U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

DOT HS 807 067
NHTSA Technical Report
February 1987

A Preliminary Evaluation of Seat Back Locks
for Two-Door Passenger Cars with Folding Front Seatbacks

Technical Report Documentation Page

1. Report No. DOT HS 807 067	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A PRELIMINARY EVALUATION OF SEAT BACK LOCKS for Two-Door Passenger Cars with Folding Front Seatbacks		5. Report Date February 1987 6. Performing Organization Code
7. Author(s) Charles J. Kahane, Ph.D.		8. Performing Organization Report No.
9. Performing Organization Name and Address Office of Standards Evaluation National Highway Traffic Safety Administration Washington, D.C. 20590		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation National Highway Traffic Safety Administration Washington, D.C. 20590		13. Type of Report and Period Covered NHTSA Technical Report 14. Sponsoring Agency Code

15. Supplementary Notes

An agency staff review of an existing Federal regulation performed in response to Executive Order 12291.

16. Abstract

Federal Motor Vehicle Safety Standard 207 specifies strength requirements for automotive seats and their attachment assemblies, so as to minimize the possibility of their failure by forces acting on them as a result of vehicle impact. The standard includes a requirement that front seats with folding seatbacks be equipped with a locking device, designed to limit the forward motion of the seatback in a collision and to keep the seatback away from front seat occupants. These seat back locks were installed in domestic two-door passenger cars during 1967-68. The objectives of this preliminary evaluation are to determine if seat back locks are effective in reducing deaths or injuries and to measure the actual cost of the locks. The evaluation is based on statistical analyses of Washington, Texas, New York, Fatal Accident Reporting System and Multidisciplinary Accident Investigation data (with special emphasis on back seat occupants, frontal crashes, and crashes involving occupant ejection or vehicle fire), sled test analyses and a cost study of production lock assemblies. It was found that the locks hold seatbacks in place in crashes when the back seat is unoccupied, but locks or other seat components often separate at moderate crash speeds when there are unrestrained back seat occupants. No statistically significant injury or fatality reductions were found for seat back locks in any of the accident data files or in the sled tests. The locks add about $14 (in 1985 dollars) to the lifetime cost of owning and operating a car.

17. Key Words seat back lock; seating system; back seat; sled test; ejection; crashworthiness; evaluation; fire; biomechanics; accident analysis; statistical analysis;		18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 253	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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LIST OF ABBREVIATIONS

ABC	police reported nonfatal injury severity scale
ACIR	Automotive Crash Injury Research
AIS	Abbreviated Injury Scale
AMC	American Motors Corporation
bleed.	bleeding
CDC	Collision Deformation Classification
Co.	Company
Corp.	Corporation
CPI	Consumer Price Index
CPIR	Collision Performance and Injury Report
CRASH	Computer Reconstruction of Accident Speeds on the Highway
Crit.	Criterion
CSI	Chest Severity Index
df	degrees of freedom
FARS	Fatal Accident Reporting System
fpc	finite population correction
g	unit of acceleration approximately equal to 32.2 ft/sec^2
GM	General Motors Corp.
HIC	Head Injury Criterion
HPR	High Penetration Resistant windshield
HSRI	Highway Safety Research Institute, now called UMTRI
HYGE	trade name for an accelerator sled
Inj.	Injury
Install.	Installation

KA, K + A	police-reported serious or fatal injuries
KAB, K + A + B	police-reported moderate, serious or fatal injuries
L	left
Lacerat.	Laceration
MDAI	Multidisciplinary Accident Investigation
mph	miles per hour
MSC	Mean Strain Criterion
MVMA	Motor Vehicle Manufacturers Association
MY	Model Year
NC	North Carolina
NCSS	National Crash Severity Study
NHTSA	National Highway Traffic Safety Administration
No.	number
NY	New York State
NYSICS	New York State Injury Coding System
Occ.	Occupants
R	right
Red.	Reduction
SAE	Society of Automotive Engineers
Sev.	Severity
SBL	Seat Back Locks
TAD	Traffic Accident Data project accident severity scale
TLI	Total Laceration Index
Tot.	total
unch.	unchanged
VIN	Vehicle Identification Number
Yrs.	Years

ACKNOWLEDGMENTS

Arnold Johnson developed and managed the sled testing project, which provided essential data for this evaluation as well as much insight on the performance of unrestrained dummies in frontal crashes. Larry Blincoe, Dan Cohen, Mark Edwards, Jerome Kossar, Sue Partyka, Rob Sherrer and John Van Dyke reviewed the manuscript and/or provided helpful suggestions on data sources and analysis methods. John Garrett, Ernie Grush, Marie Hansen, Richard Humphrey, Anil Khadilkar and Joseph C. Marsh IV provided information on seat and door installation methods, facilitated access to data files or explained details in the sled test procedure.

EXECUTIVE SUMMARY

Federal Motor Vehicle Safety Standard 207, which took effect for passenger cars on January 1, 1968, is one of the National Highway Traffic Safety Administration's initial vehicle regulations. It specifies strength requirements for automotive seats and their attachment assemblies, so as to "minimize the possibility of their failure by forces acting on them as a result of vehicle impact." Many of the specific requirements of Standard 207 are based on the Society of Automotive Engineers' Recommended Practice J879, which had already been in place since November 1963. The one significant difference between Standard 207 and Recommended Practice J879 - the one tangible modification of vehicle seating systems in model years 1967-68 - was the introduction of seat back locks in the folding front seatbacks of passenger cars with two doors.

In a two-door car without seat back locks, the seatback may fold over without restraint in a frontal crash and press on the backs of front seat occupants while they are impacting the steering assembly or instrument panel, possibly increasing the severity of those impacts. The purpose of seat back locks is to limit the forward motion of folding seatbacks in crashes and keep the seatback away from the front seat occupant at the time they impact the steering assembly or instrument panel. Seat back locks are potentially even more important when there are unrestrained back seat passengers in the car (although, actually, this is not a crash situation addressed by Standard 207). If the locks hold the seatback upright and in place, they can help prevent back seat passengers from being thrown into the front half of the compartment, where they might injure a front seat occupant, impact the windshield or instrument panel, or be ejected from the car through open doors or windows.

Current imports as well as older domestic cars have manually operated seat back locks which must be disengaged each time a back seat passenger enters or leaves the car. Current domestic vehicles have an automatic lock which allows the seatback to move freely except during impacts or other sudden decelerations. A possible side effect of manual seat back locks is that they might slow down back seat passengers' egress from the car in emergency situations such as fires or immersion in water.

Executive Order 12291 (February 1981) requires agencies to evaluate their existing regulations. The objectives of an evaluation are to determine the actual benefits - lives saved, injuries prevented, damage avoided - and costs of safety equipment installed in production vehicles in connection with a standard. This report is a preliminary evaluation of seat back locks for two-door passenger cars - i.e., the specific piece of safety equipment installed in connection with Standard 207.

The cost of seat back locks was estimated by analyzing the components of the locks that were actually installed in six production cars. It is estimated that manual seat back locks add $12.83 (in 1985 dollars) to the lifetime cost of purchasing and operating a two-door car. Automatic locks add $14.14 to lifetime cost. In 1985, 3.2 million two-door cars were sold with automatic locks and 1.3 million with manual locks; thus the total consumer cost of the locks was about $62 million.

The effectiveness of seat back locks was estimated by analyzing sled test results and highway accident data. There were 28 frontal sled tests with an average of three instrumented, unrestrained dummies per test: 14 runs with a seat assembly that included seat back locks and 14 matching runs under identical conditions and with the same type of seat, except that the locks were disabled to allow free movement of the seatback as in a pre-standard car. Well over a million accident cases from Washington State, Texas, New York, the Fatal Accident Reporting System, Multidisciplinary Accident Investigation and the National Crash Severity Study were statistically analyzed. The analysis strategy is to calculate the reduction in casualty risk in two-door cars in the model years immediately after the introduction of seat back locks; since many safety devices besides the locks were installed in those years, the reduction in the two-door cars is compared to the corresponding reduction in four-door cars of the same makes, models and model years. Since four-door cars received the same safety equipment as two-door cars except seat back locks, they act as a control group for the purpose of this evaluation. They are not always a perfect control group, as will be documented in the evaluation.

The effectiveness analysis addresses two questions. Do seat back locks prevent the loading of the seatback on the front seat occupants and retain back seat passengers within the rear half of the passenger compartment? Do seat back locks reduce deaths and injuries? The answer to the first question is fundamentally, "No." Specifically, when there are unrestrained back seat passengers, seat back locks or other seating system components were torn loose in every sled test at 26.5 mph and in a large percentage of frontal crashes of moderate severity on the Multidisciplinary Accident Investigation file:

Frontal Delta V (mph)	Percent of Cars with Seats Torn Loose
Less than 10	6
10-14.9	21
15-19.9	35
20-29.9	47
30 or more	88

At lower speeds, even when seating components were not torn loose, seatbacks were deflected forward to the point where they could not be relied on to keep back seat passengers in the rear half of the passenger compartment and away from front seat occupants. Seat back locks did perform better when the back seat was unoccupied: all seats remained intact in the sled tests, while 12 percent of seats tore loose at 20-25 mph and 26 percent at 25-30 mph in the accident file. Nevertheless, when the back seat is unoccupied, the sled tests showed that, even without seat back locks, the seatback only makes a minimal contribution to impact forces on front seat occupants.

Under these circumstances, it is unreasonable to expect seat back locks to have much effect on fatality or injury rates. Indeed, no significant casualty reduction was found in the sled tests or any of the accident data files, in spite of the large samples of data analyzed and the strenuous efforts to avoid biases in the analyses. Positive results were not obtained for any seating position (front seat occupants with nobody sitting behind them, front seat occupants with somebody sitting behind them, back seat passengers) or any specific injury type. No benefits were found in frontal crashes, or for restrained occupants, or unrestrained occupants.

One consistent statistical finding was that occupant ejection decreased dramatically in four-door cars in the model years that seat back locks were first installed in two-door cars, but that such a reduction did not take place in the two-door cars. Analyses of the National Crash Severity Study and the Multidisciplinary file suggest that these effects may largely if not entirely be due to changes in door locks and latches that merely coincided with the introduction of seat back locks. These door latch modifications greatly improved door integrity in crashes for four-door cars, but not for two-door cars. In other words, four-door cars are not an appropriate control group for the analysis of ejections. Nevertheless, the possibility cannot be ruled out that seat back locks may slightly increase front seat occupants' risk of ejection, because they prevent seatbacks from folding over and blocking avenues of ejection.

The Fatal Accident Reporting System data at least appear to be consistent with a tentative conclusion that manual seat back locks may quite possibly have increased the risk, as feared, of back seat passengers dying in vehicle fires, but the increase may have been offset by a decrease of front seat occupants' risk in those accidents. None of the results on vehicle fires, however, were statistically significant.

This evaluation is called a "preliminary" one because, statistically speaking, it is difficult to prove definitively that a safety device is not effective. That is because the absence of statistically significant positive findings does not constitute proof that a safety device is completely ineffective. There might still be some narrowly defined crash types where the locks are, in fact, beneficial but there are simply not enough data of that type of crash for a statistically meaningful effectiveness analysis. Specifically, it seems logical that SBL might be beneficial for children riding in the back seat in moderate speed frontal crashes (Delta V 20 mph or less): the SBL may withstand the relatively light impact load of a child and the seatback may retain the child within the safer rear half of the passenger compartment, whereas in a car without SBL, the child might be propelled over the folded seatback and contact the windshield, header, instrument panel or a front seat occupant. Even though the analyses of this evaluation do not show any fatality or injury reductions with SBL for child back seat occupants, the sample size for this limited crash situation is too small for the results to be convincing evidence that, in fact, SBL are not effective there. Similarly, it seems logical that SBL might account for a modest reduction of nonfatal injuries in low to moderate speed frontal crashes (Delta V 15 mph or so), especially when there are adults in the back seat; as above, the available data did not show a significant positive effect but do not preclude the possibility that there is, in fact, a modest positive effect. These crash situations could be possible topics for further study.

What has been accomplished, though, is that a large number of accident cases from various files were analyzed by techniques that are believed to be unbiased. If seat back locks had a positive overall effect even as small as a few percent, it should have appeared in at least some of the analyses, but no such effects were found. The frequent tearing loose of the locks at Delta V over 15 mph when there are back seat occupants and the minimal amelioration of occupant trajectories, as observed in the sled tests, even when the locks remain intact are important additional justifications for a preliminary conclusion, based on available data, that seat back locks have generally not been effective in reducing deaths or injuries.

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 Evaluation of NHTSA regulations and programs

Executive Order 12291, dated February 17, 1981, requires Federal agencies to perform evaluations of their existing regulations [9]. The evaluations should determine the actual costs and actual benefits of existing rules. More recently, Executive Order 12498, dated January 4, 1985, requires agencies to develop a regulatory planning process including publication of plans to review existing regulations pursuant to Executive Order 12291 [10].

The National Highway Traffic Safety Administration began to evaluate its existing Federal Motor Vehicle Safety Standards in 1975 [28]. Its goals have been to monitor the actual benefits and costs of safety equipment installed in production vehicles in response to standards. More generally, evaluations compare a standard's actual on-the-road performance and effectiveness with goals that may have been specified when the rule was initially promulgated - e.g., in its preamble, regulatory impact analysis, or other supporting documents - including analyses of possible benefits or impacts that had not been originally anticipated. The agency has published 14 comprehensive evaluations of safety standards or other vehicle programs to date. NHTSA intends to evaluate every one of its safety standards that can be associated with a tangible, clearly defined modification in production vehicles and whose costs and benefits can be measured by analyzing data on production vehicles.

1.2 Evaluation of Standard 207

Federal Motor Vehicle Safety Standard 207 specifies strength "requirements for automotive seats, their attachment assemblies, and their installation to minimize the possibility of their failure by forces acting on them as a result of vehicle impact [4]." It took effect for passenger cars on January 1, 1968 and for multipurpose passenger vehicles, trucks and buses on January 1, 1972. Standard 207 is essentially associated with one tangible vehicle modification: the introduction of seat back locks (SBL) in the folding front seatbacks of passenger cars with two doors. Moreover, Standard 207 requires SBL to withstand a force equal to 20 times the weight of the seatback, applied in a forward direction.

The other requirements of Standard 207 are largely based on SAE Recommended Practice J879 [40] pp. 954-955, which had been in place since November 1963. It required that the front seat must not become detached from the adjuster attachment bolts, the adjuster mechanisms must not separate and the seat adjusters must not become detached from the car's floorpan, when a static load of 20 times the weight of the seat assembly is applied in a forward or a rearward direction. It also required seatbacks to remain intact when subjected to a rearward moment of 4250 inch-pounds at each seating position, applied at the center of gravity of the seatback and calculated about the rear attachments of the seat frame to the seat adjusters. Standard 207 kept the requirements essentially without change. (The last requirement was reworded, however. The rearward moment was reduced to 3300 inch-pounds, but calculated about the seating reference points rather than the rear attachments of the seat frame to the seat adjusters. Since the distance between the height of the applied load and the axis about which the moment is calculated is less in Standard 207 thah in the SAE practice, a smaller bending moment is created even though the same force level is applied. In July 1968, after Standard 207 took effect, the SAE revised Recommended Practice J879 and issued J879b, making it consistent with the NHTSA standard, including the SBL requirement [39].) A NHTSA contractor examined seating systems of 12 domestic cars from model year 1969, especially the adjuster mechanisms and tracks and the portion of the floorpan where the tracks are attached, and concluded that no reinforcements were made in those structures in response to Standard 207 [20], p. 16. The conclusion has to be viewed with a degree of caution because the contractor did not examine pre-Standard 207 vehicles for comparison, nor imported cars which, perhaps, might not have followed the SAE practice before Standard 207. Nevertheless, the preponderant evidence suggests that the only tangible car seat modification in the 1966-69 era (other than head restraints) was the introduction of SBL in the folding seatbacks of two door cars. An evaluation of Standard 207 is primarily an evaluation of SBL.

1.3 Why evaluate seat back locks?

Although SBL are not as prominent as some other safety modifications since 1960, they meet the criteria for NHTSA evaluations. They are a well defined piece of safety equipment, added at a specific, known date to a particular group of passenger cars - see Section 1.4. There is no problem, unlike with many of the safety standards, of determining "if" something was done to cars and if so, "what" and "when"? SBL had significant, measurable cost, adding $12-15 to the lifetime cost of a 2 door car

- see Section 1.5. The price of SBL per car easily exceeds the incremental cost of High Penetration Resistant windshields over pre-Standard glazing [27], pp. 222-223, and is comparable to energy absorbing steering columns [23], pp. 119-129. In addition to raising costs, the manually operated SBL that were originally used in cars had a small but evident effect on vehicle performance as perceived by consumers: they had to disengage the locks before they could get into or out of the back seat. NHTSA does not possess survey data indicating vehicle owners' attitudes toward the locks. The domestic manufacturers' subsequent shift to automatic inertial SBL (see Section 1.4) could be a sign, however, that owners complained about having to operate the locks manually.

The potential benefits of SBL, like the costs, are capable of being quantified and evaluated. Specific hypotheses can be formulated about the effect of SBL on occupant kinematics and injury risk - see Section 1.6. The hypotheses can be tested experimentally by running sled tests with and without SBL or by analyzing accident data: here, the fact that SBL were introduced only in 2 door cars makes it possible to use 4 door cars as a control group and compare the casualty reduction in 2 door cars (post vs. pre-Standard 207) to the reduction in 4 door cars. Finally, the evaluation is needed because, to date, there has been only one study [2] of the effectiveness of SBL and it did not have clear-cut results - see Section 1.8.

1.4 SBL implementation dates

Costenoble reported in 1978 that SBL were introduced in all

General Motors 2 door cars in model year 1967 and in the other domestic cars in model year 1968 [7], pp. 49-50. She also stated that many imported cars contained SBL before Standard 207 took effect, including Volkswagen and Opel by 1966 and Fiat, Renault, Datsun and Sunbeam by 1967. These statements were recently checked with Multidisciplinary Accident Investigation (MDAI) data, by tabulation of the variables "left/right front seat back locks equipped" against model year. The MDAI data confirmed that SBL were implemented at GM in 1967 and Ford and Chrysler in 1968. The sample was too small for clear results on American Motors or imported cars. AMC and imports are excluded from the accident data analyses of Chapters 3-5 for that reason and also because most imports of the mid to late 1960's were 2 door cars and there would not be an adequate sample of control group vehicles (4 door cars) for comparison purposes.

At first all SBL were of the manual type. Persons desiring to enter the back seat of a 2 door car could not fold over the front seatback until they disengaged the lock by operating a lever or pressing a button. Circa 1980, the domestic manufacturers switched to automatic inertial SBL, which operate much like inertial safety belt retractors. The front seatback folds over freely as in a pre-SBL car except during the moments when the car is subjected to decelerations by impacts, road bumps or emergency braking. The major importers continued to use manual SBL through 1986 [3].

The accident data analyses of this evaluation are all based on cars with manual SBL, produced during the first 4 model years after the SBL implementation date (1967-70 for GM and 1968-71 for Ford and Chrysler). The sled tests used front seats from Chevrolet Citations, which had automatic SBL (although the inertial actuation device was bypassed for the tests). Thus, both types of SBL were studied in the evaluation.

1.5 Costs of SBL

The cost of manual SBL was analyzed by a NHTSA contractor in 1979 [20] and the cost of automatic inertial SBL, by another contractor in 1986 [3]. The contractors calculated the weight added to cars by SBL and the "purchase price increase," which is based on the value of materials, labor, tooling, assembly, overhead, manufacturer's and dealer's markups and taxes. The results in [20] for four manual SBL are:

	Weight (pounds)	Purchase Price Increase (1979 Dollars)
69 Ford Mustang	2.95	6.46
69 Ford Thunderbird	3.32	7.34
69 Chevrolet Nova	2.93	9.84
69 Pontiac Firebird	1.10 on p. 18, 1.89 on p. A-3	2.67

The results for the first three cars are reasonable and consistent, especially since the Mustang had a simpler lever for operating the SBL than did the Thunderbird and Nova, as evidenced by the photographs in [20]. The much lower results for the Firebird are anomalous, especially since the photographs suggest it had almost the same hardware as the Mustang; in addition, the report gives two conflicting values for added weight, as noted above. It is possible that the cost estimates for the Firebird were incorrectly calculated or transcribed in several categories. Only the results for the first 3 vehicles are used here for computing the average. The contractor's cost estimates in 1979 dollars can be converted to 1985 prices by multiplying them by 1.30, the Consumer Price Index (CPI) multiplier for new cars. Each pound of weight added to a car results in a 1.17 gallon increase in the lifetime fuel consumption of a car [11]. The net present value of the increase in fuel consumption is $0.72 for each pound of weight added to the car [11]. The lifetime cost for the manual SBL in 1985 dollars is:

	Weight (pounds)	Purchase Price Increase (1985 $)	Lifetime Cost Increase (1985 $)
69 Ford Mustang	2.95	8.40	10.89
69 Ford Thunderbird	3.32	9.54	12.34
69 Chevrolet Nova	2.93	12.79	15.26
AVERAGE	3.07	$10.24	$12.83

Weights and price increases were estimated for automatic inertial SBL in 3 model year 1986 cars, one from each of the large domestic manufacturers [3]. The results are highly consistent. The amounts in [3] are stated in 1984 prices. Here, they are converted to 1985 prices by a CPI multiplier of 1.03:

	Weight (pounds)	Purchase Price Increase (1985 $)	Lifetime Cost Increase (1985 $)
86 Chevrolet Camaro	3.95	10.41	13.74
86 Dodge 400	3.84	10.32	13.55
86 Ford Tempo	4.08	11.70	15.14
AVERAGE	3.96	$10.81	$14.14

It can be concluded with confidence that the lifetime cost per car of SBL of either type is not far from $13, since the six cars above had fairly similar costs. On the other hand, it cannot be concluded with confidence that automatic SBL are more expensive than manual, since the observed average difference ($1.31) is small compared to the variation within each type, given the small and not completely representative samples of cars of each type and the possibility of differences in the cost estimation methods of the two contractors.

