71

Drivers = 1.63

The table shows that the CPIR occupants in the right-front seat generally tended to sustain more severe injuries than did the drivers. The mean injury severity level for right-front passengers is 1.71 AIS units as compared with the mean of 1.63 AIS units found for drivers. This is in part due to the greater proportion of serious injuries sustained by right-front passengers when their vehicle was struck on that side than that sustained by drivers when their vehicle was struck on the left side. However, the data does indicate that seating location should be controlled when gauging the net effect of side guards on injury severity.

The final mitigating factor to be considered is restraint system use. A number of studies have shown that restraints generally exercise an injury reducing effect so this factor should be controlled (10). Tables 14 and 15 present the distribution of injury severity values for drivers and right-front passengers, respectively, according to restraint use and by the side of the vehicle struck in the crash. An occupant was defined as using a restraint if he wore either a lap belt or a torso device.

The tables suggest that restrained occupants in the CPIR file tended to sustain proportionately fewer severe injuries than unrestrained occupants. Drivers who wore a restraint had a mean injury level of about 0.50 AIS units lower than those without a restraint regardless of the side of impact. The difference in mean injury severity differed according to the side of impact for right-front passengers, but in either case, the use of a restraint markedly reduced the mean injury severity level. Although the number of cases in which the occupant used a restraint is too small for firm conclusions to be drawn, the patterns which emerge indicate that restraint usage should be controlled in the subsequent analyses.

The evidence reveals that a number of factors are associated with injury severity in the side-contact accidents recorded in the CPIR file. Occupants tend to be more seriously injured when their car is struck on the side by which they are sitting. In general, right-front passengers are more severely injured than are drivers. Also, restraining belts seem to reduce the incidence of serious injury to occupants in either seating location and with either left- or right- impact. This complexity influences the research strategy for assessing the effect of side-guard beams. Drivers and right-

Table 14

AIS (0-6+) for Side-Contact Drivers Controlling on Restraint System Usage by Side of Impact

Right Side Impact

#	0	1	2	3	4	5	6+	MD	N
Rest.	5	8	1	0	0	0	0	0	14
No Rest.	23	44	15	6	1	3	4	0	96

%	0	1	2	3	4	5	6+	MD
Rest.	35.7	57.1	7.1	0.0	0.0	0.0	0.0	0.0
No Rest.	24.0	45.8	15.6	6.2	1.0	3.1	4.2	0.0

Mean Injury Level

Restraint Used = 0.71

No Restraint Used = 1.20

Left Side Impact

#	0	1	2	3	4	5	6+	MD	N
Rest.	4	10	5	1	0	0	1	0	21
No Rest.	9	44	17	10	0	3	8	0	91

%	0	1	2	3	4	5	6+	MD
Rest.	19.0	47.6	23.8	4.8	0.0	0.0	4.8	0.0
No Rest.	9.9	48.4	18.7	11.0	0.0	3.3	8.8	0.0

Mean Injury Level

Restraint Used = 1.38

No Restraint Used = 1.88

Table 15

AIS (0-6+) for Side-Contact Right-Front Passengers
Controlling on Restraint System Usage by
Side of Impact

Right Side Impact

#	0	1	2	3	4	5	6+	MD	N
Rest.	2	2	1	0	0	0	1	0	6
No Rest.	5	13	7	3	2	0	5	0	35

%	0	1	2	3	4	5	6+	MD
Rest.	33.3	33.3	16.7	0.0	0.0	0.0	16.7	0.0
No Rest.	14.3	37.1	20.0	8.6	5.7	0.0	14.3	0.0

Mean Injury Level

Restraint Used = 1.67

No Restraint Used = 2.11

Left Side Impact

#	0	1	2	3	4	5	6+	MD	N
Rest.	3	2	0	0	0	0	0	0	5
No Rest.	7	14	4	2	0	0	1	1	29

%	0	1	2	3	4	5	6+	MD
Rest.	60.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
No Rest.	24.1	48.1	13.8	6.9	0.0	0.0	3.4	3.4

Mean Injury Level

Restraint Used = 0.40

No Restraint Used = 1.21

front passengers must be treated as separate groups because right-front passenger injury is on the whole more severe than that sustained by the driver. Moreover, the occupants should be further distinguished according to the side of impact because the injury level increases when the occupant is sitting on the side which is struck. Finally, any effect attributable to side-guards must be measured with seat belt usage controlled.