The total annual cost of SBL in the United States is obtained by multiplying sales of 2 door cars by the cost per car. The calculation is performed separately for domestic vehicles, which use automatic SBL and imports, which have manual SBL. In 1985, 8 million North American cars were sold in the United States. The proportion of domestic cars with 2 doors has remained at 40 percent since 1982 [45], [46], [47]. In 1985, 2.8 million cars were imported from overseas. The proportion of imports with 2 doors has remained at 47 percent since 1983 [45], [46], [47]. Thus, the total annual cost of SBL is:

	Cars Sold	Percent with 2 Doors	2 Door Cars Sold	Cost per Car	Total Cost
Domestic	8,000,000	40	3,200,000	$14.14	$45.2 M
Imported	2,800,000	47	1,316,000	$12.83	$16.9 M
				TOTAL (1985 $)	$62.1 million

1.6 Potential benefits of SBL

Many of the potential benefits that occupants could obtain from

SBL are outlined in a 1969 paper by Severy, Brink, Baird and Blaisdell [42], pp. 323-325. In a 2 door car without SBL, the folding front seatback can move forward without restraint, especially in a frontal crash. The load of the seatback is added to the weight of front seat occupants as they contact structures at the front of the passenger compartment, increasing the severity of those contacts. "Effective latching [of the seatback by SBL] for the front seat occupants relieves them of seatback inertial loading that might be derived from the hinged backrest as it abruptly shifts forward during impact, pressed against their backs." SBL are of potentially even greater value when there are unrestrained back seat passengers as well as front seat occupants. It should be noted, though, that the preamble of Standard 207 does not explicitly claim benefits for SBL in this situation, nor does the standard itself contain tests simulating a crash where the back seat is occupied. In a car without SBL, the back seat passenger will move forward with the seatback and the combined load will be applied to the front seat occupant, magnifying the effect described above. Even worse, as the seatback tips over forwards, it can act as a ramp for the back seat passenger, who will then vault head first into the front half of the passenger compartment, contacting structures in that area or making head to head impacts with front seat occupants. According to Severy, "Effective latching of hinged seatbacks provides protection for unbelted rear seat passengers, preventing them from being ramped against front seat occupants or into the windshield or header."

The potential benefits of SBL, then, include a reduction of thoracic injuries in frontal crashes for front seat occupants with nobody sitting behind them; a larger reduction of such injuries for front seat occupants with somebody sitting behind them; and a significant reduction of head injuries for front seat occupants with somebody sitting behind them and for back seat passengers. It would be appropriate to perform separate analyses for the three types of occupants (front seat with nobody behind them, front seat with somebody behind them, back seat) since different hypotheses apply to each group.

Severy et al add an important caveat to their list of potential benefits: the SBL must perform in crashes up to a reasonably high level of severity. If the SBL separate during the impact or even if they hold together but allow large amounts of forward deflection of the seatback, they will not prevent seatback loads on the front seat occupant or ramping by back seat passengers. The actual requirements of Standard 207 must be examined in this context. The standard requires SBL to remain intact when exposed to a load of 20 times the weight of the seatback. In frontal crashes with an unoccupied back seat, that load is produced by a deceleration of 20 g's, a level that typically occurs in frontal crashes with Delta V of, say, 25-35 mph - a high level of severity for an unrestrained occupant. But when there are one or more back seat occupants, the level of protection set by Standard 207 is much lower. Typical values for the weight of a seatback are 26 pounds for a 1980 Chevrolet Citation [16], pp. A-28 - A-30 and 36 pounds for a 1981 Plymouth Reliant [17], pp. A-29 - A-32. If a back seat occupant weighs 150 pounds, the combined load of the seatback and the back seat occupant will exceed 20 times the weight of the seatback at deceleration levels well below 10 g's. Unless the SBL actually installed in vehicles far exceed the standard's minimum requirements, SBL separation can be expected at crash severities well below those that are dangerous for unrestrained occupants. Moreover, Standard 207 only requires that seat components remain intact, allowing an unlimited amount of seatback deformation which, as stated above, could defeat the potential advantage of SBL. For these reasons, Severy et al believed that Standard 207 should have much higher test loads (e.g. application of a bending moment of 100,000 inch-pounds rather than 3,300) and a limitation on the amount of deflection that is allowed in the tests [42], p. 325.

SBL could have additional effects, not necessarily positive, in two specific accident situations: fire/immersion and occupant ejection from the vehicle. In an emergency egress situation, such as a fire or immersion in water, the back seat occupant of a 2 door car has a difficult task of getting out of the car: waiting, if necessary, for the front seat occupants to exit, folding over the seatback and leaving by the front door. Ball presented the hypothesis that manual SBL could further complicate the process, since the back seat occupant must remember to release them [2]. Moreover, on many cars it is impossible to disengage the SBL while someone presses the seatback forward, as is likely to happen to a person who is in a panic to leave the car. Thus, manual SBL might increase the likelihood of a back seat passenger burning or drowning. Automatic inertial SBL would not have that shortcoming, since the seatback moves freely except during an impact. On the other hand, the SBL could help a front seat occupant exit more rapidly: it might hold seatbacks in place and enable the occupant to get to the door immediately, rather than having to push the seatback out of the way or extricate himself from being pinned under the seatback or a back seat passenger. Intuitively, the positive effect for the front seat occupant seems much smaller than the negative one for the back seat passenger - but that might be compensated for by the much higher occupancy rate of the front seat.

The logic for occupant ejection is the reverse. Occupants are burned or drowned when they cannot exit the vehicle quickly enough, whereas an ejectee is one who is caused to exit the vehicle too quickly. A seatback held upright by SBL could act as a barrier between back seat occupants and front doors or glazing. But front seat occupants might fare better without SBL, since the pressure of the unrestrained seatback on their backs could hold them away from open doors, while a folded over seatback on the opposite side of the car could act as a barrier between them and the door on the opposite side. Here, unlike fires and immersions, there ought to be no difference between manual and automatic SBL, since the phenomena take place during an impact. Intuitively, any negative effects for the front seat occupant would probably be small, since the seatback is unlikely to press on the front seat occupant or remain folded over for a large proportion of the impact sequence. If the data analyses show large negative "effects" on occupant ejection risk, it is appropriate to suspect that something other than SBL is to blame.

1.7 Evaluation methods and their limitations

The principal difficulty in evaluating SBL is that the potential benefits, as described in the preceding section, are not likely to be large in absolute terms and therefore not easy to measure in a statistically reliable way. There are some safety devices (e.g., adhesive bonding of the windshield [27]) whose benefits, although not large in absolute terms, are relatively great and readily measurable in one or two specific crash situations. Unfortunately, SBL are not in that category.

The difficulty is compounded in analyses of highway accident data by the fact that many important crash protection devices were introduced at the same time, or nearly the same time as SBL:

HPR windshields	1966
padded instrument panels [26], p.123	1966-68
energy absorbing steering assemblies	1967-68
SBL	1967-68
improved door latches [14]	1967-68
head restraints [24], p. 104	1967-69
shoulder belts	1968

How is the effect of SBL to be distinguished among the effects of the other devices?

The approach used throughout the evaluation is to use <u>control</u> groups or controlled experiments as much as feasible. In the sled tests of Chapter 2, two identical series of sled test are run: one with a sled buck containing seats equipped with SBL, the other with the same sled buck, except that the SBL are disengaged and the seat can fold over freely. In the accident data analyses of Chapters 3, 4 and 5, cars with 4 doors are used as the control group. That approach, originally developed by Ball [2], is based on the <u>fact</u> that all the safety standards of the

1960's, except SBL, were implemented in 4 door cars at the same time as in 2 door cars - and the assumption that the relative effect of all the safety standards, except SBL, is the same in 4 door cars as in 2 door cars. Thus, the net effectiveness of SBL is the amount by which the casualty reduction in 2 door cars (post vs. pre-SBL) exceeds the reduction in 4 door cars (after vs. before the date of SBL implementation in 2 door cars of the same make and model). Unfortunately, the assumption that the effects of the other standards is the same in 4 door and 2 door cars is not foreordained to be valid and, specifically, will be shown incorrect in the case of the door latch improvements (see Section 5.3). Moreover, the analyses can be biased by the market shift that took place in the years just before and after SBL: 2 door cars accounted for 41 percent of sales in 1963 [50] and 55 percent in 1971 [48]. If the growth in 2 door car sales was comprised especially of younger, less experienced drivers who had more severe crashes, the casualty rate comparison could be biased against 2 door cars and SBL. Section 3.1 describes the additional analysis techniques aimed at identifying and removing those kinds of bias.

Another guideline for the analysis is that it should conform to the hypotheses on effectiveness stated in Section 1.6. For example, since SBL may have different effects for front seat occupants with nobody sitting behind them, front seat occupants with somebody behind them and back seat passengers, separate analyses should be performed for the three types of occupants. Crashes with fires or ejections should be analyzed separately to test the hypotheses in Section 1.6. The sled test films and accelerometer data are reviewed in detail in Section 2.2 to see if SBL have the specific effects on occupant kinematics that were proposed by Severy et al [42]. Severy also warned that the minimum strength requirements of Standard 207 are too low to assure seating system integrity in moderately severe crashes; the actual performance of SBL will be observed in sled tests (Section 2.2) and accident data (Section 5.4) to test the validity of Severy's concerns.

This preliminary evaluation analyzes numerous sled tests and over a million accident cases, but none of the data showed significant benefits for SBL. Statistically, it is easy to prove definitively that a safety device is effective but difficult to prove that it is not. That is because statistical methods typically test a null hypothesis that a safety device is not effective. If the statistically significant positive effects are found, the null hypothesis is rejected - i.e., there is convincing evidence that the safety device is effective. But the lack of statistically significant positive results is not, by itself, convincing evidence that the null hypothesis is true and the device is not effective. For that reason, this study, none of whose results show effectiveness, is called a "preliminary" evaluation. There might still be some limited, narrowly defined portion of the crash environment where SBL are, in fact, beneficial, but there are simply not enough data of that type of crash for a statistically meaningful effectiveness analysis. Specifically, it seems logical that SBL might be beneficial for children riding in the back seat in moderate speed frontal crashes: the SBL may withstand the relatively light impact load of a child (see Table 5-4) and the seatback may retain the child within the safer rear half of the passenger compartment, whereas in a car without SBL, the child might be propelled over the folded seatback and contact the windshield, header, instrument panel or a front seat occupant. Even though the analyses of this evaluation do not show any fatality or injury reductions with SBL for child back seat occupants, the sample size for this limited crash situation is too small for the results to be convincing evidence that, in fact, SBL are not effective there. Similarly, it seems logical that SBL might account for a modest reduction of nonfatal injuries in low to moderate speed frontal crashes (Delta V 15 mph or so), especially when there are adults in the back seat; as above, the available data did not show a significant positive effect but do not preclude the possibility that there is, in fact, a modest positive effect. These crash situations could be possible topics for further study. Nevertheless, the data make a strong case that SBL have little or no overall effect:

- o The sled tests showed that SBL definitely modified occupant kinematics, but not in a way that would reduce injuries significantly, primarily because seatbacks are substantially deflected even with SBL.
- o Accident data showed that SBL or other seat components separate even in medium severity crashes when there are back seat occupants. Thus, as Severy feared, SBL have limited effectiveness in the type of crashes where they might have been most useful.
- o A massive amount of accident data was analyzed by techniques that are believed to be unbiased. If SBL had a positive effect even as small as a few percent, it should have appeared in at least some of the analyses, but no such effects were found.

The most prominent effect seen in the accident data was a dramatic reduction of occupant ejection in 4 door cars at the time that

SBL were introduced in 2 door cars, but no comparable reduction in the 2 door cars - suggesting, at first glance, a strong negative "effect" for SBL. The data in Section 5.3 make a rather convincing case that the phenomenon is primarily if not entirely due to factors other than SBL. Nevertheless, the possibility cannot be ruled out that SBL may have had a slight negative effect on ejection.

The sample size of crashes involving fires was too small for definitive, statistically significant results. The data at least appear to be consistent with a tentative conclusion that SBL increased the risk of fire fatalities in the back seat, while possibly reducing them in the front seat, consistent with the hypotheses in Section 1.6.

1.8 Review of Ball's study of SBL

The only previous statistical analysis of accident data pertaining to SBL was performed in 1980 by Ball et al under a contract sponsored by NHTSA's Office of Program Evaluation and managed by Kahane [2]. It is based on statistical analyses of State accident files from Texas (1972-74), North Carolina (1973-75) and New York (1974). Records were extracted for drivers of any domestic 2 door or 4 door passenger car of any known model year involved in a frontal crash. The cases were initially cross-tabulated by number of doors (2 vs. 4), pre vs. post SBL implementation date, and injury severity (police reported K + A vs. B + C + uninjured, or K + A + B vs. C + uninjured, or any injury vs. uninjured). Injury rates were computed for the 2 door cars, pre and post-SBL and for the 4 door cars (the control group) before vs. after the implementation date for SBL in 2 door cars of the same makes and models. The effectiveness of SBL was defined the same way as in Section 3.1.1 of this report:

$$\text{effectiveness} = 1 - \left(\frac{\text{inj. rate, 2 dr., post}}{\text{inj. rate, 2 door, pre}}\right) / \left(\frac{\text{inj. rate, 4 dr., post}}{\text{inj. rate, 4 door, pre}}\right)$$

The resulting effectiveness estimates [2], p. 2-4, were:

State	Calendar Year	Net Inj. Red. for SBL (%) K + A	K+A+B	Any Injury
TX	1972	+5	-3	-2
	1973	-7	-1	+1
	1974	-3	-16	-13
NY	1974	-27	-15	-8
NC	1973	-50	-7	-10
	1974	-29	-27	-19
	1975	+20	+12	+1

Sixteen of the 21 observed effectiveness values are negative, suggesting at first glance that SBL significantly increased injury risk. Since the calculations are based on cars of all ages, however, they may be biased, especially, by the market shift from 4 to 2 door cars that took place in the years just before and after SBL (see Section 1.7). If the growth in 2 door car sales was comprised especially of younger, less experienced drivers who had more severe crashes, the casualty rate comparison could be biased against 2 door cars and SBL. More generally, with so many model years of cars included in the calculations and with so many things besides SBL happening to cars over those years, it is difficult to believe that the observed effects are really due to SBL.

Ball acknowledged the possibility of biases in the results and attempted to control for them by using control variables such as driver age, crash mode, roadway type, damage severity, vehicle manufacturer or vehicle weight, as suggested by Kahane, the contract manager. Essentially, separate analyses were performed for each combination of values of the selected control variables and the results averaged. The use of control variables did control for a small portion of the biases and resulted, on the average, in just slightly less negative effectiveness estimates [2], p. 2-5:

State	Calendar Year	Net Inj. Red. for SBL (%) (Adjusted by Control Variables) K + A	K+A+B	Any Injury
TX	1972	+5	-1	-2
	1973	-13	-4	-1
	1974	+2	-10	-8
NY	1974	-18	-12	-7
NC	1973	-44	-4	-8
	1974	-19	-20	-15
	1975	+27	+15	+6

The differences between the adjusted results and the earlier table of simple effectiveness estimates is usually not more than a few percent. Just as before, 16 of the 21 effectiveness estimates are negative, suggesting that SBL significantly increased injury risk.

These negative results cannot be accepted as valid because it is not evident that the use of control variables successfully removed the biases. In 1980, control variables were considered a good way to adjust data files (as, indeed, they are in the case of detailed NHTSA accident files such as the National Crash Severity Study - see, for example, the evaluations of energy absorbing steering assemblies [23], pp. 164-193, and side door beams [26], pp. 183-252). Subsequent experience showed that control variables are not useful for removing biases in State accident files. NHTSA's 1982 evaluation of head restraints [24], Sections 5.3 and 5.6, provided insights on analysis of State data. It showed that the use of a wide range of model years creates a risk of vehicle age related biases and that, with State data, control variables only remove a minimal portion of the vehicle age biases. Instead, the most suitable control techniques with State data are to restrict the range of model years as much as possible (as in Section 5.6.2 of [24]) or to perform regressions (as in Section 5.6.3 of [24]). An especially satisfactory technique for controlling vehicle age biases in large State data files is to limit the analysis to cars built just one model year before or after the implementation of the safety device, then expand it to 2 model years before and after, then ±3 and ±4 model years, generating a sequence of effectiveness estimates. This year by year approach was developed in the 1983 evaluation of side marker lamps [25] and again applied in studying windshield modifications [27]. It is the critical difference between Ball's analyses and the work in Chapters 3 and 4 of this report, some of which covers the same data files used by Ball.

CHAPTER 2

STATISTICAL ANALYSES OF SLED TEST DATA

The most precise way to determine if seat back locks (SBL) are effective in crashes is to compare the occupant injury experience in a car with SBL to the experience of identical occupants in an identical car - except that this car does not have SBL - in an identical crash situation. Only in the laboratory, with simulated crashes and anthropomorphic dummies, can such a close match be obtained. A NHTSA contractor performed 14 frontal sled tests with a sled buck that simulated the passenger compartment of a 1981 Chevrolet Citation with operational SBL [34], [35], [36], [43]. Speeds ranged from 15 to 30 mph. The sled bucks were occupied by 2 to 4 unrestrained 50th percentile Part 572 dummies. The contractor performed 14 other sled tests that were identical in every respect - speed, crash pulse, dummy positioning - except that the SBLs were removed to allow the seatbacks to pivot freely in the crash, simulating a pre-Standard 207 car. The injury predictions for the 42 dummies in the cars with SBL were compared to the values for the corresponding dummies in the cars without SBL. No statistically significant differences (two-sided alpha = .05) were found for any of the injury criteria.

2.1 Planning and running the sled tests

The principal guideline for the sled testing program was to obtain matching pairs of crashes, identical in all respects except that one of them was with SBL and the other without them. Every precaution had to be taken to avoid sources of variation other than the presence/absence of SBL.

2.1.1 Sled buck, test setup and crash modes

The sled buck had to be the passenger compartment of a passenger car, in order that the dummies' injury measurements realistically simulate the injury producing contacts experienced by car passengers in highway accidents. One possibility would have been to construct a non-SBL sled buck from a pre-Standard 207 car and an SBL-equipped sled buck from a post-Standard 207 car. That approach had to be rejected because it was inconsistent with the principal guideline: there are many differences between pre and post-Standard 207 cars besides SBL (e.g., energy-absorbing steering columns were introduced in most cars at the same time as SBL). Instead, a single sled buck was constructed from a post-standard, SBL equipped passenger car and the non-SBL tests were run with the same buck, but after disabling the locks so that the seatback would pivot freely in the crash. It would have been desirable to build sled bucks from a representative selection of passenger cars, but that would have been well beyond the scope of available resources. Instead, a single buck was developed from a 1981 Chevrolet Citation sedan with a split-bench front seat. The 1981 Citation is equipped with automatic inertial SBL (see Section 1.4). Since it was unknown whether the crash sensing device would respond in a sled test as it does in a real crash, the contractor bypassed the emergency locking device and assured that the seats were locked from the start, in those tests that were to be run with functioning SBL. The Citation was close to the median - in terms of mass, interior room and component stiffness - among cars produced and sold in the United States at the time of the sled test study (1984-85). The passenger compartment structure was severed from the hood and trunk regions and mounted on the sled as described in [32], pp. 10-12.

The sled itself was of the decelerator type. The sled buck was gradually accelerated to the desired impact speed by pneumatic pistons. The crash event was then simulated by allowing the sled buck to be stopped by a system of steel bands and rollers programmed to deform at a rate which reproduces the deceleration pulse seen in vehicle-to-barrier impacts. Although this type of sled will generally not have the same level of repeatability of crash pulses as a HYGE (accelerator) sled, the contractor achieved an acceptable repeatability: peak sled g's had a 3 percent coefficient of variation, at any given sled speed, throughout the project. That is as good as what has been achieved in some projects with HYGE sleds [30]. It is also a negligible source of variation compared to other factors affecting injury criteria in this study.

The study was limited to frontal and frontal-oblique impacts because they were believed to be the type of crash where SBL are most likely to be of value (see Section 1.6). The limitation to frontal crashes made it possible to seat up to 4 unrestrained dummies in the sled buck on each test, 2 in the front and 2 in the back, because there is little or no interaction between the left and right side dummies.

Experience with 30 degree oblique vehicle-to-barrier crash tests indicates that dummies tend to impact with the passenger compartment on a line about 11 degrees to the side of the longitudinal axis (since the car is rotated during the impact). Thus, the oblique impacts were simulated by mounting the sled at an 11 degree angle (see also [32], pp. 60-65). Only a single series of oblique tests was run during the project and it was arbitrarily decided to run 1:00 (right corner) impacts.

2.1.2 Dummies and injury parameters

Since all available Hybrid III dummies were committed to other NHTSA studies, the sled tests were performed with Part 572 dummies simulating the 50th percentile adult male [5]. The unrestrained front seat dummies were considered likely to contact the windshield and were furnished with chamois face coverings to allow measurement of the laceration index. The back seat dummies were not equipped with the coverings. The injury criteria measured in the tests corresponded with the instrumentation that is customarily supplied for Part 572 dummies:

- o Head Injury Criterion (HIC)
- o Head resultant g's (3 millisecond peak values were measured by the contractor)
- o Mean Strain Criterion (MSC) for the head
- o Total Laceration Index (TLI) for the face (front seat dummies only)
- o Chest g's, the 3 millisecond peak of the resultant upper spine acceleration
- o Chest Severity Index (CSI), also known as the Gadd Severity Index
- o Left femur load in pounds
- o Right femur load in pounds

In the tests with back seat dummies, it was found that the front seat dummies suffered two impacts of comparable severity and opposite directions of force: first, when they impacted the front of the passenger compartment and later, when the back seat dummies propelled the seatbacks into the front dummies' backs. Since the second impact directly involves the seatback, it was considered especially likely to be influenced by the presence or absence of SBL and consequently of particular interest to this study. Thus, for the 30 front seat dummies that had another dummy behind them, peak head and chest g's were measured for the whole crash, the first impact alone, and for subsequent impacts alone.

2.1.3 Sled test matrix

The objective of the sled test program was to evaluate the effectiveness of SBL. Consistent with that objective, the range of test speeds should include any where SBL have a reasonable chance of affecting the risk of serious injuries. Another consideration is that the speeds should not be so high as to cause irreparable damage to the sled buck or so low that the dummies' injury criterion measurements cannot be meaningfully related to levels of injury risk (e.g., HIC of 100 or less). Since the project was one of the first to include a large number of sled tests with unrestrained adult dummies and, especially, unrestrained back seat dummies, the suitable speed ranges were not known in advance and had to be established by trial and error. It was found that impact speeds above 27 mph were likely to result in significant damage to structural elements of the sled buck, such as the A pillar and windshield header. Such damage must be avoided because, even if repaired, it could affect the windshield's response to impact on subsequent tests. Impact speeds under 20 mph did not produce injury criterion measurements large enough for meaningful estimates of serious injury risk. Therefore, almost all of the tests were conducted impact speeds of 22.5 or 26.5 mph, except for a pair of tests at 15 mph and another pair at 30 mph, at the end of the project, when the buck was expendable. The range appears narrow at first glance but is reasonable for unrestrained occupants: it is in the 20-30 mph rangeof Delta V where the unrestrained occupant, in cars of the 1960-85 era, had a substantial likelihood of serious injury yet that likelihood could be reduced by safety improvements that were built into the vehicle (e.g., energy absorbing steering columns, High Penetration Resistant windshields).

The contractor sought to design the system of steel bands and rollers so as to reproduce the crash pulses actually observed in frontal barrier impacts of Chevrolet Citations, many of which had been performed in earlier NHTSA contracts [36], pp. 5-7. These crash pulses achieved peak decelerations of 8 g's in 15 mph impacts, 12 g's at 22.5 mph, 15 g's at 26.5 mph and 18 g's at 30 mph, based on interpolation of the graphs on p. 7 of the contractor's October 1984 report [36]. The contractor's sled pulses generally averaged a little bit below that: 9 g's at 15 mph, 11 g's at 22.5 mph, 14 g's at 26.5 mph and 15 g's at 30 mph (see Appendix A of this report). Those peaks are mild in comparison with the barrier test experience of other cars. For example, NHTSA compliance tests for Standard 213, which are intended to represent barrier crashes of the average car of the mid-to-late 1970's, develop close to 15 peak g's at 18.5 mph and 22 g's at 27.5 mph. The shape and intensity of the sled pulse usually has a large influence on dummies' injury criteria, but is not so important in this study of exclusively unrestrained dummies. Since the dummies do not make early contact with a restraint system, they get relatively little benefit from a soft "ride-down" of the vehicle. By the time unrestrained dummies have moved forward and contacted the instrument panel and other structures, those structures will have close to zero velocity, even with the soft crash pulses used by the contractor.

The sled test study had to be limited to unrestrained dummies, because resources were unavailable for running both restrained and unrestrained sled test matrices. Since most occupants were unrestrained in the 1960-85 era, the study concentrated on them. The effectiveness of SBL for belted occupants is studied in the accident data only (Sections 3.2.6 and 4.5).

The actual sled test matrix was based on 29 tests, since that was as many as available resources allowed. Since each test without SBL had to have a corresponding test with SBL, that meant 14 pairs of tests (the 29th test was used in the process of determining the appropriate speed range). Rather than using a complete block design or always varying the test parameters from pair to pair, NHTSA directed the contractor to emphasize the 3 most "fundamental" test conditions where many unrestrained occupants are injured yet SBL might have significant benefits: the 22.5 mph frontal impact with dummies in the front and back seats, the 26.5 mph frontal with the front and back seats occupied and the 26.5 mph impact with only the front seat occupied. Three pairs of tests were run for each of these conditions. The remaining tests were run at speeds from 15 to 30 mph, with one pair of tests for each of 5 parameter combinations; all were frontal except for two pairs of oblique tests at 22.5 mph.

Table 2-1 lists the 29 tests in the order that they were run, showing the contractor's test number (which follows chronological order), speed, direction of force, back seat occupancy and SBL status. Table 2-2 shows the experimental design matrix for the study. The three left columns indicate the parameters for each pair of tests: speed, direction of force and occupancy. The last two columns show, respectively, the number of the test(s) that was run without SBL and with SBL.

The test matrix must not allow biases such as a tendency to perform the SBL test with only certain dummies or only at the early (late) part of the project. Those biases were avoided. As Table 2-1 shows, the SBL and non-SBL tests were scattered throughout the project, in no particular order. The same dummies were used at the same seat positions in all the tests; since every test with SBL has a companion test without SBL, the same dummy will be exposed to identical crash parameters with and without SBL.

2.1.4 Running the sled tests

Prior to the entire sled test series, the contractor performed the standard thoracic impact test (at 14 feet per second) on each of the 4 Part 572 dummies [5], p. 440. Because little was known about the potential effects of unrestrained impacts on the dummies, the calibration test

TABLE 2-1

SLED TEST MATRIX
(IN CHRONOLOGICAL ORDER)

Contractor's Test Number	Targeted Impact Speed (mph)	Principal Direction of Force	Back Seat Occupied?	Seat Back Locks?
2915*	12.5	frontal	no	no
2918	22.5	frontal	no	no
2921	15	frontal	yes**	no
2924	15	frontal	yes**	yes
2927	30	frontal	no	no
2935	26.5	frontal	no	yes
2938	26.5	frontal	no	yes
2941	26.5	frontal	no	no
2944	26.5	frontal	no	no
2947	26.5	frontal	no	no
2950	26.5	frontal	no	yes
2957	26.5	frontal	yes	yes
2962	26.5	frontal	yes	yes
2967	26.5	frontal	yes	no
2972	26.5	frontal	yes	no
2977	26.5	frontal	yes	no
2982	26.5	frontal	yes	yes
2994	22.5	frontal	yes	yes
2995	22.5	frontal	yes	yes
2996	22.5	frontal	yes	no
3002	22.5	frontal	no	yes
3003	22.5	oblique	no	yes
3004	22.5	oblique	no	no
3008	22.5	oblique	yes	no
3009	22.5	oblique	yes	yes
3016	22.5	frontal	yes	yes
3017	22.5	frontal	yes	no
3018	22.5	frontal	yes	no
3021	30	frontal	no	yes

*Not used in the analyses - initial run to help establish speed range
**Dummies in the driver's and left rear seats only

TABLE 2-2

SLED TEST MATRIX
(IN SCHEMATIC ORDER)

Targeted Impact Speed (mph)	Principal Direction of Force	Back Seat Occupied?	Contractor's Test Numbers Without SBL	Contractor's Test Numbers With SBL
15	frontal	yes*	2921	2924
22.5	frontal	no	2918	3002
22.5	frontal	yes	2996 3017 3018	2994 2995 3016
22.5	oblique	no	3004	3003
22.5	oblique	yes	3008	3009
26.5	frontal	no	2941 2944 2947	2935 2938 2950
26.5	frontal	yes	2967 2972 2977	2957 2962 2982
30	frontal	no	2927	3021

*Dummies in the driver's and left rear seats only was initially repeated after each use of a dummy; in the last half of the project, the calibration was performed after every third use of a dummy. The results were satisfactory: the dummies always met the Part 572 criteria for peak impactor force, peak chest deflection and hysteresis. Moreover, even when the test results for the 4 different dummies were pooled, only 1 of the 66 values of peak impactor g's was more than 10 percent away from the average value.

The sled buck had to be refurbished after each test, because it was damaged by the unrestrained dummies. The front seat assembly, instrument panel, dashboard, glove compartment, heater core, sun visors, windshield and steering assembly (including brackets) were replaced after <u>each</u> test in which they were contacted by a dummy, even a minor contact. They were replaced by used but undamaged Chevrolet Citation parts (except the windshields, which were new). The replacement seat assemblies included the tracks for the seats. Each new seat was anchored in the sled buck by the same procedure as the original seat. The replacement steering assemblies were diagnosed by the procedure described in GM shop manuals to assure that the energy-absorbing column would function as designed. The sled buck was reinforced at the firewall, steering column support structure, roof, A pillar and windshield header areas in order to minimize the possibility of damage to those structures; since dummies did not directly contact them in these moderately severe frontal sled tests, their reinforcement probably had little influence on the injury severity measurements. It was also necessary to reinforce the floor under the rear seat and anchor the rear seat in place more firmly. (For more details about the test setup see [51], pp. 2-8 - 2-13; however, NHTSA and the contractor agreed to modify some of the procedures in that work plan, as explained by Khadilkar [31]).

The sled tests were filmed primarily by onboard cameras, operating at 1000 frames per second, shooting through the open side windows. Dummy faces were coated with colored chalk to leave a record of contacts with vehicle interior surfaces.

The sled tests were successful in gathering data on the dummy responses. The 28 sled tests used for the analysis involved 84 dummies. HIC and the other head injury measurements were obtained for all of the dummies; so was the right femur load. Peak chest g's and left femur load were unknown for just one dummy; Chest Severity Index could not be calculated in 2 cases. All of the accelerometer traces are documented in [34], [35], [36], or [43]. Appendix A of this report lists the injury criterion measures and test conditions for each dummy.

2.2 Discussion of sled test results

One of the most valuable aspects of the sled test study is that it is possible to see how seatbacks actually perform in crashes. The following discussion of what happened in the sled test films, relating the events in the films to injury severity results, will show that SBL did have a noticeable effect on seatback performance and dummy motion, but little effect on injuries.

In each of the crashes there was an initial impact of the front seat dummies into the frontal components of the passenger compartment. If the back seat was unoccupied, the initial impact was the only one that made a significant contribution to injury risk. But if the back seat was occupied, there was an important second impact when the unrestrained back seat dummies contacted the front seatback, propelling it forward into the front seat dummies just when they were rebounding from the initial impact. While SBL significantly change the motion of the seatback, they do little to alleviate the severity of either impact.

What is most evident from the films is that the front seatback, properly "locked" in place with SBL, is not even remotely a "rigid" structure. Even without any loading by a back seat occupant, the locked front seatback is carried, by its own momentum, about halfway from its original position to the instrument panel before it is "caught" by the SBL in a 22.5 mph frontal crash. (Of course, without SBL, the seatback moves forward without any restraint in frontal and frontal-oblique crashes.) When, in addition, the front seatback is loaded by the back seat dummy, the seatback is deformed and deflected all the way to contact with the front seat dummy, notwithstanding the SBL. In fact, SBL do not appear to reduce the speed at which the front seatback contacts the front seat occupant, after it has been contacted by the back seat occupant.

These observations apply to 22.5 mph crashes. But in 26.5 mph crashes, the effect of the SBL was even less. In the 3 tests with locked seatbacks and back seat dummies, the front seatback did not stay in place. On one of the tests (no. 2962), both SBL were sheared off. On the other two (nos. 2957 and 2982), the front seat was pulled completely out of its track on one side.

The preceding phenomena (extensive deflection of the seatback at 22.5 mph and separation of the SBL or track at 26.5 mph) are perhaps a reflection of the specific hardware used in the 1981 Chevrolet Citation or the manner in which the hardware was installed in the sled buck and might not be representative of other cars. The MDAI data (Section 5.4), however, suggest that separation of the SBL or the track is common for all types of cars when there are back seat occupants.

The films make it possible to see the influence of seatback motion on dummy trajectories in detail. Here is what happens in the initial impact of the front seat dummies into the front of the passenger compartment, which is the only important impact when there are no back seat dummies. As the sled buck decelerates, the dummies continue straight forward in a sitting posture and the front seatback rotates forward with them. When the car has SBL, the seatback stops moving about half way to the instrument panel and has no further effect on dummy trajectories in this phase of the impact. When there are no SBL, the seatback continues forward with the occupant, but not really touching the occupant. Next, the dummy in the driver's seat engages the steering assembly with its chest and gets one of its strongest deceleration spikes of the initial impact phase. At that moment, however, the seatback is barely in contact with the dummy's back and has little effect on the dummy's trajectory. As the steering column is compressed and begins to decelerate the dummy, the seatback gradually "catches up" with the dummy and begins to load it in the upper thorax. That process takes some time because the front of the seatback is soft and is deflected several inches. By the time the seatback bottoms out on the dummy, the dummy has more or less bottomed out on the steering assembly and instrument panel. Thus, the additional load of the seatback may have added slightly to the loads experienced by the dummy's thorax, but over an extended time period and without any noticeable spike. The dummy in the right front seat is even less influenced by SBL. This dummy continues forward until it contacts the instrument panel, which is well forward of the steering assembly. By the time the dummy engages the instrument panel, the seatback has rotated about as far forward as it can go and is beginning to move more downward than forward. Only the upper part of the seatback scrapes against the dummy's back while the dummy is bottomed out on the instrument panel.

When there are dummies in the back seat, they continue to move forward as the sled buck decelerates. If the car has SBL, the locks "catch" the front seatback, as mentioned above, and hold it in a more or less upright position. The back seat occupant contacts the front seatback with his knees first and then with his head and chest. The seatback deflects forward easily and only decelerates the back seat occupant a small amount. The back seat dummy and seatback together plow into the front seat dummy just as it is rebounding from the steering assembly or instrument panel, resulting in a severe blunt impact to the front seat dummy's upper spine or the back of its neck.

When the car does not have SBL, the films suggest that the results are a bit less severe for the front seat dummy but more severe for the back seat dummy. Without SBL, as mentioned above, the seatback continues to rotate forward until it bottoms out on the front seat dummy and the front of the passenger compartment. By that time, the top of the seatback is well to the front of the lower part of the seatback. The back seat dummy initially engages the seatback with its knees only and rotates forward head first. When the dummy's head reaches the front seatback, it has some of the weight of the upper torso behind it, possibly sustaining a more severe impact than it would have with SBL. On the other hand, the second impact seems a little less severe for the front seat dummies: they are not rebounding as rapidly at the moment of impact as they are in the case with SBL because the earlier motion of the unlocked seatback retarded their rebound. Also, with the seatback in a more forward and less vertical position, the back seat dummy appears to strike more of a glancing impact. The injury parameters measured on the dummies (described in the next section) are consistent with what appeared in the films (decreased head injury for the back seat dummy and increased 2nd impact thorax injury for the front dummy in the SBL runs), although the observed differences in the injury parameters were not statistically significant (two-sided alpha = .05).

In a few tests, the back seat dummy's head and thorax bypassed the bucket style front seatback and entered the front portion of the passenger compartment. That is usually undesirable because the back seat dummy can strike hard surfaces such as the windshield and instrument panel or make direct head to head contact with a front seat dummy (although in some cases the back seat dummy avoids head contacts and is better off). In the oblique tests, not surprisingly, bypassing occurred in the test without SBL. Since the front seatback is further forward when there are no SBL, the back seat dummy must travel a greater distance to reach the seatback. In an oblique crash, that means enough lateral travel to miss the seatback. In the straight frontal crashes, however, bypassing occurred only on some of the tests <u>with</u> SBL, at 22.5 mph. It appears that the back seat dummies twisted the top of the seatback and then slid past it. Bypassing did not happen in the 26.5 mph tests with SBL, perhaps because the SBL sheared off or the seat came loose from its track before much twisting occurred.

The tests revealed some other phenomena, unrelated to SBL but of more general interest. They showed that unrestrained dummies score much higher on the injury parameters than restrained dummies would have under similar test conditions. In particular, the unrestrained Part 572 dummies could not repeatably meet the criteria of Standard 208 (HIC below 1000, chest g's below 60 and femur load below 2250 pounds), even though the tests were run at well below the 30 mph and roughly 22 peak sled g's used for Standard 208 testing. Table 2-3 shows that both front seat dummies met the Standard 208 criteria on just 4 of the 12 tests at 22.5 mph, one of the 12 tests at 26.5 mph and neither of the 2 tests at 30 mph. (Chest g's are tabulated only for the initial impact of the front seat dummy into the steering assembly or instrument panel, since the second impact of the back seat dummy into the front seatback and front seat dummy would not

TABLE 2-3

PERFORMANCE OF UNRESTRAINED DUMMIES RELATIVE TO STANDARD 208 CRITERIA (HIC=1000, Chest g's=60, Femur Load=2250: values exceeding these criteria are underlined)

	Drivers				Right Front Passengers				
			Femur Load				Femur Load		
Test No.	HIC	Chest g's*	L	R	HIC	Chest g's*	L	R	Pass 208?
				22.5 mph tests					
2918	213	41.2	1152	1178	146	50.3	497	513	Yes
2994	293	41.7	872	642	376	20.0	1103	901	Yes
2995	385	35.0	1513	581	477	24.9	1829	485	Yes
2996	457	30.0	1276	712	474	27.8	1922	1364	Yes
3002	234	46.5	<u>2925</u>	780	546	29.5	1355	<u>2436</u>	No
3003	235	29.0	<u>3445</u>	515	394	40.2	<u>3136</u>	1798	No
3004	277	39.0	<u>3841</u>	323	234	36.6	1738	2148	No
3008	227	36.7	2108	509	337	46.4	<u>3524</u>	<u>2356</u>	No
3009	185	35.0	<u>4403</u>	567	413	39.0	<u>4173</u>	<u>3378</u>	No
3016	738	38.0	1344	440	253	45.0	<u>2692</u>	2156	No
3017	139	40.0	2192	624	<u>1111</u>	49.1	<u>3814</u>	<u>3195</u>	No
3018	167	37.1	1280	359	<u>3068</u>	48.9	<u>2899</u>	2120	No
				26.5 mph tests					
2935	477	53.9	1745	1935	218	50.9	1349	1276	Yes
2938	351	51.0	1965	998	298	<u>75.8</u>	<u>2323</u>	<u>2251</u>	No
2941	321	47.7	2062	1536	459	<u>70.1</u>	1418	<u>2921</u>	No
2944	433	<u>67.7</u>	1803	1079	345	<u>67.8</u>	<u>2779</u>	1873	No
2947	543	<u>67.7</u>	<u>2622</u>	725	428	<u>73.5</u>	<u>3668</u>	<u>2983</u>	No
2950	762	54.7	<u>2831</u>	530	376	55.6	2322	2133	No
2957	578	<u>72.6</u>	1629	721	327	<u>74.1</u>	<u>2702</u>	1535	No
2962	397	50.0	<u>2564</u>	562	<u>4307</u>	<u>78.1</u>	<u>3459</u>	<u>2901</u>	No
2967	640	60.0	<u>4039</u>	650	934	<u>80.0</u>	<u>3647</u>	<u>3320</u>	No
2972	228	40.3	1866	987	819	53.2	<u>2875</u>	2036	No
2977	450	59.5	2056	767	<u>2723</u>	55.8	<u>2459</u>	<u>2933</u>	No
2982	326	56.7	1450	777	334	<u>60.3</u>	<u>2775</u>	<u>2279</u>	No
				30 mph tests					
2927	533	54.8	865	1428	<u>1958</u>	<u>79.2</u>	2213	1745	No
3021	696	<u>68.8</u>	1841	738	<u>1629</u>	<u>84.6</u>	<u>3859</u>	<u>5129</u>	No

*In tests where there was a back seat dummy, accelerations of the front seat dummy which were attributable to the back seat dummy were not considered in the calculation of peak chest g's.

have occurred in Standard 208 testing.) The table shows, however, that many of the dummies were unable to meet the Standard 208 criteria for femur load, while they had acceptable head and chest scores. The high severity of the right front passenger's left femur load is primarily due to contacts with the heater core. It is also possible, however, that the femur loads in the sled tests may have increased in some cases because the contractor had to reinforce the firewall in order to maintain the structural integrity of the sled buck: some of the dummies' knees may have contacted hardened spots in the firewall beyond the instrument panel. Table 2-4 compares the dummy performance relative to Standard 208 criteria for HIC and chest g's, only. Ten of the 12 tests at 22.5 mph had passing head and chest scores for both dummies, but 2 right front passengers had HIC over 1000. At 26.5 mph, only 3 of 12 tests had passing head and chest scores for both dummies; most of the right front dummies had more than 60 chest g's. Neither test at 30 mph met Standard 208 criteria.

It was also noteworthy that the Citation's energy absorbing steering columns were compressed all the way or almost all the way (i.e., 4-5 inches), in every test at 22.5 mph or more, even in the oblique tests at 22.5 mph. Nevertheless, the successful compression of the column in almost every case did not fully dissipate the kinetic energy of the driver dummy's thorax. The chest accelerometer traces all show nearly the same pattern: an initial peak of 40-50 g's at about 100 milliseconds, apparently representing a "threshold" force needed to initiate compression of the column; deceleration then rapidly drops off to a trough of close to 10 g's as the column compresses, absorbing relatively little energy during the

TABLE 2-4

PERFORMANCE OF UNRESTRAINED DUMMIES
RELATIVE TO THE HEAD AND CHEST CRITERIA OF STANDARD 208
(HIC=1000, Chest g's=60: values
exceeding these criteria are underlined)

	Drivers		Right Front Passengers		
Test No.	HIC	Chest g's*	HIC	Chest g's*	Pass 208?
22.5 mph tests					
2918	213	41.2	146	50.3	Yes
2994	293	41.7	376	20.0	Yes
2995	385	35.0	477	24.9	Yes
2996	457	30.0	474	27.8	Yes
3002	234	46.5	546	29.5	Yes
3003	235	29.0	394	40.2	Yes
3004	277	39.0	234	36.6	Yes
3008	227	36.7	337	46.4	Yes
3009	185	35.0	413	39.0	Yes
3016	738	38.0	253	45.0	Yes
3017	139	40.0	1111	49.1	No
3018	167	37.1	3068	48.9	No
26.5 mph tests					
2935	477	53.9	218	50.9	Yes
2938	351	51.0	298	75.8	No
2941	321	47.7	459	70.1	No
2944	433	67.7	345	67.8	No
2947	543	67.7	428	73.5	No
2950	762	54.7	376	55.6	Yes
2957	578	72.6	327	74.1	No
2962	397	50.0	4307	78.1	No
2967	640	60.0	934	80.0	No
2972	228	40.3	819	53.2	Yes
2977	450	59.5	2723	55.8	No
2982	326	56.7	334	60.3	No
30 mph tests					
2927	533	54.8	1958	79.2	No
3021	696	68.8	1629	84.6	No

*In tests where there was a back seat dummy, accelerations of the front seat dummy which were attributable to the back seat dummy were not considered in the calculation of peak chest g's.

main portion of its stroke; finally, at 125 milliseconds, deceleration reaches a second and usually worse peak as the dummy bottoms out the column and is brought to an abrupt stop.

2.3 Statistical analysis of sled test results

2.3.1 Average values for the injury criteria - with and without SBL

Appendix A of this report shows the injury criterion scores for each of 42 dummies in tests without SBL as well as the scores for 42 dummies in corresponding tests with SBL. The best overall measure of the performance of SBL is to compute the average scores for the 42 dummies without SBL and compare them to the averages with SBL.

Table 2-5 displays the average scores on the 7 injury criteria that were measured on every dummy. The 42 dummies without SBL had an average HIC of 464. (In the case of HIC, Chest Severity Index and Mean Strain Criterion, the "average" is not the simple arithmetic average but the antilog of the average of the logs of the values. The logarithm transformation was employed because the distributions are highly skewed and the arithmetic averages are not good indicators of central tendency because they are pulled to the right by an outlier or two.) The 42 dummies with SBL had an average HIC of 408, which is 12 percent lower than the non-SBL dummies. In Table 2-5 as well as the remaining tables of this chapter, positive numbers in the reduction columns indicate that the dummies with SBL had better results than the non-SBL dummies; negative numbers indicate worse results. The reduction, however, is not statistically significant (two-sided alpha = .05), as will be shown in the next

TABLE 2-5

SLED TEST RESULTS - ALL DUMMIES
(42 dummies in tests with SBL vs.
42 dummies in identical tests without SBL)

	Average Severity		Reduction for SBL		Significance Test for Matched Pair Comparison**	
	Without Locks	With Locks	Ab-solute	Relative (%)	t	Signi-ficant?
HIC*	464	408	56	12	0.84	no
Head g's	71.6	70.4	1.2	2	0.22	no
Mean Strain Crit.*	0.0058	0.0051	0.0007	12	1.13	no
Chest g's	45.4	47.3	-1.9	-4	-0.85	no
Chest Sev. Index*	235	242	-7	-3	-0.27	no
Left femur load	1689	1689	none	none	0	no
Right femur load	1167	1173	-6	-1	-0.04	no

*Values shown are the antilogs of the average of the logs of these criteria.

**t test with two-sided alpha = .05

section. The SBL dummies also had slightly lower scores than the non-SBL cases on the other two measures of head injury: a 2 percent reduction of peak head g's and a 12 percent drop in Mean Strain Criterion. They were, however, a little worse off on both chest injury scores: a 4 percent increase on peak chest g's and a 3 percent increase on Chest Severity Index. There was hardly any difference between the two groups on femur load.