3.2.3 Side-Guard Beams and Injury Severity

The first examination of the effect of side-guards upon injury severity entails comparing the overall injury severity sustained by drivers of vehicles equipped with side-guard beams with the overall injury severity recorded for those drivers in vehicles without side-guards. This analysis controls on the side-of-impact factor by including only those drivers whose car was struck on the left side. Table 16 presents this information for the drivers of 1969-1973, 1970-1973, and 1971-1973 model vehicles. For the drivers in the 1969-1973 and 1970-1973 sets of model year cars, the mean injury value for those in vehicles without side beams is greater than those in vehicles with them. For drivers in 1971-1973 model cars, there is a slightly higher mean injury for those in cars with side guards than there is for those in cars without beams. However, none of these differences attains the 0.05 level of significance. One cannot, then, be confident that the observed differences in the mean injury severity for drivers which is associated with the side-guard beam did not occur by chance.

Table 17 contains the comparable injury severity information for right-front passengers in cars with and without side-guard beams. Only those right-front passengers whose vehicle was struck on the right side are included in the table. Due to the limited number of cases, these occupants are not further divided into sets according to the model year of their car. The table indicates that the mean injury level for right-front passengers in cars without a side-guard is considerably greater than that found for those in cars with the beams. However, the small number of cases available precludes a firm conclusion being drawn.

Table 16

Overall Injury Severity for CPIR Drivers Hit on Left Side Controlling for Side-Guard Beam

1969-1973 Model Year Vehicles

#	0	1	2	3	4	5	6+	MD	N
Without	5	25	10	6	0	2	5	0	53
With	3	15	6	4	0	1	2	0	76

%	0	1	2	3	4	5	6+	MD
Without	9.4	47.2	18.9	11.3	0.0	3.8	9.4	0.0
With	9.7	46.4	19.4	12.9	0.0	3.2	6.5	0.0

Mean Injury (0-6+)
Without Side-Guard = 1.94
With Side-Guard = 1.81

Significance
.71

1970-1973 Model Year Vehicles

#	0	1	2	3	4	5	6+	MD	N
Without	4	21	10	5	0	2	3	0	45
With	3	15	6	4	0	1	2	0	31

%	0	1	2	3	4	5	6+	MD
Without	8.9	46.7	22.2	11.1	0.0	4.4	6.7	0.0
With	9.7	48.4	19.4	12.9	0.0	3.2	6.5	0.0

Mean Injury (0-6+)
Without Side-Guard = 1.87
With Side-Guard = 1.81

Significance
.87

1971-1973 Model Year Vehicles

#	0	1	2	3	4	5	6+	MD	N
Without	3	12	6	3	0	2	3	0	29
With	0	5	3	3	0	1	1	0	13

%	0	1	2	3	4	5	6+	MD
Without	10.3	41.4	20.7	10.3	0.0	6.9	10.3	0.0
With	0.0	38.5	23.1	23.1	0.0	7.7	7.7	0.0

Mean Injury (0-6+)
Without Side-Guard = 2.10
With Side-Guard = 2.38

Significance
.63

Table 17

Overall Injury Severity for CPIR Right-Front Passengers Hit on Right Side Controlling for Side-Guard Beam

1969-1973 Model Year Cars

#	0	1	2	3	4	5	6+	MD	N
Without	2	6	4	1	1	0	5	0	19
With	3	5	2	2	1	0	0	0	13

Mean Injury (0-6+)	Significance
Without Side-Guard = 2.68	.09
With Side-Guard = 1.46	

However, analyzing the information contained in Tables 16 and 17 may not produce the most useful statistics for summarizing the association between the side-guard beam and injury severity. The maximum number of cases available for the analysis of the vulnerable occupants (those whose vehicle was struck on the side on which they were sitting) is 129 drivers and 32 right-front passengers. Measures of significance and association lose their capacity to discriminate when, as in this instance, the cases are distributed across a table containing many cells. Clearly, cutting the data further by side of impact or belt usage and analyzing it in tabular form severly reduces the utility of the analysis.