Each dummy is given equal weight in computing the simple averages of Table 2-5. Since the dummies were distributed about equally between three seat position conditions - in the front seat with nobody behind them, in the front seat with somebody behind them, and in the back seat - the average is not necessarily representative of highway crashes, where the vast majority of occupants sit in the front seat and nobody is sitting behind them. But with the small samples of dummies available here, there is little to be gained by "weighting" the cases to be more representative of highway crashes.

Table 2-6 is limited to the subset of dummies that were in the front seat and had no dummy sitting behind them: 12 with SBL and a corresponding 12 without SBL. Here, the dummies with SBL had slightly worse results on two of four head injury measures (HIC and peak g's) but better on the other two (Mean Strain Criterion and laceration index). They had fractionally lower scores on the chest injury measures but worse scores on femur load. Any comparison, however, needs to be tested for statistical significance before it can be accepted as a genuine indication

TABLE 2-6

SLED TEST RESULTS - DUMMIES IN THE FRONT SEAT WITH NO DUMMY POSITIONED BEHIND THEM (12 dummies in tests with SBL vs. 12 dummies in identical tests without SBL)

	Average Severity		Reduction for SBL		Significance Test for Matched Pair Comparison**	
	Without Locks	With Locks	Ab-solute	Relative (%)	t	Signi-ficant?
HIC*	385	432	-47	-12	-0.71	no
Head g's	60.9	71.4	-10.5	-17	-2.16	no
Mean Strain Crit.*	0.0051	0.0045	0.0006	12	0.73	no
Tot. Lacerat. Index	5.83	5.04	0.79	14	1.26	no
Chest g's	56.2	53.4	2.8	5	0.81	no
Chest Sev. Index*	335	330	5	1	0.12	no
Left femur load	2055	2425	-370	-18	-1.07	no
Right femur load	1538	1710	-172	-11	-0.42	no

*Values shown are the antilogs of the average of the logs of these criteria.

**t test with two-sided alpha = .05

of an effect of SBL. In particular, all the differences in Table 2-6 will be shown nonsignificant (two-sided alpha = .05) in the next section.

Similarly, Table 2-7 displays the results for dummies in the front seat that had a dummy behind them and Table 2-8 shows the average scores for back seat dummies. The results of the comparisons are discussed in the next section.

2.3.2 Significance of the results: t tests of matched pairs

The sled tests were peformed over a range of speeds and impact modes, with dummies in a variety of seat positions. These factors, which were intentionally part of the experimental design, cause much variation from test to test. It would not be appropriate to test statistical significance in the ordinary way - i.e., to compute the average and standard deviation for the tests with SBL and the same for the tests without SBL and to do a t test for the difference between two samples - because these standard deviations would be inflated and the significance of differences understated. A better approach, consistent with the experimental design, is to recognize that each dummy in a test with SBL has a matching partner in a test without SBL - at the same seat position, speed and impact mode. Table 2-2 shows which test without SBL is matched to which test with SBL. Within tests, dummies are matched by seat position, e.g., the driver dummy in test 2921 with the driver dummy in test 2924. The differences in HIC, chest g's, etc. between two such matching dummies are only attributable to SBL and/or sources of variation that are beyond the experimenter's control, i.e., sampling error. The

TABLE 2-7

SLED TEST RESULTS - DUMMIES IN THE FRONT SEAT
WITH A DUMMY POSITIONED BEHIND THEM
(15 dummies in tests with SBL vs.
15 dummies in identical tests without SBL)

	Average Severity		Reduction for SBL		Significance Test for Matched Pair Comparison**	
	Without Locks	With Locks	Ab-solute	Relative (%)	t	Signi-ficant?
HIC*	491	394	97	20	0.75	no
Head g's from:						
any contact	68.7	67.3	1.4	2	0.17	no
1st contact	68.1	67.3	0.8	1	0.17	no
later contacts	40.5	29.1	11.4	28	1.19	no
Mean Strain Crit.*	0.0062	0.0050	0.0012	19	1.15	no
Tot. Lacerat. Index	4.03	4.13	-0.10	-2	-0.31	no
Chest g's from						
any contact	50.3	56.4	-6.1	-12	-1.49	no
1st contact	47.3	46.2	1.1	2	0.37	no
later contacts	31.6	39.6	-8.0	-25	-1.03	no
Chest Sev. Index*	313	413	-100	-32	-1.72	no
Left femur load	2457	2202	255	10	1.03	no
Right femur load	1496	1243	253	17	1.16	no

*Values shown are the antilogs of the average of the logs of these criteria.

**t test with two-sided alpha = .05

TABLE 2-8

SLED TEST RESULTS - DUMMIES IN THE BACK SEAT
(15 dummies in tests with SBL vs.
15 dummies in identical tests without SBL)

	Average Severity		Reduction for SBL		Significance Test for Matched Pair Comparison**	
	Without Locks	With Locks	Absolute	Relative (%)	t	Significant?
HIC*	507	403	104	21	0.78	no
Head g's	83.0	72.8	10.2	12	0.97	no
Mean Strain Crit.*	0.0060	0.0060	none	none	0	no
Chest g's	30.9	32.4	-1.5	-5	-0.38	no
Chest Sev. Index*	122	98	24	20	0.85	no
Left femur load	553	508	45	8	0.57	no
Right femur load	542	673	-131	-24	-2.22	yes

*Values shown are the antilogs of the average of the logs of these criteria.

**t test with two-sided alpha = .05

differences are computed for the 42 matched pairs of dummies, and a t test is performed to check if the average difference is significantly different from zero. The results of the t tests are shown in the next to last column of Table 2-5. The last column indicates whether the observed value of t is significant (two-sided alpha = .05) with 41 degrees of freedom. (Chest g's and left femur load were missing on one dummy with SBL - see Section 2.1.4 - and Chest Severity Index could not be calculated for two dummies. For these injury measures, the dummy with the missing data and its matching partner without SBL were not used in the statistical analysis. Significance was tested with the remaining matched pairs, with 1 or 2 fewer df.)

Table 2-5 shows that none of the differences between SBL and non-SBL injury rates even come close to statistical significance. The largest value of t is 1.13, for Mean Strain Criterion, whereas t would have to be over 2.02 for statistical significance (with two-sided alpha = .05 and 41 df). Table 2-5 also illustrates that the value of t depends on the repeatability of the injury criterion as well as the magnitude of the observed difference. For example, the t value for chest g's is -0.85 even though the difference between SBL and non-SBL is just 4 percent, whereas the t value for HIC is 0.84 although there was a 12 percent reduction in HIC. That is because chest g's are a far more repeatable criterion than HIC, having only 1/3 as large a coefficient of variation.

Table 2-6 analyzes the 12 pairs of dummies that were in the front seat and did not have another dummy sitting behind them. Here there are 8 injury criteria, since the Total Laceration Index was measured on all front seat dummies. There were no significant differences between SBL and non-SBL on any of the criteria, although the 17 percent increase in peak head g's in the SBL group comes "close" to significance: it has a t value of -2.16, whereas -2.20 would be the critical value with 11 df. The fact that another head injury measure (Mean Strain Criterion) decreased even while head g's increased is also evidence that the observed increase in head g's is probably not due to SBL. The observed increases in femur loads are likewise not meaningful, as they do not come close to statistical significance.

Table 2-7 considers the 15 pairs of dummies that were sitting in the front seat and had another dummy directly behind them. As explained in Sections 2.1.2 and 2.2, they were subjected to two major impacts during the crash: the initial contact with the front of the passenger compartment and the subsequent interaction with the back seat dummy. Peak head and chest g's were measured for each contact separately as well as for both combined. The other criteria, such as HIC, MSC and CSI, are calculated over both impacts. Table 2-7 does not show significant differences on any of the criteria. Consistent with the discussion in Section 2.2, however, the dummies in the crashes with SBL had 25 percent higher peak chest g's on the impact caused by interaction with the back seat dummy, possibly accounting for the 32 percent overall increase in Chest Severity Index and the 12 percent increase in overall peak chest g's. None of those increases, on the other hand, was statistically significant although the one for Chest Severity Index came fairly close (t = -1.72, where -2.15 is the critical value with two-sided alpha = .05 and df = 14 and -1.76 is the critical value with one-sided alpha = .05).

Finally, Table 2-8 analyzes the 15 pairs of dummies located in the back seat. None of the observed differences are statistically significant, except that the dummies with SBL had "significantly" higher right femur loads. That result may be spurious: by now, 34 significance tests have been performed in Tables 2-5 - 2-8 and, with alpha = .05, at least one of the tests could be expected to have significant results even if there were no real differences. At any rate, the femur loads for the back seat dummies (542 without SBL and 673 with SBL) are always far below the levels associated with serious injuries. Consistent with the discussion in Section 2.2, the back seat dummies with SBL had 21 percent lower HIC than those without SBL and 12 percent lower peak head g's. Neither of these reductions, however, even approaches statistical significance. Moreover, the other measure of head injury (Mean Strain Criterion) was unchanged.

2.3.3 Nonparametric significance tests

There is another, simpler way to analyze the data and determine if SBL reduced injuries. For each matched pair of dummies, score one point for SBL if the SBL dummy did better on a particular injury criterion and score one point for non-SBL if that dummy did better. Tally the scores for all the matched pairs. If the SBL dummies score significantly more than 50 percent of the points, it is concluded that SBL is effective in reducing that injury criterion. This nonparametric approach has the advantage that a consistent trend in favor of one side would not be obscured by a few outliers in the opposite direction. It has the disadvantage of being even less likely to detect significant differences than the preceding matched pair t tests.

Table 2-9 shows the nonparametric test results for all 42 matched pairs. None of the observed differences were statistically significant. The SBL dummies had lower HIC than their non-SBL counterparts in 26 out of 42 cases. Nevertheless, that is not significantly different from a 50-50 split (one-sided alpha = .05, using an exact binomial test). The SBL dummies likewise performed slightly better, but not significantly better, on the other two head injury measures. The non-SBL dummies had slightly better results on the two chest scores, with lower chest g's in 24 out of 41 tries and lower CSI on 22 out of 40 tries. Again, those are not significantly different from 50-50. The results on femur load were virtually even.

Table 2-10 subdivides the analysis by seating position. There was no significant difference between SBL and non-SBL on any injury criterion. (Even the 11-4 splits observed in two cases are not in the critical range of a binomial distribution with p = .5.) In all seat positions, the SBL dummy did slightly better than the non-SBL dummy on the head injury measures. The chest injury scores were marginally in favor of the non-SBL dummies, while the femur load results were inconsistent (but within the noise range of a binomial distribution with p = .5). Among the front seat dummies with a dummy sitting behind them, the non-SBL group did

TABLE 2-9

NONPARAMETRIC ANALYSIS OF SLED TEST RESULTS - ALL DUMMIES
(42 dummies in tests with SBL vs.
42 dummies in identical tests without SBL)

Injury Criterion	Number of Matched Pairs with: Non-SBL Dummy Better	SBL Dummy Better	Tie Score	Missing Data	Significant Difference* between SBL and Non-SBL?
HIC	16	26	0	0	no
Head g's	18	23	1	0	no
Mean Strain Crit.	18	24	0	0	no
Chest g's	24	17	0	1	no
Chest Sev. Index	22	18	0	2	no
Left femur load	20	21	0	1	no
Right femur load	22	20	0	0	no

*Exact binomial test with one-sided alpha = .05

TABLE 2-10

NONPARAMETRIC ANALYSIS OF SLED TEST RESULTS - BY SEAT POSITION

Injury Criterion	Number of Matched Pairs with: Non-SBL Dummy Better	SBL Dummy Better	Tie Score	Missing Data	Significant Difference* between SBL and Non-SBL?
FRONT SEAT DUMMIES WITH NO DUMMY BEHIND THEM					
HIC	5	7	0	0	no
Head g's	4	7	1	0	no
Mean Strain Crit.	6	6	0	0	no
Tot. Lacerat. Index	4	7	1	0	no
Chest g's	7	5	0	0	no
Chest Sev. Index	6	6	0	0	no
Left femur load	8	4	0	0	no
Right femur load	5	7	0	0	no
FRONT SEAT DUMMIES WITH A DUMMY BEHIND THEM					
HIC	6	9	0	0	no
Head g's from:					
any contact	6	9	0	0	no
1st contact	6	9	0	0	no
later contacts	9	6	0	0	no
Mean Strain Crit.	5	10	0	0	no
Tot. Lacerat. Index	5	8	2	0	no
Chest g's from:					
any contact	9	6	0	0	no
1st contact	6	9	0	0	no
later contacts	8	7	0	0	no
Chest Sev. Index	10	5	0	0	no
Left femur load	4	11	0	0	no
Right femur load	6	9	0	0	no
BACK SEAT DUMMIES					
HIC	5	10	0	0	no
Head g's	5	10	0	0	no
Mean Strain Crit.	7	8	0	0	no
Chest g's	8	6	0	1	no
Chest Sev. Index	6	7	0	2	no
Left femur load	8	6	0	1	no
Right femur load	11	4	0	0	no

*Exact binomial test with one-sided alpha = .05

better on both "later contacts" measures, but not significantly better.

It would be tempting, but not valid, to combine the results on several injury measures - say HIC, head g's, Mean Strain Criterion and Total Laceration Index - to obtain a single large sample where, in fact, the SBL dummies are better off "significantly" over 50 percent of the time. But the significance test for a binomial distribution is only valid if the elements of the sample are <u>independent</u> trials. In this case, HIC, head g's, MSC and TLI are measured from the same pair of sled tests. If HIC is high, it is almost always the case that peak head g's and MSC are also high. Thus, HIC, head g's and MSC from the same sled tests are hardly independent in a statistical sense.

CHAPTER 3

ANALYSES OF WASHINGTON, TEXAS AND NEW YORK STATE ACCIDENT DATA

Accident data from 3 States, comprising well over a million persons involved in crashes, were statistically analyzed. They did not show seat back locks (SBL) to be effective in reducing injury risk at any severity level. They did not show effectiveness at any seat position or specific injury type. SBL were not effective when occupants were restrained and likewise when they were unrestrained. Worse than that, the risk of occupant ejection was always higher in 2 door cars than in 4 door cars, but the Washington data hint at a possibility that the discrepancy between the two types of cars became even wider after the introduction of SBL.

3.1 Analysis method

The principal difficulty in analyzing State data files is that the effect of SBL is expected to be small in comparison to the other safety features that were introduced at about the same time, not to mention the other trends and year to year changes of injury rates that are typically found in State files. Moreover, the discussion of Section 1.6 and the sled tests of Chapter 2 do not suggest any specific injury type or crash situation where SBL could be intuitively expected to have a high effect (unlike, say, High Penetration Resistant windshields, which can specifically be expected to reduce serious facial lacerations). So it is not possible to focus the analysis on one specific injury type. In the sled tests of Chapter 2 it was possible to control the crash conditions and vehicle configurations and to obtain pairs of crashes that were identical except that one of them was with SBL and the other without. Such a priori control is impossible with highway accident data. Thus it will be necessary to analyze State data for all types of crashes and to eliminate the biases caused by other safety devices, etc., by the use of a control group and by limiting the data to as few model years as possible before and after the introduction of SBL.

3.1.1 The control group: 4 door cars

In all analyses, the control group is the 4 door passenger car, which was unaffected by the introduction of SBL. Ball originally developed this approach in his study of SBL [2] (see Section 1.8). The injury reduction for 2 door cars with SBL versus those without SBL is measured relative to the corresponding injury reduction in 4 door cars of the same model years.

All of the analyses of accident data (Chapters 3-5) are limited to the big 3 domestic manufacturers, since they appear to have been the only companies that met the following conditions during the years before and after the introduction of SBL (circa 1963-71): (1) The company produced both 2 and 4 door cars; (2) The VIN can be decoded to reveal if a car had 2 or 4 doors; (3) It is known exactly when SBL were introduced (see Section 1.4).

The analysis method is illustrated, for example, by the first 4 lines of data in Table 3-1, which is based on 1973-77 Washington State

TABLE 3-1

WASHINGTON STATE 1973-77: K + A (FATAL OR SERIOUS) INJURY RATES, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	605	22,913	2.64		
	first 1 after	522	23,301	2.24	15	
2	last 1 before	859	28,541	3.01		
	first 1 after	843	32,533	2.59	14	-1% Z=0.19
4	last 2 before	1305	46,787	2.79		
	first 2 after	1102	47,855	2.30	17	
2	last 2 before	1752	55,031	3.18		
	first 2 after	1842	67,435	2.73	14	-4% Z=0.74
4	last 3 before	1980	68,407	2.89		
	first 3 after	1527	68,411	2.23	23	
2	last 3 before	2496	77,660	3.21		
	first 3 after	2845	103,545	2.75	15	-11% Z=2.38*
4	last 4 before	2568	85,055	3.02		
	first 4 after	1912	87,130	2.19	27	
2	last 4 before	3010	90,724	3.32		
	first 4 after	3572	132,175	2.70	19	-12% Z=2.95*

***Statistically significant effect** (two-sided alpha = .05 - i.e. Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

crashes. The third line shows that in 2 door cars of the last model year before SBL (i.e. 1966 GM, 1967 Ford and 1967 Chrysler products - see Section 1.4), 859 of 28,541 occupants had serious or fatal injuries. (A and K are the respective police codes for serious and fatal injuries.) That is an injury rate of 3.01 percent. The fourth line shows that in 2 door cars of the first model year with SBL (1967 GM, 1968 Ford and 1968 Chrysler products) the serious injury rate was 2.59 percent. That is a 14 percent gross reduction in the injury rates in 2 door cars. Much if not all of that reduction, however, may be attributed to energy absorbing steering columns and other safety devices introduced in 1967-68 as well as the typical downward trend of injury rates in State data as cars get newer. The first two lines of data show the corresponding results for the control group, 4 door cars. The first line shows that 1967 GM, 1968 Ford and 1968 Chrysler products - i.e., cars that would have been "of the last model year before SBL" if they had been 2 door cars - had a serious injury rate of 2.64 percent. The second line shows that 1967 GM, 1968 Ford and 1968 Chrysler products with 4 doors (cars that would have been "of the 1st model year with SBL" if they had been 2 door models) had a 2.24 percent serious injury rate. That is a 15 percent injury reduction for the control group. The 2 door cars, which were influenced by SBL, had only a 14 percent reduction. The crucial assumption with this method is that the 2 door cars and the control group were subjected to the same influences except for the introduction of SBL in the 2 door cars. The gross reduction of the injury rates for the first MY after SBL were introduced relative to the last MY before SBL should be the same for 2 and 4 door cars, except to the extent that SBL affected injury risk. If so, the relative difference in the gross injury reductions measures the net effect of SBL. With a 14 percent gross reduction in the 2 door cars and 15 percent in the control group, the net effect is

$$1 - (1-.14)/(1-.15) = -1 \text{ percent}$$

i.e., the SBL are associated with an estimated 1 percent increase in serious injuries.

3.1.2 Limiting the data set to reduce bias

Unfortunately, the crucial assumption that 2 door and 4 door cars are subject to the same influences cannot be accepted without reservations. In fact, there are several reasons besides SBL that 2 door and 4 door cars may have different injury reductions from one model year to another. The most obvious is that 2 and 4 door cars appeal to different segments of the market, with 4 door cars typically appealing to older purchasers or for use as the "family" car. An initial remedy, which was used with every data file, was to eliminate convertibles, which have quite distinct driving patterns and injury risks and which are almost always 2 door cars. But that remedy only scratches the surface of the problem. Specifically, the 1960-75 period surrounding the introduction of SBL witnessed a major increase in the demand for 2 door cars at the expense of 4 door cars, as described in Section 1.7. The influx of smaller 2 door cars, many with inexperienced drivers, could have resulted in a steady widening of the gap between the injury rates of the 2 and 4 door cars. The analysis would misinterpret the widening gap as a negative net "effect" for SBL. That was the principal critique of Ball's approach (see Section 1.8).

The remedy is to limit the data set so as to minimize the drift in the characteristics of the 2 and 4 door car populations. One way is to use as few model years as possible, preferably only the single model years before and after the introduction of SBL. How much can the market shift in a single year? The 2 door cars of the first year with SBL will account for nearly the same market segment as the 2 door cars of the last year before SBL; the 4 door cars of the SBL introduction year appealed to more or less the same group as the 4 door cars of the year before SBL introduction. Thus the changes in the 2 door cars' injury rates from one year to the next would only be affected by market shifts to a small extent; likewise for the 4 door cars. The "net effect for SBL" - i.e., the difference between the change in the 2 door cars' injury rates and the change in the 4 door cars' injury rates - would not be biased to any large extent by market shifts.

The drawback of using just one model year before/after SBL implementation, of course, is that sample sizes are limited. A statistically more precise, although potentially more biased estimate is obtained by using data of the two model years before/after SBL introduction. Even more precise, but possibly more biased estimates are achieved by using 3 or 4 model years before/after SBL. The strategy in Table 3-1 and in all other accident data analyses of this report is to obtain all 4 estimates: the ones based on ±1, ±2, ±3 and ±4 model years, respectively. For example, in Table 3-1, the estimated "net effect of SBL" is negative 1 percent in the estimate based on the single model year before/after SBL, -4 percent in the ±2 MY estimate, -11 percent in the ±3 year sample and -12 percent in the ±4 year sample.

The advantage of calculating all 4 estimates is that the sequence of the 4 numbers gives an excellent intuitive feel for what might be the best, unbiased value for net effectiveness and how statistically reliable that value is. The sequence in Table 3-1 (-1, -4, -11 and -12 percent) suggests the presence of a secular bias that works against SBL, producing increasingly unfavorable results as the age span of the cars in the sample is widened. The ±4 year estimate of -12 percent is not valid because of the bias. The most reasonable conclusion is that SBL had little or no effect on the injuries described in Table 3-1. By contrast, the sequence of estimates in Table 3-2 is far more consistent: -6, -6, -8 and -9 percent. It is possible, of course, that the apparent consistency occurred by chance alone. Nevertheless, the most reasonable conclusion is that there is little secular drift in the estimates - i.e., about a 1 percent worsening for each year of additional data. The sequence appears to support a "best" estimate that SBL increased the likelihood of injuries described in Table 3-2 by about 5 percent. This year-by-year approach was used extensively in NHTSA's evaluations of side door beams [26], side marker lamps [25] and windshields [27]. It proved useful for isolating the effect of a safety device when there are many other factors influencing injury risk.

Another strategy for reducing bias, used in some of the Washington analyses in this chapter as well as with the FARS data in Chapter 4, is to make the 2 door and 4 door cars as similar as possible by eliminating vehicles of the one type that have no counterpart in the other type. Makes and models that were produced only with 2 doors, such as Ford

Mustang, Chevrolet Camaro and Plymouth Barracuda are excluded from the analysis. They are mostly small, sporty cars and they had an increasing market share in the later 1960's. Station wagons, which almost always have 4 doors and are generally "family" cars were likewise excluded. So were the subcompact cars, which were produced only in the post-SBL era and generally have 2 doors - they had no counterpart in the pre-SBL era. Finally, when data problems such as indecipherable VINs forced the exclusion of certain pre-SBL vehicles (e.g., Chrysler products more than 2 years before the introduction of SBL), the corresponding post-SBL vehicles were also excluded (viz., Chrysler products more than 2 years after SBL introduction).

The resulting data set consists exclusively of 2 and 4 door sedans and hardtops of the same makes and models - i.e., for any 2 door SBL equipped car on the file, there are 2 door pre-SBL, 4 door post-SBL and 4 door pre-SBL cars of the same make, model and n of model years before/after SBL introduction. That does not mean, of course, that the 2 and 4 door cars on this file have the same accident exposure. But it does cut down the possibility for bias due to secular changes in market patterns, introduction of new models with 2 doors but not with 4 doors, etc.

3.1.3 Statistical significance testing

Since the analyses can be expected to show small effects, if any, it is important to test the statistical significance of any observed effect. Specifically, it is necessary to test if the "net effect for SBL" is significantly different from zero - i.e., if the gross reduction for 2 door cars is significantly different from the gross reduction for 4 door cars. The following data table is a generalized version of the entries in Table 3-1 and all the other data analyses of this chapter:

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons
4	last j before	n_{40}	N_{40}
	first j after	n_{41}	N_{41}
2	last j before	n_{20}	N_{20}
	first j after	n_{21}	N_{21}

Under the hypothesis that the net effect of SBL is zero, the actual observed n's of injuries would have to be replaced by expected values e_{20}, e_{21}, e_{40} and e_{41} satisfying the equations:

$$(e_{21}/N_{21})/(e_{20}/N_{20}) = (e_{41}/N_{41})/(e_{40}/N_{40})$$

$$e_{20} + e_{21} = n_{20} + n_{21}$$

$$e_{40} + e_{41} = n_{40} + n_{41}$$

$$e_{20} + e_{40} = n_{20} + n_{40}$$

The equations are solved for the e's, using the values of the n's and N's actually observed in the tabulated data. The solutions are used to calculate a chi square statistic:

$$X = (e_{20}-n_{20})^2/e_{20} + \dots + (e_{41}-n_{41})^2/e_{41}$$

The observed net effect of SBL will be termed "statistically significant with two-sided alpha = .05" whenever

$$Z = (X/fpc)^{.5}$$

is greater than 1.96, where

$$fpc = 1 - \min(n_{ij}/N_{ij})$$

is a finite population correction. Two-sided alpha = .05 is the criterion for statistical significance throughout Chapters 3-5. It should be noted, though, that an effect is significant at the .1 level if Z exceeds 1.645 and at the .01 level if Z exceeds 2.58.

3.2 Washington State data

NHTSA has acquired numerous State accident tapes to compile its Crash Avoidance Research data file. The tapes can be equally useful for crashworthiness analyses. Washington, however, was the only State whose tapes were suitable for evaluating SBL: NHTSA has tapes dating back to 1973 - and old data are needed to evaluate SBL, which were installed in 1967-68. Moreover, Washington data permit differentiation between 2 and 4 door cars - the VIN is recorded on the file and, additionally, the data contain codes to identify the vehicle type. Finally, police are instructed to identify every occupant involved in a crash, not just injured occupants. That makes it possible to compute injury rates. Injury severity is defined according to the ABC scale used by police in most States, as follows: A = disabling injury, B = non-disabling (evident) injury and C = possible injury. The data also indicate if an occupant was ejected or restrained.

Washington data for calendar years 1973-77 were analyzed. By 1977, the newest pre-SBL vehicles were 10 years old. Since those 5 years of data provided an ample number of accident cases, there was no need to use later years of data where the pre-SBL cars would have been even older. The first step of the data reduction was to identify those cars which were GM, Ford or Chrysler products built within 4 years of the company's SBL implementation date. The VINs were analyzed and compared to the police report's assessment of model, model year, number of doors and body style. If there was disagreement, the VIN-based assessments were used. Drivers, right-front, left-rear and right-rear passengers were identified and other occupant records discarded. Initially a vehicle oriented file was created, with occupant data on all 4 of those seat positions. That made it possible to identify if front seat occupants had somebody sitting behind them. Subsequently, an occupant oriented file was produced for the analyses. The 5 years of Washington data contained records of 395,624 front or rear outboard occupants of GM, Ford or Chrysler cars produced within 4 years of the SBL implementation date.

3.2.1 Analysis of injuries - full data set

Table 3-1, which has already been discussed to some extent in Sections 3.1.1 and 3.1.2, does not show any benefits for SBL in reducing fatal (K) or serious (A) injuries. Two door cars of the first year with SBL had an injury rate of 2.59 percent, which is 14 percent lower than the rate for 2 door cars of the last year before SBL (3.01%). But the control group of 4 door cars experienced a 15 percent reduction between the same 2 model years. (The energy-absorbing steering column, which was introduced in the same model year as SBL in GM and Ford cars, is partly responsible for the large injury reduction in both 2 and 4 door cars.) The net reduction for SBL - based on a comparison of the gross reductions for 2 door cars and the control group - is negative 1 percent and is not statistically significant, since Z is only 0.19, whereas 1.96 would be needed for significance (see Section 3.1.3).

When the data are extended to include 2 model years before and after the SBL implementation date, the net reduction for SBL is -4 percent, which is also nonsignificant. In the ±3 year comparison, the net effect is minus 11 percent, which is significantly different from zero, since Z = 2.38, which is greater than 1.96. The ±4 year result is negative 12 percent, again significant. The sequence of effectiveness estimates (-1, -4, -11 and -12 percent) shows a drift toward steadily worsening results. As stated in Section 3.1.2, this is probably due to an increasing divergence in the severities of crashes experienced by 2 and 4 door cars. If the sequence could be extrapolated back to a "±0 year estimate" - not subject to that kind of bias - it would probably show little effect for SBL. Note, also, that the gross injury rates in Table 3-1 never show an actual increase for 2 door cars; they just don't decrease as rapidly as for the 4 door cars. All this seems to support the conclusion that SBL had little or no effect.

Table 3-2 shows the corresponding results for moderate to serious (K, A or B) injuries. Here, the results are even less favorable for SBL. The sequence of net effectiveness results is -6, -6, -8 and -9 percent. The last three are significantly different from zero. The highly consistent sequence with only a slight negative drift is quite compatible with a conclusion that SBL had a negative 5 percent effect (although it is possible that the initial -6 percent result is just due to bad luck and the subsequent ones, bias plus bad luck).

TABLE 3-2

WASHINGTON STATE 1973-77: K + A + B (MODERATE/SERIOUS) INJURY RATES, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2,522	22,913	11.01		
	first 1 after	2,206	23,301	9.47	14	
2	last 1 before	3,632	28,541	12.73		
	first 1 after	3,804	32,533	11.69	8	-6% Z=1.86
4	last 2 before	5,429	46,787	11.60		
	first 2 after	4,573	47,855	9.56	18	
2	last 2 before	7,379	55,031	13.41		
	first 2 after	7,928	67,435	11.76	12	-6% Z=2.56*
4	last 3 before	8,134	68,407	11.89		
	first 3 after	6,449	68,411	9.43	21	
2	last 3 before	10,579	77,660	13.62		
	first 3 after	12,047	103,545	11.63	15	-8% Z=3.67*
4	last 4 before	10,403	85,055	12.23		
	first 4 after	8,160	87,130	9.36	23	
2	last 4 before	12,564	90,724	13.85		
	first 4 after	15,285	132,175	11.56	16	-9% Z=4.78*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

Table 3-3 shows that SBL had little or no net effect on overall (K + A + B + C) injury rates. The sequence of net reductions is 0, -2, -2 and -4 percent (only the last of them is statistically significant). It suggests a modest downward drift of about 1 percent for each additional model year and a starting point close to zero.

3.2.2 <u>Analysis of ejections - full data set</u>

The most disquieting results from Washington are contained in Table 3-4. They show a consistently large negative "net effect" of SBL on the risk of occupant ejection in a crash -- at least, based on the method defined in Section 3.1.1 for measuring net effect. The sequence of estimates is -41, -30, -25 and -35 percent. All of the estimates are statistically significant, even the one based on ±1 model year.

Major parts of this report are devoted to checking the effect on ejections in other data files and assessing how "real" the observed effects might be. Section 1.6 offered an intuitive explanation why ejection risk might have increased slightly for front seat occupants as a result of SBL. But that could hardly explain "increases" on the order of 30 percent as shown in Table 3-4. One possibility is that something besides SBL was done to 4 door cars but not to 2 door cars (or vice versa) at about the same time as SBL were implemented - i.e., that 4 door cars are not a true control group for the analysis of ejections; it will be discussed in Section 5.3.

Another explanation is that the "model" for estimating "net"

TABLE 3-3

WASHINGTON STATE 1973-77: OVERALL INJURY RATES, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	5,132	22,913	22.40		
	first 1 after	4,910	23,301	21.07	6	
2	last 1 before	6,990	28,541	24.49		
	first 1 after	7,551	32,533	23.20	5	none Z=0.32
4	last 2 before	10,784	46,787	23.05		
	first 2 after	10,022	47,855	20.94	9	
2	last 2 before	13,797	55,031	25.07		
	first 2 after	15,639	67,435	23.19	7	-2% Z=1.11
4	last 3 before	15,889	68,407	23.23		
	first 3 after	14,221	68,411	20.79	11	
2	last 3 before	19,575	77,660	25.21		
	first 3 after	23,885	103,545	23.07	8	-2% Z=1.67
4	last 4 before	20,118	85,055	23.65		
	first 4 after	17,997	87,130	20.66	13	
2	last 4 before	23,022	90,724	25.38		
	first 4 after	30,564	132,175	23.12	9	-4% Z=3.55*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 3-4

WASHINGTON STATE 1973-77: EJECTEES PER 1000 OCCUPANTS, ALL SEATING POSITIONS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	N of Occ.	Ejectees per 1000 Occ.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	118	22,913	5.15		
	first 1 after	82	23,301	3.52	32	
2	last 1 before	204	28,541	7.15		
	first 1 after	225	32,533	6.92	3	-41% Z=2.01*
4	last 2 before	260	46,787	5.56		
	first 2 after	172	47,855	3.59	35	
2	last 2 before	457	55,031	8.30		
	first 2 after	471	67,435	6.98	16	-30% Z=2.23*
4	last 3 before	406	68,407	5.94		
	first 3 after	238	68,411	3.48	41	
2	last 3 before	695	77,660	8.95		
	first 3 after	678	103,545	6.55	27	-25% Z=2.27*
4	last 4 before	553	85,055	6.50		
	first 4 after	297	87,130	3.41	48	
2	last 4 before	818	90,724	9.02		
	first 4 after	841	132,175	6.36	29	-35% Z=3.42*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

effectiveness, as defined in Section 3.1.2, simply does not function well in the present context. Table 3-4 reveals that the ejection risk in 2 door cars of the early post-SBL years (circa 1970) was nearly twice as high as in 4 door cars. (Note that convertibles have already been removed from the data and are not accounting for any of the difference.) Some of that difference is unquestionably due to the smaller size and more severe crashes of the 2 door cars - but certainly not all: Table B-4 in Appendix B shows that close to a 2 to 1 ratio persists even when the data are limited to cars of the same makes and models. Conversely, Tables 3-1 - 3-3 show that the injury rates in 2 door cars are only 10 to 25 percent higher than in 4 door cars - reflecting the fact that 2 door cars are in more severe crashes, but nowhere near a 2 to 1 ratio.

If 2 door cars have an intrinsically much higher ejection rate than 4 door cars, it could upset the model, which compares the relative risk reductions in 2 and 4 door cars. It would take a much larger absolute risk reduction in the 2 door cars to obtain the same relative reduction as in the 4 door cars - i.e., a zero "net effect." Table 3-4 shows that the negative "net effects" are not in any way due to an actual gross increase in the 2 door cars. In fact, the ejection risk always decreased in the 2 door cars. In absolute terms, the decrease was about the same as in the 4 door cars. But in relative terms, the decrease was much less in the 2 door cars since the base was greater.

Table 3-5 summarizes the net effects computed in Tables 3-1 - 3-4 and their statistical significance. Henceforth, only summary tables

TABLE 3-5

WASHINGTON STATE 1973-77: NET EFFECT OF SBL ON INJURY RISK (BY SEVERITY LEVEL) AND EJECTION RISK

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables 3-1 - 3-4)

Effect on Risk of		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
K + A (serious) injuries		-1	-4	-11	-12
	Z=	.19	.74	2.38*	2.95*
K + A + B (moderate/serious) inj.		-6	-6	-8	-9
	Z=	1.86	2.56*	3.67*	4.68*
Any injuries		none	-2	-2	-4
	Z=	.32	1.11	1.67	3.55*
Ejections		-41	-30	-25	-35
	Z=	2.01*	2.23*	2.27*	3.42*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

will accompany the text. The detailed tables showing injury rates are contained in Appendix B.

3.2.3 Analysis of injuries - matching makes and models

Section 3.1.2 suggested that biases could be further reduced by limiting the data to 2 and 4 door cars of the same makes and models. The results in Table 3-5, based on the full data set, tend to show a bias against 2 door cars which gets worse as more model years are included. So it is worthwhile to explore techniques that might reduce bias. With Washington data, the first step was to eliminate all vehicles whose VIN could not be deciphered to determine the number of doors - i.e., Chrysler products of 1965 or earlier and Buicks, Oldsmobiles and Pontiacs of 1964 or earlier. Matching post-SBL vehicles were likewise eliminated: Chryslers of 1970 or later and Buicks, Oldsmobiles and Pontiacs of 1969 or later. An additional precaution was to drop any car with unknown VIN or whose police-reported model, model year or body style did not match the VIN decode. All station wagons were dropped (convertibles had already been eliminated even from the "full" data set). Finally, all models produced only with 2 doors or only with 4 doors during 1963-71 were excluded: Challenger, Barracuda, Mustang, Pinto, Lincoln Mark, Cougar, Riviera, Cadillac Limousine, Eldorado, Corvette, Camaro, Monte Carlo, Vega, Toronado, Firebird and Grand Prix. The exclusions had the effect of cutting the sample size from 395,624 to 154,491.

Table 3-6 presents the net effectiveness estimates for the reduced data set, just as Table 3-5 showed them for the full data set.

TABLE 3-6

WASHINGTON STATE 1973-77: NET EFFECT OF SBL ON INJURY RISK (BY SEVERITY LEVEL) AND EJECTION RISK

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

(Summary of Tables B-1 - B-4)

Effect on Risk of		Net Effect of SBL (%)* — Number of Model Years before/after SBL Installation in 2 Door Cars: ±1	±2	±3	±4
K + A (serious) injuries		+5	-2	-7	-9
	Z=	.49	.32	1.14	1.55
K + A + B (moderate/serious) inj.		-2	-3	-4	-4
	Z=	.48	.99	1.15	1.41
Any injuries		none	-1	-1	-2
	Z=	.00	.55	.65	1.31
Ejections		-12	-17	-10	-20
	Z=	.49	1.00	.68	1.42

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. **None of the observed net effects were statistically significant** (two-sided alpha = .05 - i.e., Z greater than 1.96).

(Tables B-1 - B-4 in Appendix B show the actual injury rates on which Table 3-6 is based.) Table 3-6 suggests that the exclusions were generally helpful in reducing biases, because the negative results are not as negative as in Table 3-5. In fact, none of the net effects with the reduced data set are statistically significant. That may, however, be due to the smaller sample size as well as a reduction in bias.

Specifically, the sequence of net reductions for SBL on serious (K + A) injuries is 5, -2, -7 and -9 percent. That could be indicative of an initial positive effect for SBL with an ever increasing bias that masks the effect. A likelier explanation, however, is that the effect of SBL is close to zero, the bias against SBL is relatively weak and the initial, nonsignificant positive 5 percent effect for SBL is a coincidence. The evidence for the latter explanation is that the other results in Table 3-6 (moderate and minor injuries and ejections) show little bias or drift against SBL and that the injury rate in 2 door cars of the first year with SBL (see Table B-1) is lower than in subsequent years, contrary to the usual age trend and probably due to chance alone.

The sequence for moderate to serious (K + A + B) injuries is -2, -3, -4 and -4 percent. It suggests that SBL had little or no effect and that the method of limiting the data set to matching makes and models helped to eliminate most of the biases in the data. The sequence for all types of injuries, 0, -1, -1, and -2 percent, is even more supportive of both of those conclusions.

3.2.4 Analysis of ejections - matching makes and models

The limited data set's results on ejections are not too different from those of the full data set (Section 3.2.2). Table 3-6 shows that the sequence of estimates is -12, -17, -10 and -20 percent. Although none of these estimates is significantly different from zero and all of them are about half as large as for the full data set, the sequence nevertheless shows a consistent negative effect for SBL. Since the preceding section showed that the limited data set was successful in removing most of the year to year biases from the injury analyses, it is unlikely that the negative effect for ejections is due to those kinds of biases. Instead, it is necessary to consider the other possibilities mentioned in Section 3.2.2: (1) The negative effect is at least partly "real"; (2) Something was done to 4 door cars in 1967-68 that was not done to 2 door cars; (3) The model for computing effectiveness, based on the relative differences in the gross improvements for 2 and 4 door cars, is not suitable for studying ejection rates.

The limited data set shows clearly that the risk of ejection is intrinsically higher in 2 door cars than in 4 door cars, at least in cars of the 1963-71 era. Tables B-1, B-2 and B-3 show that injury rates in 2 door cars are only 10-15 percent higher than in 4 door cars of the same makes and models (presumably reflecting the fact that the 2 door cars are driven a little harder and have slightly more severe crashes, even for the same makes and models). But Table B-4 shows that 2 door cars have 60-90 percent higher ejection rates than 4 door cars of the same makes and models, a disproportionate increase in view of the small differences in the injury rates. Table B-4 also shows that the 2 door cars with SBL had consistently lower ejection rates than the 2 door cars without SBL and that the absolute risk reductions for the 2 door cars was as large or larger than the reductions in the 4 door cars. But in relative terms, the risk reductions in the 4 door cars were always larger than in the 2 door cars.

The Washington results on ejections will be compared to those in fatal accidents (Sections 4.3, 4.4 and 4.8.2) and in NHTSA's detailed data files (Sections 5.2 and 5.3). The report's conclusions on ejection are presented in Section 6.3.

3.2.5 Effect of SBL on injuries by seat position - full data set

The discussion of the sled tests (Section 2.2) identified three groups of persons with fundamentally different collision kinematics and potential SBL effects: front seat occupants with nobody sitting behind them, front seat occupants with somebody sitting behind them and back seat passengers. The Washington data set contains enough cases for separate analyses of all three groups. It is necessary, however, to use the full data set; the limited set of matching makes and models would be too sparse for the latter two groups of persons. The full data set, as found in Section 3.2.1, can cause biases and it is necessary to inspect the sequence of estimates for ±1, ±2, ±3 and ±4 model years to distinguish between possible real effects and biases.

The results for front seat occupants with nobody sitting behind

TABLE 3-7

WASHINGTON STATE 1973-77: NET EFFECT OF SBL ON INJURY RISK (BY SEVERITY LEVEL)

- BY SEAT POSITION -

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables B-5 - B-13)

Effect on Risk of	Net Effect of SBL (%)** — Number of Model Years before/after SBL Installation in 2 Door Cars: ±1	±2	±3	±4
FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM				
K + A (serious) injuries	none	-6	-11	-13
	Z= .00	.96	2.26*	2.95*
K + A + B (moderate/serious) inj.	-5	-9	-9	-11
	Z=1.34	3.11*	4.09*	5.50*
Any injuries	+1	-2	-3	-5
	Z= .35	1.26	1.95	3.94*
FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM				
K + A (serious) injuries	-23	-10	-15	-13
	Z= .79	.55	.94	.88
K + A + B (moderate/serious) inj.	-7	+6	+2	+2
	Z= .48	.63	.29	.35
Any injuries	-10	-4	-2	-2
	Z= 1.03	.62	.33	.50

***Statistically significant effect** (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 3-7 (concluded)

Effect on Risk of		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
BACK SEAT OCCUPANTS					
K + A (serious) injuries		-7	+11	-16	-14
	Z=	.24	.60	.93	.91
K + A + B (moderate/serious) inj.		-24	-3	-9	-4
	Z=	1.57	.33	1.09	.62
Any injuries		-12	+1	none	-2
	Z=	1.28	.14	.07	.40

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

them (explored in detail in Tables B-5, B-6 and B-7) ought to be similar to those for all occupants, because in the Washington accident files, 80 percent of all occupants are in the front seat and have nobody behind them. The top third of Table 3-7 shows that the observed "effects" for SBL are almost all unfavorable. The sequence of estimates for serious injuries is 0, -6, -11 and -13 percent. The last two numbers are statistically significant. The sequence appears to indicate that the true effect of SBL is close to zero and that the data contain a bias against SBL that grows by about 3 percent per year. The estimates for moderate to serious injuries are -5, -9, -9 and -11 percent; the last 3 numbers are statistically significant. This sequence suggests a slightly smaller bias against SBL and a zero or slightly negative "true" effect for SBL. The sequence for overall injury rates, 1, -2, -3, and -5 percent, indicates that SBL had little or no effect.

The data set of front seat occupants with somebody sitting behind them (documented in detail in tables B-8, B-9 and B-10) contains only a tenth as many cases as the preceding ones and is subject to more sampling error. In particular, none of the observed effects is significantly different from zero. Nevertheless, the sequences shown in the middle portion of Table 3-7 are rather consistent. The sequence for serious injuries is consistently negative for SBL with little apparent year to year bias: -23, -10, -15 and -13 percent. The sequences for moderate injuries (-7, 6, 2 and 2 percent) and overall injury risk (-10, -4, -2 and -2 percent) appear to converge to a zero effect for SBL. The Washington data are consistent with the sled test results (Table 2-7), which showed no SBL benefits for dummies in the front seat with a dummy positioned behind them. It is noteworthy that the reported injury rates for front seat occupants with a person behind them (Tables B-8 through B-10) are 25 to 100 percent higher than those for front seat occupants with nobody behind them. That may be largely due to underreporting of uninjured back seat occupants in minor crashes in Washington. But it may also partly reflect the risk of injuries to front seat occupants as a result of direct or indirect collisions with unrestrained back seat occupants - phenomena often seen in the sled tests.

The results for back seat passengers (see the lower section of Table 3-7 as well as Tables B-11, B-12 and B-13) are based on about the same number of cases as the preceding ones. The sequence of observed effects on serious injuries was -7, 11, -16 and -14 percent. For moderate to serious injuries it was -24, -3, -9 and -4 percent. The sequence for overall injury risk was -12, 1, 0 and -2 percent. Those trends suggest that the effect of SBL was zero, at best. They diminish the faint hopes, based on the sled tests, that SBL may have been of some utility, at least, for the back seat occupant.