Incorporating the range of factors necessary for a thorough assessment of the effect of side-door beams on injury severity necessitates moving to mathematical models. These models allow for statistical controls on the important variables rather than the physical controls used in subsetting the cases into tabular form. The analysis does not suffer from the attrition in the number of cases which occurs when physical controls are imposed. That is, all of the cases with relevant information contribute to the statistics summarizing the effect of side-door beams which are derived from the mathematical models. The conclusions drawn from the analysis rest, then, on a far greater sample size and hence comprise more reliable estimates of the effects in which we are interested.

Accordingly, this phase of the analysis consists of a number of regression models which use the injury severity values recorded for the occupants as the dependent variable. (7) The models also include several independent variables--the one of primary interest being a dichotomous side-guard/no-side guard one. Other independent variables are used to measure the effects of the additional factors such as side of impact or use of restraint which seem to influence the injury level sustained by the occupant. Each occupant is assigned appropriate values for the various independent variables. For example, drivers receive a one and right-front occupants a zero for the seated location variable; occupants whose vehicles were struck on the left receive a zero and those whose cars were struck on the right a one for the "right-side impact" variable. By including these variables explicitly in the model, their effects on injury severity are measured at the same time that the effect of the side guard-no side guard variable is gauged. Thus, the analysis provides statistics summarizing the net effect of side-guard beams on occupant injury controlling for the influence of the other independent variables.

The regression models produce two important measures regarding the relationship between the independent variables and the dependent variable. First, the regression coefficient measures the functional relationship between an independent variable and the dependent variable. In this analysis, the regression coefficient guages the amount of change in the injury severity recorded for the CPIR file occupants associated with factors such as whether the person is driving or sitting in the right-front seat, or whether the vehicle is impacted from the left or right side, or whether the restraint is used or not. The coefficient, moreover, is subject to a significance test which indicates the degree of confidence one can have that a coefficient as large as the one found for the sample exists in the larger (and in this instance with the CPIR file, unknown) population. Second, the regression models produce partial correlation coefficients which measure the predictive association between each independent variable and the dependent variable. This statistic indicates the capacity of the independent variable to predict the variation in the dependent variable.

Both of these statistics provide valuable information for assessing the effect of side-guard beams on the level of injury sustained by the occupants.

The analysis begins with the basic case of side-guard beam and injury severity and moves progressively to more complex models incorporating additional variables. First, the injury severity variable is regressed on the dichotomous side-guard beam/no side-guard beam variable. If side-guard beams exercise a general effect on the severity of injury recorded for the CPIR occupants, then the regression coefficient should attain statistical significance. That is, the effect observable in the sample should be sufficiently large for one to conclude that it did not occur by chance, but instead, reflects an actual difference in the large accident population (of unknown dimensions) sampled by the CPIR file. Moreover, if side-guard beams exercise an important effect on injury severity levels, then the correlation coefficient between these two variables should reflect that a sizable amount of variance in the occupant injury severity variable is explained by the side-guard variable.

These regressions were conducted upon two sets of cases. The first consists of all drivers and right-front passengers whose accidents were investigated in the 1970-1973 period; the second consists of only those above drivers and right-front passengers who were sitting on the side of the vehicle which received the direct impact of the crash. Table 18 contains the results for the whole population being considered and table 19 contains the comparable results for the vulnerable sub-group.

Table 18

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity -- All Drivers and Right-Front Occupants

Occupants with:	Regression Coefficient	N	Signif- icance	Partial Correlation
1969-1973 Model	-0.05	230	.80	-.017
1970-1973 Model	0.17	198	.42	.058
1971-1973 Model	0.10	110	.72	.035

The table shows that there are only slight differences in the injury severity levels recorded for those occupants in vehicles which had side-guard beams as compared with those which did not have them. For those with 1969 through 1973 model year cars, the presence of side beams reduces the mean injury severity value by about 0.05 of an AIS unit. For occupants in 1970 through 1973 model cars, the mean injury level for people in vehicles with side-guards was 0.17 injury severity units greater than that for those without side beams. The occupants of 1971-1973 model year vehicles included in the file had a mean injury level 0.10 units greater if their cars had side-guard beams than if their cars did not. However, none of these differences in the mean injury level associated with the presence or absence of side beams attained the conventional 0.05 level of significance. One cannot, therefore, be confident that these observed differences are different from zero. Hence, one cannot conclude from these data that there is a measurable effect due to side-guard beams present in the population of accidents sampled by the CPIR file. Moreover, the power of the side guard variable to predict the person's recorded injury level is quite low for all three model year groups. The correlation coefficients assume trivial values indicating that very little of the variation in injury severity among all of the occupants is explained by the side-door beam variable.