3.2.6 Effect on injuries of restrained occupants - full data set

Belt usage has always been high in Washington [18]. There are enough (63,640) restrained occupants in the full data set for an analysis of the effects of SBL. The analysis is needed especially because the sled test study was limited to unrestrained occupants.

Table 3-8 (which, in turn, is based on the detailed Tables B-14, B-15 and B-16) is not favorable for SBL. The sequence of effects on serious (K + A) injuries is -16, -6, -25 and -21 percent. None of the effects was statistically significant: since belted occupants have lower injury rates than others, it takes a larger sample and/or effect to achieve significance. The sequence does not indicate any obvious year to year biases and a zero or negative effect for SBL. The sequence for moderate to serious injuries is -19, -11, -11 and -8 percent. If there is any bias here, it would seem to be in favor of SBL. Although the effects are not significant at the .05 level, they come "close" to significance (Z as high as 1.91) and the consistent trend seems to be negative for SBL. The four estimates for overall injury risk, 2, 0, -1 and -1 percent, indicate that SBL had little or no effect.

3.2.7 When children ride in the back seat

Intuitively, one situation where SBL might be especially effective is when the back seat is occupied by a child, e.g., up to 12 years old. In a frontal crash at moderate speed, the SBL may withstand the relatively light impact load of a child (see Table 5-4) and the seatback may retain the child within the safer rear half of the passenger compartment, whereas in a car without SBL, the child might be propelled over the folded seatback and contact the windshield, header, instrument panel or a front seat occupant. Table 3-9 presents Washington results on children up to age 12 who rode in the back seat (top half) as well as the persons who were sitting in front of those children (lower half). It is not limited to frontal crashes but includes all crash modes, since impact

TABLE 3-8

WASHINGTON STATE 1973-77: NET EFFECT OF SBL ON INJURY RISK (BY SEVERITY LEVEL)

- BELTED OCCUPANTS -

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables B-14 - B-16)

Effect on Risk of		Net Effect of SBL (%)* — Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
K + A (serious) injuries		**-16**	**-6**	**-25**	**-21**
	Z=	.60	.31	1.59	1.30
K + A + B (moderate/serious) inj.		**-19**	**-11**	**-11**	**-8**
	Z=	1.74	1.47	1.91	1.57
Any injuries		**+2**	**none**	**-1**	**-1**
	Z=	.29	.16	.41	.18

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. **None of the observed net effects were statistically significant** (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE 3-9

WASHINGTON STATE 1973-77: NET EFFECT OF SBL ON NONEJECTED OCCUPANTS' INJURY RISK (BY SEVERITY LEVEL) WHEN UNRESTRAINED CHILDREN# ARE IN THE BACK SEAT

- BY SEAT POSITION -

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
NONEJECTED UNRESTRAINED CHILDREN# IN THE BACK SEAT				
K + A (serious) injuries	+2	−145	−108	−71
	Z= .03	1.64	1.62	1.28
K + A + B (moderate/serious) inj.	+38	−3	none	+7
	Z= 1.57	.12	.00	.44
Any injuries	−9	−17	−11	−17
	Z= .42	1.12	.90	1.43
NONEJECTED FRONT SEAT OCCUPANTS WITH AN UNRESTRAINED CHILD# SITTING BEHIND THEM				
K + A (serious) injuries	−65	−234	−234	−162
	Z= .79	2.74*	3.19*	2.76*
K + A + B (moderate/serious) inj.	−6	−23	−10	−11
	Z= .20	.97	.59	.66
Any injuries	−38	−32	−24	−27
	Z=1.60	1.95	1.83	2.28*

***Statistically significant effect** (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Children up to (and including) 12 years old location is not coded in Washington, but ejectees are excluded so as to eliminate a situation where results are known to be unfavorable for SBL. The sample sizes for Table 3-9 are about 1/4 as large as those for back seat occupants of all ages (Table 3-7), almost precluding any hope for statistically meaningful results.

The numbers in Table 3-9 do not indicate effectiveness for SBL. Eight of the 12 results for children riding in the back seat are negative, although none are statistically significant even at the .1 level. All 12 of the effectiveness estimates for the persons sitting in front of those children are negative (lower half of Table 3-9) and 4 of them are statistically significant. Such results are unrealistic and typically are obtained when data are cut too thin. At any rate, though, there is nothing in Table 3-9 to support the hypothesis that SBL are especially useful when children ride in the back seat.

3.3 Texas data on drivers' injury risk

Automated Texas accident files for the years 1972-74 are available at NHTSA and were used in the evaluations of head restraints [24], side door beams [26], braking improvements [29], side marker lamps [25], and windshield improvements [27]. (Texas data were also available for 1977 and later calendar years but were not used because pre-1966 cars did not have their model years identified.) Texas files do not list VINs. On the other hand, they identify "body styles," such as 2 door sedan, coupe or hardtop; 4 door sedan or hardtop. While these classifications cannot be checked against VINs as in Washington, their distributions by make and model appeared to be correct. A major drawback of Texas data is that uninjured passengers are usually not listed on the police report - only drivers. Injury rates cannot be computed for passengers, so the analyses had to be limited to drivers. For the same reason, it is impossible to ascertain if there was anybody sitting behind the driver - thus, drivers with a person sitting behind them could not be separately analyzed. The data do not routinely indicate if a driver was ejected or restrained. A compensating advantage of the Texas data is that vehicle damage is described by the TAD system [44], making it possible to distinguish frontal from other crashes with reasonable confidence. Texas uses basically the same ABC scale for coding injuries as Washington.

The first step of the data reduction was to identify GM, Ford and Chrysler cars built within 4 years of the company's SBL implementation date. Since there are plenty of Texas data, station wagons as well as convertibles were excluded and the analysis limited to sedans, hardtops and coupes. A record was created for each driver, indicating the vehicle's model, model year, number of doors and damage location (frontal or other) and the driver's injury rating. The 3 years of Texas data produced a file containing 830,656 drivers, 346,540 of whom were known to have been in frontal crashes. The sample, then, appears at first glance to be twice as large as the 1973-77 Washington file. Texas, however, has a lower reporting threshold and, as a result, a lower injury rate. The number of injuries on the file (a more appropriate measure of effective sample size) is about the same for Texas (3 years - drivers only) and Washington (5 years - including passengers).

3.3.1 All crashes

Table 3-10 (which, in turn, is based on the detailed tabulations B-17 - B-22) indicates a perplexing trend at all severity levels. The results for the first model year after SBL installation, relative to the last year before SBL installation, are always favorable to SBL and, in the case of serious injuries, the 12 percent net reduction for SBL is statistically significant, although "just barely" so, at the .05 level (Z = 2.02). It is not significant at the .01 level. When one more model year is added to the analysis, the net effect drops to nothing and in the ±3 and ±4 year comparisons, the results are negative. Specifically, for serious injuries, the sequence of effectiveness estimates is 12, 0, -4 and -5 percent. For moderate to serious injuries, it is 6, -1, -6 and -7 percent (the last two estimates are significantly different from zero). The net effects on overall injury risk are 3, 0, -3 and a significant -4 percent. These sequences are ambiguous, especially considering the higher sampling error of the estimates based on fewer model years. One possibility is that the effect of SBL is positive, strongly so for serious injuries, and that there is a strong year to year bias working against SBL. A much likelier explanation is that the results for ±1 model year are distorted by sampling error (even to the point of spurious significance in the case of serious injuries), the net effect of SBL is close to zero and there is a slight year to year bias against SBL, resulting in modestly negative estimates in the ±3 and ±4 model year comparisons. The best evidence for the second explanation is that the sequences become stable after the ±2 model year comparison and especially after the ±3 model year comparison, showing little year to year drift. Most of the

TABLE 3-10

TEXAS 1972-74: NET EFFECT OF SBL ON
DRIVERS' INJURY RISK (BY SEVERITY LEVEL)

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables B-17 - B-22)

Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
DRIVERS IN ALL CRASHES				
K + A (serious) injuries	+12 Z= 2.02*	none .08	-4 1.11	-5 1.35
K + A + B (moderate/serious) inj.	+6 Z= 1.83	-1 .43	-6 3.08*	-7 4.15*
Any injuries	+3 Z= 1.29	none .01	-3 1.91	-4 2.86*
DRIVERS IN FRONTAL CRASHES				
K + A (serious) injuries	+16 Z= 2.03*	+6 1.00	+2 .48	+1 .51
K + A + B (moderate/serious) inj.	+8 Z= 1.83	+3 .98	-2 .33	-2 1.08
Any injuries	+8 Z= 2.16*	+3 1.32	+1 .59	none .18

***Statistically significant effect** (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

movement is between the ±1 and ±2 year results, indicating that the ±1 year result is "off" due to sampling error and the additional model year "evened things up."

3.3.2 Frontal crashes

The pattern for frontal crashes, shown in the lower half of Table 3-10, is nearly identical to the one for all crashes, although slightly more favorable to SBL. The sequence for serious injuries is uniformly positive: 16, 6, 2 and 1 percent. The first of those estimates is "barely" significant at the .05 level ($Z = 2.03$) but not at the .01 level; the remainder are not significant even at the .1 level. For moderate injuries, the sequence is 8, 3, -2 and -2 percent (none of them significant). The observed effects of SBL on overall injury risk in frontal crashes are 8, 3, 1 and 0 percent, only the first of which is significant at the .05 level, although not at the .01 level. As above, the best explanation would appear to be that the first year's results are off due to sampling error, the effect of SBL is small or zero and there is a slight year to year bias against SBL. The most optimistic note is that the results for frontal crashes are uniformly a bit better than for all crashes. That might be construed as a slight positive effect in frontal crashes, although, to be sure, there is no statistically significant basis for saying so.

3.4 New York State data - effect of SBL by injury type

Automated New York State accident files have the exceptional advantage of using the New York State Injury Coding System (NYSICS), which describes the body region, type and severity of a victim's principal injury. The data were used to great advantage in NHTSA's evaluation of windshield improvements [27], where they appropriately identified what types of injuries were mitigated by High Penetration Resistant windshields. Only the 1974 and 1977 files were available for access at NHTSA. The latter was not used because it contains too few pre-SBL cars (the lifespan of the average auto is short because of the New York climate). For the evaluation of SBL, injury rates are computed for each specific injury type - e.g., the percentage of all occupants who have a fractured leg. Each of these specific injury rates is then subjected to the same analyses as were applied to the K + A, K + A + B, and overall injury rates in Washington and Texas.

The data reduction for New York was almost the same as for Washington. New York codes the vehicle make and body style (2 or 4 doors) but not the model; however, the VIN is coded as well. As in Washington, GM, Ford and Chrysler cars built within 4 years of the SBL implementation date were selected. The number of doors was based on the VIN, when known and decodable, and on the police report, otherwise. Station wagons were included but convertibles excluded. An occupant oriented file was created, containing a record for each driver, right-front, left-rear or right-rear passenger. The file, based on a single year of New York data, contained 142,862 records.

Table 3-11 shows the net effect of SBL on each of the 19 most common specific injury types in New York. The detailed data on the numbers of injuries of each type and the injury rates is presented in Table B-23 for the ±1 model year comparison, Table B-24 for ±2 model years, Table B-25 for ±3 model years and Table B-26 for ±4 model years. The injuries are listed by frequency of occurrence, with the most common - minor head or facial bleeding - listed first. Five more severe injury types, which would usually be rated 2 or higher on the Abbreviated Injury Scale (AIS) [1] are denoted by capital letters.

Table 3-11 suggests that SBL might have increased the risk of injuries with minor head or facial bleeding. The sequence of effectiveness estimates, -9, -5, -9, and -9 percent shows no drift or bias in either direction. The last two numbers in the sequence are statistically significant. The results for injuries involving severe head or facial bleeding are also unfavorable, with a sequence of -10, -11, -12 and -17 percent. None of those estimates is statistically significant, however, and a slight year to year drift against SBL may have made the last number worse than it really is. The results for concussions are likewise bad: -53, -20, -14 and -16 percent. In fact, for every type of head injury, the numbers are consistently negative. The sled test results (Table 2-5) showed a slight, although nonsignificant tendency toward lower head injury with SBL. The New York data essentially end that hope.

Table 3-11 shows little net effect on injuries to other body regions. The sequence for neck or back pain is uniformly negative: -18, -13, -6 and -7 percent. The ±2 year estimate is "barely" significant at the .05 level (Z = 2.01). The smaller, nonsignificant ±3 and ±4 year

TABLE 3-11

NEW YORK STATE 1974: NET EFFECT OF SBL ON INJURY RISK

- BY INJURY TYPE -
(Ordered by frequency of occurrence - most common first.
Capital letters denote the more serious injury types.)

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables B-23 - B-26)

Body Region	Injury Type		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Head	minor bleed.		-9	-5	-9	-9
		Z=	1.23	.89	1.98*	2.21*
Neck/back	pain		-18	-13	-6	-7
		Z=	1.90	2.01*	1.03	1.43
Head	pain		-3	+2	-2	-7
		Z=	.25	.24	.37	1.20
Leg	pain		+1	+2	+2	+5
		Z=	.18	.26	.28	.64
Head	contusion		+10	-12	-6	-10
		Z=	.74	1.16	.70	1.23
Arm	pain		+9	+11	+2	+4
		Z=	.60	1.04	.25	.51
Torso	pain		+1	+2	+3	+4
		Z=	.05	.13	.33	.50
HEAD	SEVERE BLEED.		-10	-11	-12	-17
		Z=	.60	.92	1.14	1.82

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 3-11 (concluded)

Body Region	Injury Type		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Leg	contusion		-12	-16	-9	-6
		Z=	.52	.91	.62	.52
Arm	minor bleed.		-24	-22	-24	-17
		Z=	.90	1.18	1.52	1.21
Head	abrasion		-3	-7	-20	-13
		Z=	.12	.41	1.24	.90
HEAD	CONCUSSION		-53	-20	-14	-16
		Z=	1.63	1.01	.85	1.03
Leg	minor bleed.		+1	none	-2	-10
		Z=	.03	.02	.11	.62
All over	pain		+52	+12	-3	none
		Z=	2.49*	.63	.16	.01
Arm	contusion		-13	-24	-31	-24
		Z=	.36	.92	1.37	1.23
Leg	abrasion		-19	-16	-21	-10
		Z=	.52	.63	.94	.51
LEG	FRACTURE		+14	-8	+11	+1
		Z=	.45	.31	.56	.01
ARM	FRACTURE		+27	+18	+20	+10
		Z=	.78	.73	.93	.45
TORSO	INTERNAL		-24	+4	+6	+14
		Z=	.52	.14	.22	.69

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 3-12

NEW YORK STATE 1974: NET EFFECT OF SBL ON INJURY RISK, NONEJECTED OCCUPANTS IN FRONTAL IMPACTS

- BY INJURY TYPE -
(Ordered by frequency of occurrence - most common first. Capital letters denote the more serious injury types.)

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

			Net Effect of SBL (%)**			
			Number of Model Years before/after SBL Installation in 2 Door Cars			
Body Region	Injury Type		±1	±2	±3	±4
Head	minor bleed.		-8	none	-4	-6
		Z=	.96	.01	.85	1.26
Head	pain		-18	-3	-6	-9
		Z=	1.35	.33	.81	1.22
Neck/back	pain		-21	-20	-8	-11
		Z=	1.19	1.66	.79	1.24
Leg	pain		-2	+6	+8	+11
		Z=	.14	.57	.87	1.33
Head	contusion		-1	-13	-9	-15
		Z=	.05	1.03	.88	1.64
HEAD	SEVERE BLEED.		+5	+1	-3	-9
		Z=	.29	.07	.23	.86
Torso	pain		+10	+13	+12	+13
		Z=	.51	.98	1.06	1.29
Arm	pain		-5	+9	-1	+2
		Z=	.26	.69	.07	.15

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 3-12 (concluded)

Body Region	Injury Type		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Leg	contusion		-56	-38	-31	-22
		Z=	1.70	1.71	1.73	1.38
Head	abrasion		-10	-13	-22	-12
		Z=	.33	.62	1.24	.75
HEAD	CONCUSSION		-16	-15	-3	-6
		Z=	.46	.64	.13	.32
Arm	minor bleed.		none	-14	-24	-20
		Z=	.01	.57	1.14	1.09
Leg	minor bleed.		+17	+9	+12	-2
		Z=	.56	.43	.67	.13
All over	pain		+65	-7	-23	-22
		Z=	2.82*	.25	.87	.89
Leg	abrasion		-60	-27	-36	-19
		Z=	1.19	.88	1.29	.83
Arm	contusion		+22	+17	-1	-4
		Z=	.60	.60	.02	.16
LEG	FRACTURE		+25	-6	-7	-20
		Z=	.74	.22	.30	.81
HEAD	FRACTURE		+10	+7	+16	+16
		Z=	.23	.21	.62	.65
TORSO	INTERNAL		-10	+10	+14	+24
		Z=	.19	.32	.52	.99
ARM	FRACTURE		-6	+1	+3	-5
		Z=	.12	.02	.09	.18

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

estimates, however, suggest that the significance of the ±2 year number may be spurious. The only injury type with consistently good results is arm fractures, with 27, 18, 20 and 10 percent reductions. None of them are even close to statistical significance (Z is always less than 1). The mildly positive results on arm pain (a less severe form of blunt arm trauma) support the result on the fractures, but the results on arm contusions are consistently negative. The New York data show a slightly positive, although certainly nonsignificant effect on internal torso injuries, but little or no effect on torso "pain." Effects on leg injuries are close to zero.

Table 3-12 is identical to Table 3-11 except that it is limited to frontal impacts and occupants who were not ejected - i.e., the crash mode where SBL might be expected to have the most favorable results. The effectiveness estimates differ little, however, from those in Table 3-11. For example, in the ±1 year comparison column of Table 3-11, there are 8 positive and 11 negative results, whereas there are 7 positives and 12 negatives in the corresponding column of Table 3-12. Similarly, there are 6 positive results in the ±4 year column of Table 3-11 and 5 in the same column of Table 3-12. The only finding that offers any encouragement is that 7 of the 8 results for torso injuries are positive; none of them, however, are statistically significant even at the .1 level. Moreover, the positive results on torso injuries might be a consequence of the negative findings on almost all other injury types: since New York police record only one injury per person, an increase of more visible wounds in other body regions means fewer opportunities to record torso injuries.

CHAPTER 4

ANALYSES OF THE FATAL ACCIDENT REPORTING SYSTEM

The Fatal Accident Reporting System (FARS) is a census of the nation's fatal accidents since 1975. By the end of 1985, FARS contained records of 36,993 fatalities who were occupants of passenger cars built within 4 years before or 4 years after the seat back lock (SBL) implementation date. Analyses of the FARS data did not show SBL effective in reducing fatality risk. Just as in nonfatal accident data from Washington State, the risk of ejection was always higher in 2 door cars than in 4 door cars, but significantly more so in the years after the implementation of SBL.

4.1 Analysis method

The analysis of State accident data (Section 3.1) consisted of calculating the change in injury rates in 2 door cars, before vs. after SBL, and comparing it to the corresponding change in the control group of 4 door cars (see Section 3.1.1). The analysis was initially limited to cars of the last model year before SBL was implemented vs. the first year after SBL implementation. Subsequently, it was extended to 2 model years before/after SBL, then ±3 model years, then ±4 (see Section 3.1.2). The same procedure is used for analyzing FARS, with one important difference. The State data contained records of all crash involved occupants and it was possible to compute injury rates directly - i.e., the number of injured persons divided by the number of crash involved persons (injured plus uninjured). FARS does not contain records of all crash involved persons, only those who were in fatal crashes. Fatality rates cannot be computed per 100 crash involved persons. Instead, the rates must be formulated as the number of fatalities per some unit of exposure. In this chapter, fatality rates are computed per million vehicle years, as described in Section 4.1.2.

4.1.1 Fatality data

FARS includes VINs for crash involved vehicles. For those make, model and model year combinations where the VIN contains information on the number of doors, this information was used in the analysis. FARS also contains a separate variable explicitly indicating the number of doors. Unfortunately, this variable is useless because cars whose VIN does not contain information about the number of doors are almost always coded as "2 door cars." Thus, the analysis had to be limited to cars with known and decodable VIN's. That limited the file to GM, Ford and Chrysler products. Furthermore, all 1963-64 Buicks, Oldsmobiles and Pontiacs and all 1964-65 Chrysler products were excluded, because the VINs could not be decoded to indicate the number of doors. It was decided to exclude all 1969-70 Buicks, Oldsmobiles and Pontiacs and 1970-71 Chrysler products, since these cars produced 3-4 years after the SBL implementation date would have had no counterparts on the file, produced 3-4 years before SBL. All convertibles were excluded to avoid biases, as explained in Section 3.1.2. So were subcompacts (Pinto and Vega), which had no counterpart in the pre-SBL years. The file was limited to drivers and to passengers in the right front, left rear and right rear seat positions. This was the "full" FARS data set used for most of the analyses. It contained records of 36,993 fatalities as well as 11,068 occupants who were ejected from their vehicle (but not necessarily killed).

Some analyses were performed with a "reduced" data set from which station wagons and all make/models which were produced only with 2 doors or only with 4 doors had been eliminated. The detailed definitions for the reduced data set are identical to those used with Washington data. The reduced data set contained 28,618 fatalities. The data losses between the full and the reduced sets are less severe than in Washington since, as described above, many cases were already excluded from the "full" FARS data set.

4.1.2 Exposure data

The unit of exposure used as the denominator in the calculation of fatality rates is a million vehicle years. The number of vehicle years exposure accumulated by a particular make/model/model year/n of doors combination is the number of vehicles of that type registered in 1975, plus the number registered in 1976, etc., up to and including the number registered in 1985. Ideally, this number could be obtained directly from R. L. Polk registration files, which show the number of cars of a given type and model year that are registered in a given calendar year [13]. The Polk files, unfortunately, do not provide detailed make/model data for model years earlier than 1966. In any given calendar year, they do not provide detailed data for cars more than 10 years old. For this study, which requires exposure data for cars as old as model year 1963 during calendar years as recent as 1985, an imputation procedure comprising 5 steps was devised.

Step 1: Extraction of the actual Polk registration data for calendar year 1975, for cars of the last model year before SBL (1966 for GM and 1967 for Ford and Chrysler) and the first model year after SBL implementation (1967 GM and 1968 Ford and Chrysler), using automated files available at NHTSA. Convertibles, limousines and pickup-based passenger cars were dropped. All others were classified as 2 door cars (hardtops, coupes and sedans), 4 door cars (hardtops and sedans) or 4 door station wagons. These constituted the "full" data set. Make/models produced only with 2 doors or only with 4 doors, such as Mustang and Camaro, as well as station wagons were identified and excluded from a "reduced" data set. The full and reduced data sets correspond to those defined for FARS data in Section 4.1.1 and indicate the exposure accumulated during 1975 by cars produced within 1 year of the SBL implementation date.