When this regression model is applied to the group of occupants sitting on the side of the car that was struck - the vulnerable occupants - similar findings emerge.

Table 19

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity and Side of Impact -- Drivers Hit on Left Side and Right-Front Passengers Hit on Right Side

Occupants With:	Regression Coefficient	N	Significance	Partial Correlation
1969-1973 Models				
Side-Guard, Yes	-0.43	116	.19	-.123
1970-1973 Models				
Side-Guard, Yes	-0.20	100	.52	-.064
1971-1973 Models				
Side-Guard, Yes	0.01	56	.98	.003

The presence of side-guard beams is associated with a reduction in the mean injury level of occupants by 0.43 AIS units and 0.20 AIS units for people in 1969-1973 and 1970-1973 models, respectively. For those in the 1971-1973 model cars, there is an increase of 0.01 AIS units associated with side-guards. However, none of these effects is significant to the 0.05 level. The partial correlation coefficients further measure the low level of association--the amount of variance explained by the side-guard variable in the vulnerable population where the strongest correlation is found (the 1969-1973 model year set) is only 1.5%.

However, the greater injury severity sustained on the average by right-front passengers when compared with drivers observed in Table 13 may mask the effect of side-guard beams. Consequently, statistical controls were imposed upon the occupant's seated position in order to obtain a measure of the net effect of side-guards on injury severity. Two different techniques were used to control on seating location. The first approach entailed assigning each occupant to a group designating whether he was a driver or a right-front passenger. This dichotomous seating location variable (driver/right-front) was added to the regression model which contained the side-guard/no side-guard variable. These two independent variables were used to predict the occupant overall injury severity variable. The regression coefficient and the partial correlation coefficient produced by the regression model for the side door beam variable provide measures for the net effect of the beam on injury level with the occupant's seated location controlled. Table 20 contains the results of the analysis for all drivers and right-front passengers and table 21 contains the findings for the vulnerable occupants.

Table 20

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity Controlling for Seating Location -- All Drivers and Right-Front Passengers

Occupants With:	Regression Coefficient	N	Signif- icance	Partial Correlation
1969-1973 Models		230		
Side-Guard, Yes	-0.06		.79	-.017
Driver	-0.15		.53	-.042
1970-1973 Models		198		
Side-Guard, Yes	0.17		.42	.057
Driver	0.24		.32	.071
1971-1973 Models		110		
Side-Guard, Yes	0.10		.74	.032
Driver	0.39		.23	.116

The results of the analysis in table 20 also indicate that the side-guard variable has very little independent effect on the level of injury recorded for all of the occupants when seating location is controlled. Both the regression coefficients and partial correlation coefficients are virtually unchanged by the introduction of an explicit control on occupant seating location. (See table 18). The presence of side door beams reduces the mean injury level for the occupants of 1969 through 1973 model vehicles by 0.06 AIS units. The comparable effect for occupants of 1970-1973 and 1971-1973 model vehicles is to increase the injury level by 0.17 and 0.10 of an injury severity scale unit, respectively. None of these differences in mean injury severity attains the 0.05 level of significance. The trivial magnitude of the relationship between the side-guard variable and the occupant's recorded injury severity can also be seen in the small partial correlation coefficients produced by the model. The partial correlations for all three groups considered in the analysis indicate that less than one percent of the residual variance in the overall injury severity variable is explained by the side-guard beam variable.

The following table presents the results obtained from the regression analysis using only the vulnerable drivers and right-front passengers.

Table 21

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity Controlling for Seating Location and Side of Impact -- Drivers Hit on Left Side and Right-Front Passengers Hit on Right Side

Occupants With:	Repression Coefficients	N	Signif-icance	Partial Correlation
1969-1973 Models		116		
Side-Guard, Yes	-0.44		.18	-.126
Driver	-0.31		.39	-.081
1970-1973 Models		100		
Side-Guard, Yes	-0.19		.53	-.064
Driver	0.38		.28	.109
1971-1973 Models		56		
Side-Guard, Yes	0.20		.65	.062
Driver	1.23		.02	.323

The coefficients measuring the effect of side-beams do not markedly change with the addition of the seating location variable (see table 19). For occupants in 1969-1973 and 1970-1973 model year vehicles, the presence of side-guard beams are associated with a reduction in the mean injury level by 0.44 AIS units and 0.19 AIS units, respectively, with seated location controlled. Occupants in 1971-1973 models evidenced an increase in the mean injury severity of about 0.20 AIS units with side guards present and with seated position controlled. However, again, the coefficients for the side-guard variable do not attain statistical significance at the 0.05 level. The partial correlation coefficients indicate that very little variance in the injury severity variable is explained by the side-guard variable with seating location explicitly included in the regression model.

The final series of regressions controls on the restraint usage of the occupants. A dichotomous variable indicating whether the person wore a restraint (either a lap belt or a torso device) or was unrestrained was introduced into the regression model. Table 22 presents the results for all occupants.

Table 22

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity Controlling for Seating Location and Restraint Usage -- All Drivers and Right-Front Passengers

Occupants With:	Regression Coefficient	N	Signif-icance	Partial Correlation
1969-1973 Models		226		
Side-Guard, Yes	-0.07		.75	-.022
Driver	-0.11		.66	-.029
Restrained	-0.64		.02	-.151
1970-1973 Models		196		
Side-Guard, Yes	0.17		.42	.058
Driver	0.26		.28	.079
Restrained	-0.62		.02	-.163
1971-1973 Models		110		
Side-Guard, Yes	0.09		.76	.030
Driver	0.38		.24	.115
Restrained	-0.42		.25	-.112

The results of the analysis indicate that the side-guard variable does not exercise an important effect on the occupant's injury severity level with restraint usage controlled. The coefficient for all three sets of vehicle model years are about the same as when restraint system usage is not controlled. (See tables 18,20). None of the coefficients is statistically significant to the 0.05 level and the partial correlations again show that the side-guard beam variable predicts only a scant proportion of the variance in injury severity.

The following table contains the same analysis for the most vulnerable group of occupants and hence controls on side of impact.

Table 23

Regression Analysis of the Effect of Side-Guard Beams on Occupant Injury Severity Controlling for Seating Location and Restraint Usage -- Drivers Hit on Left Side and Right-Front Passengers Hit on Right Side

Occupants With:	Regression Coefficient	N	Signif-icance	Partial Correlation
1969-1973 Models		113		
Side-Guard, Yes	-0.48		.16	-.135
Driver	-0.23		.54	-.059
Restrained	-0.52		.20	-.123
1970-1973 Models		98		
Side-Guard, Yes	-0.20		.52	-.066
Driver	0.44		.22	.127
Restrained	-0.56		.13	-.154
1971-1973 Models		56		
Side-Guard, Yes	0.20		.66	.062
Driver	1.21		.02	.320
Restrained	-0.47		.34	-.131

Again, the coefficients for the side-guard beam variable do not markedly change with the explicit control on restraint system usage. (See tables 19,21) A reduction in the mean injury level of 0.48 AIS units is found for occupants in 1969-1973 vehicles equipped with side-guards, but this association is not statistically significant to the 0.05 level. Moreover, the coefficients decrease in magnitude with an increase in the modernity of the vehicles considered. The coefficient for the 1971-1973 set of cars indicates that side-guards are associated with an increase in the injury severity of the occupants, but this coefficient too, is not statistically significant. The CPIR data do not support the hypothesis that the side-guard beam exercises a consistent injury reduction effect.

3.3 Texas Data

3.3.1 Data

Comparable analyses were performed on an additional large accident data file which contains information useful for assessing the effect of side-guard beams on occupant injury. The file consists of a random sample (totalling 5%) of the accidents for the entire state of Texas which were recorded on police accident reports. The data are collected by the Texas Department of Public Safety; the sampling is performed by HSRI. This analysis uses the file containing the accidents reported in the 1972 calendar year.

The 5% sample file for Texas contains a variable which specifies the area of the vehicle which sustained the principal damage in the accident. This vehicle damage variable is derived from a TAD code recorded by the policeman investigating the accident (8). Only occupants who were in vehicles receiving damage to the left or right side of the passenger compartment are included in the analysis.