Step 2: Estimation of 1975-85 exposure of cars built within 1 year of the SBL implementation date. Step 1 indicated exactly how many cars of each make/model/body style were on the road in 1975. This step estimates how many remained on the road in each subsequent year. "MVMA Motor Vehicle Facts & Figures '82" specifies how many cars of each model year were still on the road in any calendar year up to 15 years later [37]. The proportions of cars still in service were averaged across model years to obtain survival rates up to age 15. Between ages 10 and 15, nearly 20 percent of the cars still remaining on the road are retired each year. Survival rates for ages 16-22 are estimated on the assumption that the 20 percent annual decay rate persists beyond age 15. The survival rates for cars aged 2-22 are:

Age	% Surviving	Age	% Surviving	Age	% Surviving
2	99	9	65	16	13
3	98	10	55	17	10.5
4	95	11	44	18	8
5	92	12	35	19	6.5
6	89	13	28	20	5
7	83	14	22	21	4
8	75	15	17	22	3

During 1975, for example, 1966 GM cars were 9 years old and an estimated 65 percent of the original supply were still on the road. During 1976, only 55 percent of the original supply were on the road. Thus, the 1966 GM cars accumulated 55/65 as many exposure years during 1976 as they did in 1975. They accumulated (65+55+44+35+28+22+17+13+10.5+8+6.5)/65 = 4.68 times as many exposure years during 1975-85 as they did during 1975 alone. A similar multiplication factor is developed for each of the other model years:

Model Year	Exposure Years Accumulated in 1975-85 / Exposure Years Accumulated in 1975
1963	4.34
1964	4.39
1965	4.44
1966	4.68
1967	4.97
1968	5.39
1969	5.91
1970	6.58
1971	7.19

The Polk registration figures for calendar year 1975 are multiplied by the appropriate multiplication factor to estimate the registration years accumulated during 1975-85. For example, if 100 vehicles of a particular 1968 car were still on the road in 1975, these 100 vehicles would accumulate approximately 539 exposure years during 1975-85. Finally, the Polk data, weighted by the appropriate multiplication factors, are tabulated to obtain the following exposure estimates for both the full and reduced data sets:

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	N of Exposure Years Accumulated in 1975-85
4	last 1 before	$N1_{40}$
	first 1 after	$N1_{41}$
2	last 1 before	$N1_{20}$
	first 1 after	$N1_{21}$

Step 3: Polk data are not generally available for cars produced more than one model year before the SBL implementation date. Exposure data for those model years, as well as the corresponding model years more than one year after SBL, are imputed from 1973-77 Washington State accident involvements, adjusted in Steps 4 and 5 to estimate 1975-85 nationwide vehicle years. The starting point is the "full" file of front and rear outboard occupants of GM, Ford and Chrysler cars, produced within 4 years of the SBL implementation date, involved in crashes during 1973-77 in Washington State (see Section 3.2). The underlying premise is that the number of accident involved occupants (including nonfatal and noninjury crashes), for a particular type of vehicle, is a measure of exposure of that type of vehicle and, with appropriate adjustment factors, "accident involvements" can be used as a surrogate for "vehicle years."

The first task is to subset the "full" Washington file so that it corresponds exactly to the definition of the "full" FARS and Polk files. Any case with unknown VIN or for which the VIN was inconsistent with the police report's codes for make, model or model year was dropped from the Washington data. So were Buicks, Oldsmobiles, Pontiacs and Chrysler Corp. products produced more than 2 years after the SBL implementation date as well as all subcompacts. The "reduced" Washington file already corresponds exactly to the "reduced" FARS and Polk files.

Step 4: The Washington accident involvements for calendar years 1973-77 (median year 1975) are weighted by the multiplication factors defined in Step 2 (e.g., 4.34 for MY 1963 cars) to estimate the number of accident involvements these cars would have accumulated during 1975-85. For example, if 100 occupants of a particular 1968 make/model were in accidents during 1975, approximately 539 would have been in crashes during 1975-85. The data, weighted by the appropriate multiplication factors, are tabulated to obtain the following Washington State "exposure" estimates for both the full and reduced data sets:

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	Washington Exposure Units Accumulated in 1975-85
4	last j before	Wj_{40}
	first j after	Wj_{41}
2	last j before	Wj_{20}
	first j after	Wj_{21}

Step 5: The Washington "exposure" estimates defined in Step 4 are not good national estimates, primarily because Washington had a higher proportion of 2 door cars than the national average, year after year. The Washington accident counts Wj_{ki} for the jth year before/after SBL implementation, however, can be converted into national estimates of vehicle exposure years $N'j_{ki}$ as follows:

$$N'j_{ki} = N1_{ki}(Wj_{ki}/W1_{ki})$$

where $N1_{ki}$ is the Polk estimate defined in Step 2. Note that

$$N'1_{ki} = N1_{ki}(W1_{ki}/W1_{ki}) = N1_{ki}$$

In other words, use the Polk estimates for the ± 1 model year exposure data, where they are known. For the ± 2, ± 3 and ± 4 year estimates, multiply the ± 1 year Polk number by the relative growth in the Washington accident counts $(Wj_{ki}/W1_{ki})$.

The exposure estimates as defined in Steps 1-5 will undoubtedly be inaccurate for some makes and models. For example, models that have greater than average longevity will have their exposure underestimated, the more so the older they get, because the procedure assumes the same survival rate for all models. Nevertheless, biases of this source would not tend to be large between one model year and the next one, but rather to increase gradually as a wider range of model years is added to the analysis. For example, if 4 door cars have higher survival rates than 2 door cars, the fatality rate for 4 door cars, based on the exposure estimates defined here, would be slightly higher in the last year without SBL than in the first year with SBL; the rate for 2 door cars would be slightly lower; the net result would be a slight bias against SBL. But if the analysis is expanded to include cars up to 4 years before and after the SBL implementation date, the bias would be much larger. Thus, the technique of obtaining a sequence of 4 estimates - for the ±1, ±2, ±3, and ±4 model year analyses - is especially important in this chapter, since any biases in the exposure data should manifest themselves as a gradual drift in the sequence of effectiveness estimates.

4.1.3 Statistical significance testing

The procedure for testing the statistical significance of FARS results is nearly the same as was defined for State data in Section 3.1.3. The only differences are that the first equation in Section 3.1.3 is replaced by:

$$(e_{21}/N'j_{21})/(e_{20}/N'j_{20}) = (e_{41}/N'j_{41})/(e_{40}/N'j_{40})$$

where $N'j_{ki}$ are the estimates of exposure defined in Section 4.1.2 and that the finite population correction (fpc) is always 1 - i.e., there is no fpc since the fatality count is a Poisson, not a binomial variable. The observed net effect of SBL will be termed "statistically significant with two-sided alpha = .05" whenever

$$Z = X^{.5}$$

is greater than 1.96. Two-sided alpha = .05 is the criterion for statistical significance throughout Chapters 3-5. It should be noted, though, that an effect is significant at the .1 level if Z exceeds 1.645 and at the .01 level if Z exceeds 2.58.

4.2 Effect on fatalities

Table 4-1 shows that SBL did not have a beneficial effect on

TABLE 4-1

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2463	12.632	195.0		
	first 1 after	2586	14.688	176.1	10	
2	last 1 before	2863	10.858	263.7		
	first 1 after	3827	13.942	274.5	-4	-15% Z=3.80*
4	last 2 before	4232	24.934	169.7		
	first 2 after	5738	32.552	176.3	-4	
2	last 2 before	4963	20.198	245.7		
	first 2 after	8679	31.280	277.5	-13	-9% Z=3.09*
4	last 3 before	4845	30.866	157.0		
	first 3 after	7436	40.356	184.3	-17	
2	last 3 before	5824	25.300	230.2		
	first 3 after	12550	41.782	300.4	-30	-11% Z=4.34*
4	last 4 before	5286	36.013	146.8		
	first 4 after	9548	49.249	193.2	-32	
2	last 4 before	6200	28.141	220.3		
	first 4 after	15959	50.068	318.7	-45	-10% Z=4.16*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

overall fatality risk. During 1975-85 there were 2463 occupant fatalities in 4 door cars of the last model year before SBL; those cars accumulated 12.632 million vehicle years in that time. The fatality rate was 195 per million vehicle years. The fatality rate in 4 door cars of the first year after the SBL implementation date was 176.1; thus, the fatality rate decreased by 10 percent in the control group. But in the 2 door cars, the rate increased by 4 percent in the first year with SBL. The net effect - the relative difference of the gross reductions - is a statistically significant 15 percent increase of fatality risk associated with SBL. In fact, the increase is significant at the .01 level because Z = 3.80.

When the data are extended to include 2 model years before and after the SBL implementation date, the net reduction for SBL is -9 percent, which is statistically significant. In the ± 3 year comparison, the net effect is -11 percent and in the ± 4 year comparison, it is -10 percent, both significant. The sequence of effectiveness estimates (-15, -9, -11, and -10 percent) shows great stability after the first year and little or no drift in either direction.

One trend that is obvious in Table 4-1 is that fatality rates <u>per million vehicle years</u> get steadily lower as the cars get older. The median age of cars in these FARS analyses is approximately 10 years. At those ages, cars are driven fewer miles each additional year and the decrease in absolute mileage is no longer offset by increases in the "riskiness" of the miles, as it would be at an earlier stage in a car's lifespan. Thus, the fatality rate per year decreases. (NHTSA's evaluation of side marker lamps [25], pp. 109-115, provides additional detail.)

Specifically, the sequences of <u>gross</u> reductions in the fatality rate worsen by almost exactly 14 percent for each additional model year of data, both for the control group (10, -4, -17, and -32) and the 2 door cars (-4, -13, -30, and -45). Since both sequences of gross reductions worsen at the same rate, there is little or no drift in the sequence of net reductions.

The exception to the 14 percent trend is the model year in which SBL were implemented. It coincided with the implementation of other important safety devices, such as energy absorbing steering assemblies in GM and Ford cars. The 4 door cars experienced a 10 percent decrease rather than a 14 percent increase in the fatality rate per million years, reflecting a large reduction of "intrinsic" fatality risk. The 2 door cars experienced a 4 percent increase rather than a 14 percent increase - not as good as the 4 door cars but still a reduction of "intrinsic" risk. As will be shown in Section 4.3, most of the added benefits in the 4 door cars are attributable to a reduction of occupant ejections.

Table 4-2 is identical to Table 4-1, except that the analysis is performed on the "reduced" data set, which excludes station wagons and models that were produced only with 2 doors or only with 4 doors. The exclusion of station wagons, which are typically owned by "safe" drivers, increased the fatality rates for 4 door cars (e.g., 216.4 for cars of the first 4 years after the SBL implementation date, vs. 193.2 in Table 4-1). The exclusion of "sporty" models produced only with 2 doors decreased the fatality rates for 2 door cars (e.g., 302.7 for cars of the first 4 years

TABLE 4-2

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, ALL OCCUPANTS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2089	10.121	206.4		
	first 1 after	2186	11.402	191.7	7	
2	last 1 before	2079	8.367	248.5		
	first 1 after	2724	10.317	264.0	-6	-14% Z=3.18*
4	last 2 before	3615	19.870	181.9		
	first 2 after	4869	25.096	194.0	-7	
2	last 2 before	3578	15.928	224.6		
	first 2 after	6181	23.607	261.8	-17	-9% Z=2.92*
4	last 3 before	4151	24.381	170.3		
	first 3 after	6263	30.586	204.8	-20	
2	last 3 before	4118	19.309	213.3		
	first 3 after	9056	31.865	284.2	-33	-11% Z=3.73*
4	last 4 before	4522	28.379	159.3		
	first 4 after	8038	37.147	216.4	-36	
2	last 4 before	4481	22.362	200.4		
	first 4 after	11577	38.241	302.7	-51	-11% Z=4.16*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

with SBL, vs. 318.7 in Table 4-1). Thus, the reduced data set made the fatality rates in 2 door cars closer to those in 4 door cars. But it did so in equal measure for the pre-SBL and post-SBL eras. As a result, the net effect of SBL was virtually unchanged. The sequence of effectiveness estimates for the reduced data set (-14, -9, -11, and -11 percent, all statistically significant) is almost identical to the sequence in Table 4-1 (-15, -9, -11, and -10).

4.3 Effect on ejections

All crashes on FARS must have at least one fatality in them, but FARS also provides data on the survivors in those crashes. In order to maximize sample sizes, the analyses of ejections include persons who were ejected and killed plus persons who were ejected and survived a crash that was fatal to someone else.

Table 4-3 shows a consistently large negative net effect for SBL on the number of ejectees per million vehicle years. The sequence of effectiveness estimates, -42, -26, -24 and -23 percent (all statistically significant) is remarkably similar to what was observed in the Washington State nonfatal accident data (-41, -30, -25, and -35 percent, according to Table 3-4). The FARS sequence is quite stable after the first model year and, if anything, shows a slight drift in favor of SBL, suggesting a "true" effectiveness value of perhaps -27 percent. Since, during the SBL implementation era, about 25-30 percent of all passenger car fatalities were ejectees, the 10 percent net increase in overall fatality risk (see Table 4-1 and Section 4.2) is to a large extent attributable to the 27 percent net increase in ejections.

TABLE 4-3

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, ALL SEATING POSITIONS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	597	12.632	47.3		
	first 1 after	516	14.688	35.1	26	
2	last 1 before	1004	10.858	92.5		
	first 1 after	1360	13.942	97.6	-6	-42% Z=4.80*
4	last 2 before	1019	24.934	40.9		
	first 2 after	1190	32.552	36.6	11	
2	last 2 before	1727	20.198	85.5		
	first 2 after	3026	31.280	96.7	-13	-26% Z=4.49*
4	last 3 before	1191	30.866	38.6		
	first 3 after	1595	40.356	39.5	-2	
2	last 3 before	2084	25.300	82.3		
	first 3 after	4361	41.782	104.4	-27	-24% Z=4.56*
4	last 4 before	1341	36.013	37.2		
	first 4 after	2048	49.249	41.4	-11	
2	last 4 before	2234	28.141	79.4		
	first 4 after	5445	50.068	108.8	-37	-23% Z=4.81*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

Table 4-4, which is based on the "reduced" FARS data set, shows nearly the same sequence of effectiveness estimates: -47, -25, -20 and -21 percent, all statistically significant. Although the exclusion of 4 door station wagon and 2 door "sporty" models slightly reduced the difference between 2 door and 4 door ejection rates, it did so equally for pre and post-SBL. As a result, net effects were the same as for the "full" data set. Since, with FARS, there are few differences between the full and reduced data sets, the analytic results in the remainder of the chapter will mostly be based on the full data set.

Statistically, what is causing the alarming "net" increases in ejection risk? In the Washington data (Tables 3-4 and B-4), gross ejection rates decreased substantially for both 2 door and 4 door cars. In fact, the absolute risk decreases were equally large for both types of cars. Since 2 door cars, however, had a much higher baseline ejection rate than 4 door cars, the relative decrease was larger in the 4 door cars; hence, the negative net effect. In FARS, the picture is even less attractive. Table 4-3 shows that the sequence of "gross" reductions for 4 door cars is 26, 11, -2, and -11 percent. For 2 door cars it is -6, -13, -27, and -37 percent. Both sequences have a drift of about -11 percent per added model year. If the sequences could be carried backwards to a "±0 model year" comparison (indicating the "true" effects without age related bias), they would indicate about a 33 percent reduction of ejection risk in 4 door cars in the SBL implementation year and only a 7 percent reduction in the 2 door cars.

TABLE 4-4

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, ALL SEATING POSITIONS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	509	10.121	50.3		
	first 1 after	421	11.402	36.9	27	
2	last 1 before	684	8.367	81.7		
	first 1 after	909	10.317	88.1	-8	-47% Z=4.63*
4	last 2 before	852	19.870	42.9		
	first 2 after	978	25.096	39.0	9	
2	last 2 before	1204	15.928	75.6		
	first 2 after	2035	23.607	86.2	-14	-25% Z=3.83*
4	last 3 before	991	24.381	40.6		
	first 3 after	1301	30.586	42.5	-5	
2	last 3 before	1423	19.309	73.7		
	first 3 after	2956	31.865	92.8	-26	-20% Z=3.48*
4	last 4 before	1119	28.379	39.4		
	first 4 after	1676	37.147	45.1	-14	
2	last 4 before	1568	22.362	70.1		
	first 4 after	3725	38.241	97.4	-39	-21% Z=3.96*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.
#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

In other words, something was done to 4 door cars during the SBL implementation year to reduce ejections dramatically (by 33 percent). Obviously, that "something" had nothing to do with SBL, since they were not installed in 4 door cars. In 2 door cars, ejection risk decreased only marginally (by 7 percent) - much less than in 4 door cars in relative and even in absolute terms. Four factors might possibly account for the difference:

- o Whatever was done to 4 door cars, reducing ejections, was not done to 2 door cars. This factor has nothing to do with SBL.
- o Whatever was done to 4 door cars was also done to 2 door cars, but it did not work nearly as well. This factor also has nothing to do with SBL.
- o SBL have a genuine negative effect on ejections, which, in the case of the 2 door cars, masked the highly beneficial effect of whatever was done to decrease ejections in all cars.
- o Something other than SBL was done to 2 door cars (but not to 4 door cars) and masked the highly beneficial effect of whatever was done to decrease ejections in all cars.

Section 5.3 is devoted to exploring which of the factor(s) may have been at work. Sections 4.4, 4.6 and 4.8 present more disaggregate FARS data on ejections.

4.4 Fatalities and ejections, by seat position

The discussion of the sled tests (Section 2.2) identified three groups of persons with fundamentally different collision kinematics and potential SBL effects: front seat occupants with nobody sitting behind them, front seat occupants with somebody sitting behind them and back seat passengers. FARS identifies the seat position of each occupant and makes it possible to determine if someone was sitting behind a front seat occupant. Exposure data corresponding to the fatality counts are obtained by multiplying the numbers of vehicle years in Table 4-1 by the proportion of all occupants in Washington accidents who were in a particular seating position. For example, Table 4-1 shows that 2 door cars of the first 2 years with SBL accumulated 31,280,000 exposure years in 1975-85. Since 61,500 (see Table B-5) of 67,435 (see Table 3-1) occupants of 2 door cars of the first 2 years with SBL in Washington accidents were front seat occupants with nobody sitting behind them, the appropriate "measure of exposure" for that seating position is

$$\frac{61,500}{67,435}\ 31,280,000 = 28,138,000 \text{ years}$$

It should be noted that these measures of exposure are intended only to make comparable the fatality rates, across model years and body styles, for a given seating position. But the fatality rates for different seating positions should not be compared to one another, because car occupancy in Washington might not be representative of the rest of the nation and, above all, because occupancy of some positions may have been underreported in Washington (see Section 3.2.5).

Table 4-5 summarizes the observed net effects of SBL on fatality rates, by seat position. It is based on the detailed fatality rates of Tables C-1, C-2 and C-3 in Appendix C of this report. The sequence of effectiveness estimates for front seat occupants with nobody sitting behind them was -17, -11, -13 and -11 percent, all significantly worse than zero. That sequence is just slightly worse than the one for all occupants, as derived from Table 4-1 (-15, -9, -11 and -10 percent). Like the Washington data, FARS does not show SBL to be beneficial for this type of occupant.

TABLE 4-5

FARS 1975-85: NET EFFECT OF SBL ON FATALITY RISK

-BY SEAT POSITION-

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables C-1 - C-3 and 4-1)

Effect on Fatality Risk of		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Front seat occupants with nobody sitting behind them		-17	-11	-13	-11
	Z=	3.80*	3.46*	4.76*	4.23*
Front seat occupants with somebody sitting behind them		-20	-5	-8	-11
	Z=	1.47	.55	.93	1.39
Back seat occupants		+2	+7	+5	-7
	Z=	.16	.64	.50	.74
ALL OCCUPANTS		-15	-9	-11	-10
	Z=	3.80*	3.09*	4.34*	4.16*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

The data set of front seat occupants with somebody sitting behind them (documented in detail in Table C-2) is only a tenth as large as the preceding one and is subject to more sampling error. In particular, none of the observed effects is significantly different from zero. Nevertheless, the sequence of observed effects, -20, -5, -8 and -11 percent, is almost as consistent as the preceding one and shows much the same pattern. As in Washington, the most reasonable conclusion is that SBL are not beneficial for front seat occupants, even when someone is sitting behind them.

The sequence of estimates for back seat occupants is 2, 7, 5 and -7 percent. Due to the small sample sizes and the small magnitude of the estimates, there is no clear pattern. The numbers do not indicate a significant benefit for SBL, although some might draw encouragement from the fact that they are not consistently negative as at the other seat positions.

Table 4-6 computes the observed net effect of SBL on occupant ejection rates, by seat position. (It is based on the detailed data in Tables C-4, C-5 and C-6.) The effect for front seat occupants with nobody sitting behind them was consistently negative: -38, -30, -28 and -25 percent, all statistically significant. The effect for front seat occupants with somebody sitting behind them was, in each case, even more negative: -77, -37, -30 and -35 percent. Even though sample sizes are smaller, these observed effects are so large that three of them are statistically significant. If SBL did indeed have any "true" negative

TABLE 4-6

FARS 1975-85: NET EFFECT OF SBL ON OCCUPANT EJECTION# RATES

-BY SEAT POSITION-

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables C-4 - C-6 and 4-3)

Effect on Ejection# Rates of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Front seat occupants with nobody sitting behind them	-38	-30	-28	-25
	Z= 3.94*	4.48*	4.69*	4.65*
Front seat occupants with somebody sitting behind them	-77	-37	-30	-35
	Z= 2.66*	2.01*	1.87	2.27*
Back seat occupants	-43	+4	+1	-13
	Z= 1.55	.25	.08	.89
ALL OCCUPANTS	-42	-26	-24	-23
	Z= 4.80*	4.49*	4.56*	4.81*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

effect on ejection, these results are consistent with the intuitive explanation suggested in Section 1.6 - viz., that in pre-SBL cars, the seatbacks could fold down and block front seat occupants' avenues of ejection, especially if there are back seat occupants who help force the seatbacks to fold down.

Table 4-6 shows little or no effect of SBL on the ejection of back seat occupants. The sequence of estimates is -43, 4, 1, and -13 percent, none of them statistically significant. The more favorable results for back seat occupants are again consistent with intuition: the folding over of the front seat in a pre-SBL car could give the back seat occupant a wider avenue to the front door, even while it blocks front seat occupants' ejection through that door.

4.5 Effect for restrained occupants

Unlike Washington State nonfatal accident data, belt usage is very low on FARS. Only 409 of the 36,993 fatalities in these aging, 1960's era cars were belted. That is barely enough for an analysis of fatality rates. Table 4-7 indicates that the effect of SBL was probably close to zero. The sequence of estimates is 26, 20, 3 and 1 percent. None of those estimates is statistically significant and the first two have much sampling error. Since the FARS effectiveness sequences, so far, have shown little drift in either direction, the last two estimates in the sequence, which are both close to zero, are probably unbiased. Since ejection is infrequent for belted occupants and accounted for most of the negative effects in the analyses of unbelted occupants, it is appropriate that net effectiveness for belted persons is close to zero.