The injury severity variable for the occupants records the severity according to a four level scale (Killed, A,B,C) defined by the National Safety Council. A value is assigned to all occupants in a vehicle in which any one of them is injured or killed or if the damage to the vehicle attains the TAD level of five or more. Drivers and right-front passengers about whom injury information was recorded comprise the set of occupants included in this investigation.

3.3.2 Complicating Factors

The first step in the analysis consists of assessing whether the injury severity of the occupants in cars without side guards changes with the model year. If there is little difference in the distribution of injury severity values between newer and older vehicles, then, by including the older cars, a larger set of non-side-guard vehicles can be used in the analysis. Table 24 presents the mean AIS values for drivers according to the model year of the case vehicle. Comparable data for the right-front passengers are contained in table 25.

Table 24

Mean Injury Level Recorded for Drivers
Case Vehicle Model Year Categories

	Mean	N
1965-1973 Models	3.62	212
1967-1973 Models	3.60	149
1969-1973 Models	3.66	85

Table 25

Mean Injury Level Recorded for Right-Front Passengers
by Case Vehicle Model Year Categories

	Mean	N
1965-1973 Models	3.38	74
1967-1973 Models	3.57	49
1969-1973 Models	3.54	28

The tables indicate that there is very little variation in the mean injury level for drivers or right-front passengers across the selected groups of vehicle model years. As a result, it is not necessary to divide the cases by model year and the subsequent analyses use the occupants in 1965-1973 model year cars.

The second complicating factor to be assessed is the use of a restraint system. The following table presents the distribution of restraints for drivers and right front passengers according to whether their vehicle was equipped with side-guard beams.

Table 26

Distribution of Restraint Use and Presence of Side-Guard Beams

Drivers

		No Side-Guard	Side Guard
Frequency			
	Unrestrained	163	53
	Restrained	22	13
		185	66
Percent			
	Unrestrained	88.1	80.3
	Restrained	11.9	19.7
		100.0	100.0

Right Front-Passengers

		No Side-Guard	Side Guard
Frequency			
	Unrestrained	64	30
	Restrained	6	2
		70	32
Percent			
	Unrestrained	91.4	93.7
	Restrained	8.6	6.3
		100.0	100.0

The table indicates that there is a greater proportion of drivers in cars equipped with side guards who were using a restraint than of drivers in cars without side-guard beams. Consequently, a variable indicating whether the occupant used a lap belt was included in the subsequent analyses.

3.3.3 Side-Guard Beams and Injury Severity

The first step in the analysis consists of tabulating the distribution of injury severity values for the occupants according to whether their vehicle was or was not equipped with side-guard beams. Table 27 contains this information for drivers and table 28 contains it for right-front passengers. An injury value of 1 denotes killed and an injury value of 5 indicates no injury.

Table 27

Distribution of Injury Severity Levels for Drivers in Vehicles with and without Side-Guard Beams

	K	A	B	C	D	N
Number With:	(1)	(2)	(3)	(4)	(5)	
No Side-Guard	7	21	74	53	57	212
Side-Guard	1	9	23	22	19	74

	K	A	B	C	D
	(1)	(2)	(3)	(4)	(5)
Percent With:					
No Side-Guard	3.3	9.9	34.9	25.0	26.9
Side-Guard	1.4	12.2	31.1	29.7	25.7

Mean Injury Severity

	Mean	N	Significance
No Side-Guard	3.62	212	.79
Side-Guard	3.66	74	

Table 28

Distribution of Injury Severity Levels for Right-Front Passengers in Vehicles with and without Side-Guard Beams

	K (1)	A (2)	B (3)	C (4)	D (5)	N
Number With:						
No Side-Guard	3	10	26	26	9	74
Side-Guard	1	3	14	8	6	32

	K (1)	A (2)	B (3)	C (4)	D (5)
Percent With:					
No Side-Guard	4.1	13.5	35.1	35.1	12.2
Side-Guard	3.1	9.4	43.8	25.0	18.8

Mean Injury Severity

	Mean	N	Significance
No Side-Guard	3.38	74	.67
Side-Guard	3.47	32	

The tables show that there is a very slight reduction of injury associated with the presence of side-guards--0.04 for drivers and 0.09 for right-front passengers. However, none of these differences is statistically significant to the 0.05 level.

The second step entails controlling upon the occupant's use of a restraint system. The method used here applies a regression model which uses the occupant's injury severity as the dependent variable. The predictor variables are two dichotomous--one indicates whether the vehicle was or was not equipped with side-guard beams and the second codes whether the occupant wore or did not wear a restraint. Table 29 presents the results.

Table 29

Regression Analysis of the Effect of Side-Door Beams and Injury Severity Controlling for Use of Restraint

Variable	Regression Coefficient	N	Significance	Partial Correlation
	Drivers			
Side-Guard, Yes	0.10	251	.48	.045
Restrained, Yes	-0.01	251	.95	-.004
	Right Front Passengers			
Side-Guard, Yes	0.17	102	.42	.082
Restraint, Yes	0.70	102	.05	.192

The regression analysis supports the previous finding that the presence of a side-guard beam exercises only a negligible effect on the injury level recorded for the Texas sample file occupants. The regression coefficients for both drivers and right-front passengers indicate that the mean injury severity value for occupants with side-beams is reduced by 0.10 and 0.17 injury severity units, respectively, when restraint use is controlled. The significance level indicates that these differences cannot be imputed to the entire Texas accident population. Moreover, the correlation analysis corroborates the trivial degree of association--the side-guard variable explains less than 1% of the residual variance in the variable measuring the driver's and right front passengers' injury severity. We conclude that the Texas data do not support a contention that, in general, side-guard beams exercise an important injury reduction effect.

4. Side-Impact and Vehicle Deformation

The second part of the investigation is a determination of the effect of side-door beams on the amount of crush sustained by the door of a car. The underlying assumption is that the more the door is crushed, the more chance of injury or even serious injury to the occupants inside, both because there is a greater chance of the occupant's hitting the side, and because there is less of a chance of a glancing blow for the two vehicles.

The actual dependent variable selected is the maximum of V170 and V171 of the CPIR file, the amounts of sheet metal crush sustained by the left and right side of the car respectively. By considering only those cars where the major damage was to the door area, this should be a very good indication of the actual amount of intrusion into the doors.

Having decided on a measure of the effect of the side door beam, and a data file containing that measure, we next obtained the distributions of maximum crush for cars with and without side-door beams. The following table (30) describes these distributions and presents the results of a statistical test (t test) of the hypothesis that there is no difference in the mean crush occurring to these two classes of cars.

Although we note that in this particular sample there is actually a greater average crush to the doors of side-beam cars, because the chance that this difference could be due to random error is high (.50), we cannot conclude that this implies any difference between the amounts of crush sustained by the doors equipped with side beams and those without side beams.

However, such a broad look at the data can lead to erroneous statements, since there may be some extraneous factors whose effects are correlated with side beams. For example, if side-door beams were installed only in the so-called "muscle cars", we would very likely see a greater amount of door intrusion into these cars. Yet this result would not necessarily be because door beams are inherently detrimental, but rather because "muscle cars" are probably driven faster than other cars. This example is not the case, but it does point out that caution is needed when interpreting the data.

Table 30

Distribution of Maximum Crush to Side Beam
and Non-Side Beam Cars

		Side Beam		Non-Side Beam	
		Number	Percent	Number	Percent
Maximum crush to door (inches)	0- 5	7	10.76	7	7.87
	6-10	11	16.92	18	20.22
	11-15	13	20.00	30	33.71
	16-20	11	16.92	13	14.61
	21-25	10	15.38	10	11.24
	26-25	11	16.92	6	6.74
	31-35	0	0.00	2	2.25
	36-45	2	3.10	2	2.25
	41-45	0	0.00	1	1.12
	> 45	0	0.00	0	0.00
	Total	65		89	
	Ave. Crush	16.508		15.573	

Significance (Prob. that averages are equal) .5006

What factor or factors could possibly influence our results, then? One main factor immediately comes to mind - the component of the striking vehicle's energy directed into the door. If it could be shown that the distribution of this variable is the same for both the side beam and non-side beam populations, then the comparison of the maximum crush of the door between the two groups of cars could be interpreted as truly reflecting the influence of the side-door beam. Unfortunately, the value of this factor cannot be reconstructed from the data in the CPIR file. The variables most nearly related to this factor are the sum of the energies of the two most responsible vehicles in the accident (the striking vehicle and the struck vehicle), V537, and the clock direction of force, V137. The sum of energies variable is unusable, however, as its value depends on the investigator's estimate of the impact speeds, which is based in part on the amounts of crush sustained. In continuing with the analysis then, we make the assumption that this variable is equally distributed for side beam and non-side beam cars. This leaves clock direction of force as a surrogate for the angle, and hence the proportion of the energy of impact directed into (perpendicular to) the door. By demonstrating that this variable is independent of side beams we can have more assurance that our conclusions about side beams are valid.

Accordingly, we obtain distributions of the direction of force variable for side beam and non-side beam cars. These distributions are presented in Table 31, along with the results of a statistical test (Chi-square) of the hypothesis that these distributions are the same for side beam and non-side beam cars.

Table 31

Distributions of Angle of Force for Side Beam and Non-Side Beam Cars

		Side Beam		Non-Side Beam	
		Number	Percent	Number	Percent
Angle	15^o-45^o	7	10.4	8	9.0
of	46^o-75^o	45	67.2	59	66.3
Force	76^o-90^o	15	22.4	22	24.7
	Total	67	100.0	89	100.0

Prob. that Dist. are Equal .6838

We cannot conclude that there is any difference in the direction of the force applied to the doors of the two groups of cars. Although we can claim no bias with regard to angle of force, nevertheless it is prudent to control on this variable in our analyses, to make absolutely sure of no confounding influences.

One method of control is analysis of covariance. This is a statistical technique where regressions are run on different samples and tests of the equality of these regressions are made to see if they are the same for all samples. Thus we run regressions with maximum crush as the dependent variable and angle of force as the independent variable for side beam and no side beam cars. Table 32 presents the results of this analysis.

Table 32

Results of Analyses of Covariance with Maximum Crush as Dependent Variable for Side Beam and Non-Side Beam Cars

Direction of Force (1=15^o-45^o, 2=46^o-75^o, 3=76^o-90^o)

	Constant	Slope	Prob. that Slope=0	Prob. of = Slope
No Side Beam	13.848	.8126	.6110	.0659
Side Beam	5.7766	5.0914	.0033	

Notice that while there is a difference in the slopes, this difference does not attain statistical significance. Therefore, we cannot conclude that side door beams alter the relationship between the direction of force and the resultant crush to the door of a car.

As a final check of this contention, we obtain distributions of the maximum crush to the doors of the side beam and non-side beam cars at each value of the control variable. We also test the equality of the means of these distributions for the two classes of cars. The following table presents these results.

Table 33

Distributions of Maximum Crush for Side Beam and Non-Side Beam Cars at Each Value of Angle of Force

			Maximum Crush (inches)						
			0-10	11-20	21-30,	>30	total	ave	prob. ave =
Angle 15^o-45^o	Side Beam	Number	4	1	1	0	6	12.00	.7616
		Percent	67.0	16.7	16.7	0.0			
	No Side Beam	Number	4	2	2	0	8	13.38	
		Percent	50.0	25.0	25.0	0.0			

Table 33 (Continued)

			0-10	11-20	21-30	>30	total	ave	prob. ave =
Angle 46°-75°	Side Beam	Number	10	21	11	1	43	15.84	.9955
		Percent	23.25	48.84	25.58	2.33			
	No Side Beam	Number	14	32	9	3	58	15.83	
		Percent	24.14	55.17	15.52	5.17			

			0-10	11-20	21-30	>30	total	ave	prob. ave=
Angle 76°-90°	Side Beam	Number	3	2	9	1	15	21.13	.0601
		Percent	20.0	13.33	60.0	6.67			
	No Side Beam	Number	7	8	5	2	22	15.82	
		Percent	31.82	36.37	22.73	9.09			

The table indicates some differences between the amounts of crush sustained by the two classes of cars, notably for the near perpendicular hits. However, no difference attains significance. Therefore, the conclusion reached as a result of the analysis of covariance, that side door beams have not been shown to be effective in reducing the crush to a door, is reaffirmed. Note particularly the implications of this statement. We do not say that side beams never are beneficial. There may be specialized cases where side beams have a great effect. Too, they may be of very slight benefit in a large number of cases. All we can state with assurance is that they have not shown themselves to be of great enough benefit in a large enough number of cases.

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