TABLE 4-7

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, ALL RESTRAINED OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	22	12.632	1.74		
	first 1 after	34	14.688	2.31	-33	
2	last 1 before	30	10.858	2.76		
	first 1 after	38	13.942	2.73	1	+26% Z=0.81
4	last 2 before	39	24.934	1.56		
	first 2 after	77	32.552	2.37	-51	
2	last 2 before	45	20.198	2.29		
	first 2 after	84	31.280	2.69	-21	+20% Z=0.84
4	last 3 before	49	30.866	1.59		
	first 3 after	101	40.356	2.50	-58	
2	last 3 before	52	25.300	2.06		
	first 3 after	131	41.782	3.14	-53	+3% Z=0.14
4	last 4 before	52	36.013	1.44		
	first 4 after	130	49.249	2.63	-82	
2	last 4 before	54	28.141	1.92		
	first 4 after	173	50.068	3.46	-80	+1% Z=0.05

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

4.6 Effectiveness in frontal crashes

FARS has a variable called "principal impact point" and values 1, 11 and 12 correspond to frontal impacts. There are two reasons to analyze frontal crashes separately. Intuitively, the seatback in a pre-SBL car may be more likely to fold over in a frontal crash than in other crash modes; the effect of SBL, which are designed to inhibit the folding over of the seatback, may be more prominent in frontals. Furthermore, the Texas analysis of nonfatal frontals had ambiguous results (see Section 3.3.2). Table 3-10 showed "barely" significant injury reductions in the ±1 year comparison, dwindling to zero in later comparisons. Was that a true positive, subsequently masked by biases or a spurious positive, subsequently corrected by a larger sample?

Table 4-8 shows that SBL are not effective in reducing fatalities in frontal crashes. The sequence of effectiveness estimates, -9, -3, -8 and -8 percent, is stable and the last two numbers are statistically significant. The results are nearly the same as for all crash modes (-15, -9, -11, and -10 percent), at least in the ±3 and ±4 year comparisons.

Table 4-9 presents consistently negative results for ejections in frontal crashes. The sequence of estimates is -40, -30, -25 and -24 percent, all statistically significant. It is virtually identical to the sequence for ejections in all crash modes (-42, -26, -24 and -23 percent).

Finally, Table 4-10 represents the best possible situation: frontal fatalities who were <u>not</u> ejectees. Yet, there are no benefits for

TABLE 4-8

FARS 1975-85: FATALITY RATES IN FRONTAL CRASHES, PER MILLION VEHICLE YEARS, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Frontal Crash Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	1326	12.632	105.0		
	first 1 after	1387	14.688	94.4	10	
2	last 1 before	1395	10.858	128.5		
	first 1 after	1759	13.942	126.2	2	-9% Z=1.67
4	last 2 before	2299	24.934	92.2		
	first 2 after	3012	32.552	92.6	none	
2	last 2 before	2464	20.198	122.0		
	first 2 after	3960	31.280	126.6	-4	-3% Z=0.88
4	last 3 before	2640	30.866	85.5		
	first 3 after	3853	40.356	95.5	-12	
2	last 3 before	2885	25.300	114.0		
	first 3 after	5751	41.782	137.6	-21	-8% Z=2.29*
4	last 4 before	2863	36.013	79.5		
	first 4 after	4903	49.249	99.2	-25	
2	last 4 before	3076	28.141	109.3		
	first 4 after	7392	50.068	147.6	-35	-8% Z=2.49*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE 4-9

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, IN FRONTAL CRASHES, ALL SEATING POSITIONS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Frontal Crash Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	233	12.632	18.4		
	first 1 after	193	14.688	13.1	29	
2	last 1 before	335	10.858	30.9		
	first 1 after	428	13.942	30.7	none	-40% Z=2.75*
4	last 2 before	403	24.934	16.2		
	first 2 after	432	32.552	13.3	18	
2	last 2 before	589	20.198	29.2		
	first 2 after	975	31.280	31.2	-7	-30% Z=3.04*
4	last 3 before	463	30.866	15.0		
	first 3 after	583	40.356	14.4	4	
2	last 3 before	702	25.300	27.7		
	first 3 after	959	41.782	30.1	-21	-25% Z=2.93*
4	last 4 before	506	36.013	14.1		
	first 4 after	750	49.249	15.2	-8	
2	last 4 before	750	28.141	26.7		
	first 4 after	1788	50.068	35.7	-34	-24% Z=2.99*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

TABLE 4-10

FARS 1975-85: NONEJECTION FATALITY RATES IN FRONTAL CRASHES, PER MILLION VEHICLE YEARS, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Frontal Nonejection Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	1159	12.632	91.8		
	first 1 after	1244	14.688	84.7	8	
2	last 1 before	1145	10.858	105.4		
	first 1 after	1432	13.942	102.7	3	-6% Z=0.95
4	last 2 before	1992	24.934	79.9		
	first 2 after	2687	32.552	82.5	-3	
2	last 2 before	2028	20.198	100.4		
	first 2 after	3233	31.280	103.3	-3	none Z=0.09
4	last 3 before	2291	30.866	74.2		
	first 3 after	3423	40.356	84.8	-14	
2	last 3 before	2370	25.300	93.7		
	first 3 after	4695	41.782	112.4	-20	-5% Z=1.31
4	last 4 before	2476	36.013	68.8		
	first 4 after	4347	49.249	87.9	-28	
2	last 4 before	2529	28.141	89.9		
	first 4 after	6033	50.068	120.5	-34	-5% Z=1.36

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. **None of the observed net effects were statistically significant** (2-sided alpha = .05 - i.e., Z greater than 1.96).

SBL here, either. The sequence of effectiveness estimates is -6, 0, -5 and -5 percent, none of which are significantly different from zero. Probably the only reason that the overall fatality results for frontal crashes (Table 4-8) are a bit less negative than for all crash modes (Table 4-1) is that ejectees account for a slightly smaller proportion of frontal fatalities than in the other crash modes.

Tables 4-8, 4-9 and 4-10 show that the results for SBL in frontal crashes are nearly the same as in other crash modes. The most optimistic conclusion that could be drawn from this is that all these negative effects are due to causes other than SBL, for if SBL are designed to work primarily in frontal crashes, their effect should be seen primarily in frontals - i.e., any effects seen equally in frontals and other crashes must be due to reasons other than SBL. But even this "most optimistic" conclusion does not go so far as to imply positive benefits for SBL.

4.7 Effect on fatal accidents involving fire

Section 1.6 raised a concern that the old style of manually operated SBL could impede the egress of back seat passengers from a 2 door car in emergency situations such as vehicle fires. Intuitively, the problem is the reverse of ejection: with fires, the objective is to expedite rather than block exits from the car.

FARS records whether fire occurred in an accident and which occupants were fatally injured. It does not document whether the fatal injury was caused by the fire, itself or by crash impacts. In the FARS file of cars built within 4 years of the SBL implementation date, 1277 of the 36,993 fatalities were in accidents involving fire - enough for a statistical analysis.

Table 4-11 shows that SBL has little or no overall net effect on fire-involved fatalities but may have strong effects at certain seat positions, consistent with intuition. For all seat positions combined (detailed data: Table C-7), the sequence of effectiveness estimates is -21, 0, 4 and 6 percent, none of them statistically significant. The sequence for front seat occupants with nobody sitting behind them (detailed data: Table C-8) likewise suggests little or no effect: -28, -3, 2, 4 percent (none significant).

The interesting results, however, are those for front seat occupants with somebody sitting behind them and for back seat occupants, as documented in detail in Tables C-9 and C-10. Table 4-11 shows a consistent beneficial effect for the front seat occupants with somebody behind them: 40, 68, 50 and 57 percent. The results for back seat occupants, -23, -64, -34 and -32 percent, are just as consistently negative. The numbers are certainly in the direction suggested by intuition; however, none of the 8 estimates is statistically significant, even at the .1 level. Tables C-9 and C-10 suggest, though, that the estimates fail to achieve significance primarily because the sample of fires was small in the pre-SBL cars. The following table, confined to cars of the first 4 post-SBL years, does show a significant difference

TABLE 4-11

FARS 1975-85: NET EFFECT OF SBL ON FATALITY RISK IN CRASHES INVOLVING FIRES*

-BY SEAT POSITION-

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables C-7 - C-10)

Effect on Fire Crash Fatality* Risk of		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
Front seat occupants with nobody sitting behind them		-28	-3	+2	+4
	Z=	1.06	.16	.18	.32
Front seat occupants with somebody sitting behind them		+40	+68	+50	+57
	Z=	.54	1.57	1.06	1.38
Back seat occupants		-23	-64	-34	-32
	Z=	.29	.85	.56	.55
ALL OCCUPANTS		-21	none	+4	+6
	Z=	.42	.02	.27	.47

*Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. **None of the observed net effects were statistically significant (2-sided alpha = .05 - i.e., Z greater than 1.96).

between 2 and 4 door cars in the seat positions of fire related fatalities:

	Front Seat (Someone Behind)	Back Seat	
4 doors	38	24	
2 doors	46	65	Chi Square=6.27

In the 4 door cars, back seat occupants were less likely to die in fires than the persons sitting in front of them; in 2 door cars with SBL, more so. It is unlikely, though, that the difference is purely due to SBL (FARS does not have enough pre-SBL cases to provide a meaningful answer): even without SBL it would seem harder for a back seat passenger to get out of a 2 door car than a 4 door car, especially if the front seat passenger has to get out first.

The most reasonable conclusion, based on Table 4-11, would appear to be that SBL have had little net effect on fire fatalities and that a possible negative effect for back seat occupants has been offset by slightly easier egress for the far more numerous front seat occupants. Of course, the conclusion applies only to the old type of manual SBL. For current automatic SBL, the effect should be zero since the seatback moves freely, like in a pre-SBL car, except during the moment of impact.

4.8 Effectiveness by car size and manufacturer

The data on overall fatality rates and ejections were analyzed separately for two car size groups (compact and intermediate cars; full sized and luxury cars) and for the three manufacturers (GM, Ford and Chrysler). The purpose was to find if some particular group is primarily responsible for the overall negative effects. For these analyses, the FARS, Polk and Washington data were subdivided into car size and manufacturer groups by make and model, using the same definitions for each file.

4.8.1 Effect on fatalities

Table 4-12 (based on detailed tables C-11 - C-15) shows that, indeed, the negative estimates of fatality reduction are confined to the smaller than average cars (compacts and intermediates). For the smaller cars, the sequence of effectiveness estimates is -18, -10, -13, and -9 percent, all of which are statistically significant. For full sized and luxury cars, the sequence is -4, 1, 4 and 5 percent, none of them significant. The sequence for the larger cars shows a slight drift in favor of SBL and suggests that the true effect is close to zero. The observed negative effect for the smaller cars as well as the near zero effect for the larger cars are explained by what happened to ejections, as will be discussed below.

The lower half of Table 4-12 provides effectiveness estimates for each manufacturer. The GM and Ford results are based on the "reduced" rather than the "full" FARS data set: Camaro and Firebird were introduced in 1967, simultaneous with the implementation of SBL by GM. These sporty 2 door cars raised the GM fatality rates for the full data set, resulting in spuriously large negative effects for SBL. These new models in turn reduced the market for Mustangs; with relatively fewer Mustangs, the fatality rates for 2 door Ford products declined, resulting in spurious positive effects for SBL. It made more sense to use the reduced data

TABLE 4-12

FARS 1975-85: NET EFFECT OF SBL ON FATALITY RISK

-BY CAR SIZE AND MANUFACTURER-

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables C-11 – C-15)

Effect on Fatality Risk in		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars			
		±1	±2	±3	±4
BY CAR SIZE					
Compacts and intermediates		−18	−10	−13	−9
	Z=	2.80*	2.25*	3.21*	2.49*
Full sized and luxury cars		−4	+1	+4	+5
	Z=	.73	.32	.94	1.54
BY MANUFACTURER					
General Motors#		−13	−4	−6	−5
	Z=	2.15*	.82	1.60	1.43
Ford#		−11	−4	−5	−9
	Z=	1.17	.57	.97	1.85
Chrysler		−10	−12	n.a.	n.a.
	Z=	1.10	1.90		
ALL CARS		−15	−9	−11	−10
	Z=	3.80*	3.09*	4.34*	4.16*

*Statistically significant effect (two-sided alpha = .05 – i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Excludes station wagons, convertibles and any make/models that were produced only with 2 doors or only with 4 doors.

sets, which exclude Camaro, Firebird and Mustang, among others. (But when the data are not subdivided by manufacturer, the Camaro-Firebird and Mustang effects cancel each other out and there is little difference between the full and reduced data sets, as noted in Sections 4.2 and 4.3). As for Chrysler, effectiveness estimates are available only for the ±1 and ±2 year comparisons, since the VIN before 1966 did not identify the number of doors.

Table 4-12 shows remarkable similarity in the results of the three manufacturers. The sequence of estimates is -13, -4, -6 and -5 percent for GM, -11, -4, -5 and -9 percent for Ford and -10 and -12 percent for Chrysler. These numbers are a few percent closer to zero than the ones for all manufacturers combined (-15, -9, -11 and -10), suggesting that the aggregate data may have a slight bias against SBL that made the results more negative than they should have been.

4.8.2 Ejections

Table 4-13 (which summarizes Tables C-16 - C-20) emphatically indicates that the negative results on ejection are confined to smaller cars. The sequence of estimates for compacts and intermediates is -70, -41, -41 and -40 percent - all statistically significant and completely stable after the first year. (Further subdivision of the cars into compacts and intermediates showed approximately 40 percent increases for each of those groups.) For full sized and luxury cars, the estimates are -14, 0, 10 and 11 percent - none of them significant. Since the numbers are drifting slightly in favor of SBL, the actual effect would appear to

TABLE 4-13

FARS 1975-85: NET EFFECT OF SBL ON OCCUPANT EJECTION## RATES

-BY CAR SIZE AND MANUFACTURER-

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

(Summary of Tables C-16 - C-20)

Effect on Ejection## Rates in	Net Effect of SBL (%)** — Number of Model Years before/after SBL Installation in 2 Door Cars: ±1	±2	±3	±4
BY CAR SIZE				
Compacts and intermediates	-70 Z= 4.44*	-41 4.05*	-41 4.55*	-40 4.87*
Full sized and luxury cars	-14 Z= 1.20	none .03	+10 1.46	+11 1.78
BY MANUFACTURER				
General Motors#	-30 Z= 2.31*	-13 1.45	-16 1.89	-14 1.84
Ford#	-57 Z= 2.59*	-14 1.11	none .04	-11 1.28
Chrysler	-41 Z= 2.19*	-42 3.14*	n.a.	n.a.
ALL CARS	-42 Z= 4.80*	-26 4.49*	-24 4.56*	-23 4.81*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.
#Excludes station wagons, convertibles and any make/models that were produced only with 2 doors or only with 4 doors.
##Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

be close to zero here. Table C-16 shows that, among smaller cars, 2 door cars had double the ejection rate of 4 door cars before SBL. Four door cars experienced a dramatic reduction of ejections in the year that SBL were introduced in 2 door cars, while the 2 door cars experienced little or no reduction. Once again, it is a reduction in the control group rather than an increase in the 2 door cars that causes the large negative effect for SBL. Table C-17 shows that, by contrast, there was only a moderate difference in the ejection rates of large 2 door and 4 door cars. Both groups experienced moderately large reductions of ejection risk in the years following the introduction of SBL (after correcting for the downward drift in the "gross" rates). Large 4 door cars have only a slightly lower ejection risk than small 4 door cars, whereas large 2 door cars have less than half the ejection risk of small 2 door cars, especially in the years after SBL. Many of these phenomena would seem to have more to do with door structures than with SBL, as will be discussed further in Section 5.3.

Table 4-13 shows that the observed effect of SBL on ejections was more negative at Chrysler than at GM or Ford. The sequences of estimates were -30, -13, -16, and -14 percent at GM; -57, -14, 0 and -11 percent at Ford and -41 and -42 percent at Chrysler. The ± 1 year estimates from GM and Ford and both Chrysler numbers are statistically significant. Table C-20 shows that the very negative results from Chrysler are due to an especially large reduction of ejections in the 4 door cars, rather than any increase in the 2 door cars.

4.9 When children ride in the back seat

As explained in Section 3.2.7, one situation where SBL might be especially effective is when the back seat is occupied only by children, e.g., up to 12 years old, especially in a frontal crash where nobody is ejected. Table 4-14 presents FARS results on children up to age 12 who rode in the back seat (top half) as well as the persons who were sitting in front of those children (lower half). This occupancy mode is analyzed first for all fatalities, then all nonejection fatalities and, finally, for frontal crashes in which nobody is ejected. The sample sizes for Table 4-14 are at most 1/6 as large as those for back seat fatalities of all ages (Table C-3), almost precluding any hope for statistically meaningful results.

All 12 results for children riding in the back seat (top half of Table 4-14) are negative, although none are statistically significant even at the .1 level. Nine of the 12 of the effectiveness estimates for the persons sitting in front of those children are negative (lower half of Table 4-14), although none of these, either, are statistically significant at the .1 level. There is nothing in Table 4-14 to support the hypothesis that SBL save lives when children ride in the back seat.

TABLE 4-14

FARS 1975-85: NET EFFECT OF SBL ON FATALITY RISK WHEN CHILDREN* ARE IN THE BACK SEAT

-BY SEAT POSITION-

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

Effect on Fatality Risk of		Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
CHILDREN* IN THE BACK SEAT					
All fatalities		-21	-25	-34	-39
	Z=	.47	.77	1.12	1.34
Nonejection fatalities		-13	-16	-16	-32
	Z=	.28	.45	.52	.99
Frontal noneject. fatals.		-1	-99	-70	-93
	Z=	.02	1.36	1.17	1.52
FRONT SEAT OCCUPANTS WITH A CHILD* SITTING BEHIND THEM					
All fatalities		-51	-9	-4	-4
	Z=	1.24	.35	.17	.18
Nonejection fatalities		-53	-3	none	-3
	Z=	1.16	.11	.01	.12
Frontal noneject. fatals.		-126	-11	+10	+5
	Z=	1.54	.30	.32	.17

*Children up to (and including) 12 years old.

Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. **None of the observed net effects were statistically significant (2-sided alpha = .05 - i.e., Z greater than 1.96).

CHAPTER 5

ANALYSES OF THE PERFORMANCE OF CAR DOORS AND SEATS IN NHTSA ACCIDENT FILES

Detailed NHTSA accident files such as Multidisciplinary Accident Investigation (MDAI) and the National Crash Severity Study (NCSS) do not have large enough samples for statistically meaningful analyses of the overall effectiveness of seat back locks (SBL). But they provide invaluable data on the performance of doors and seats in crashes. The data show that the integrity of doors of 4 door cars improved greatly at the same time that SBL were introduced in 2 door cars. Door integrity did not improve in 2 door cars. This is a difference between 2 and 4 door cars that is unrelated to SBL and may largely explain the significant negative "effects" on ejection associated with the implementation of SBL in Chapters 3 and 4.

The MDAI data show that SBL or other seat components in 2 door cars often give way in crashes of moderate severity, especially if there is a back seat occupant loading the front seatback. They confirm the sled test results, where seats gave way in all crashes at 26.5 mph when there were back seat occupants. The inability of SBL to hold seats in place is consistent with the principal statistical findings of Chapters 3 and 4 - viz., no reduction of injuries and fatalities.

5.1 Description of the data files

The Multidisciplinary Accident Investigation (MDAI) file contains detailed records of 9623 cars involved in crashes [8]. Many of the data were collected in 1970-74 and the study emphasized new cars; thus, much of the file consists of cars of the early 1970's, although there are also many cars of the 1960's. The unsurpassed level of detail includes complete, reliable information on the performance of door and seat components in the crash. The principal drawback of MDAI is that it is not a probability sample of crashes and, in particular, is skewed toward more severe crashes and injuries. But it can reasonably be assumed that the bias is no stronger for 2 door cars than for 4 door cars of the same model year - i.e., the analysis technique developed in Sections 3.1 and 4.1 (comparing the rates in pre and post-SBL 2 door cars to those in 4 door cars of the same model years) should not be strongly biased. Likewise, there is no evidence that MDAI investigators went out of their way to find crashes in which the seats separated - i.e., for crashes of a given severity level, the seat separation rates in MDAI (Section 5.4) may be representative. Another disadvantage is that the MDAI file does not contain estimates of Delta V. Damage data are used to obtain a rough approximation of Delta V.

The National Crash Severity Study (NCSS) is a probability sample of 12,050 towaway crashes that occurred during 1977-79 at 7 areas that, in combination, were heuristically representative of the nation [41]. Cars of all ages were sampled equally; as a result, NCSS contains numerous cars of the early post-SBL years and a moderate number of relatively old pre-SBL cars. NCSS includes complete data on occupant ejection and on doors that opened during the crash. More detailed vehicle performance data such as the separation of seat components was collected only after March 1978 and was not as complete as in MDAI. NCSS is a weighted stratified sample - i.e., the crashes resulting in fatalities or injuries requiring emergency treatment were oversampled and the other crashes must be given a higher weight to obtain unbiased estimates. Interestingly, unweighted NCSS data have about the same bias toward higher injury as MDAI. In Sections 5.2 and 5.3, the unweighted NCSS and the MDAI files are combined to produce a single, reasonably homogeneous data set with the largest possible sample size.

5.2 Analysis of ejections

The combined MDAI and NCSS files contain 114 cases of ejection from cars of the last 4 model years before SBL implementation: far fewer than the 1371 in the Washington State data (Table 3-4) or the 3575 in FARS (Table 4-3). It is unreasonable to expect a statistically reliable analysis of ejections, let alone injury rates. Table 5-1 shows that, indeed, the sample is too small to produce consistent results. The sequence of "observed effectiveness estimates for SBL" (derived exactly as in Section 3.1) is 57, 25, 13 and -12 percent; only the first is statistically significant at the .05 level, and "barely" so (Z=2.09). The sequence could be indicative of an extremely high "true" effectiveness for SBL with a large year to year bias against SBL. Far more likely, it indicates anomalous data in the small sample of cars built within 1 year before and after implementation and a correction of the anomaly as the sample is broadened. Indeed, Table 5-1 shows a large increase in the ejection rate for 4 door cars of the first year after the SBL implementation date - contrary to all the other data sets, which showed decreases.

TABLE 5-1

NCSS AND MDAI FILES: EJECTEES PER 1000 OCCUPANTS, ALL SEATING POSITIONS
(Unweighted Data)

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	N of Occ.	Ejectees per 1000 Occ.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	11	381	28.87		
	first 1 after	29	605	47.93	-66	
2	last 1 before	36	551	65.34		
	first 1 after	43	925	46.49	29	+57% Z=2.09*
4	last 2 before	22	718	30.64		
	first 2 after	55	1466	37.52	-22	
2	last 2 before	52	990	52.52		
	first 2 after	109	2265	48.12	8	+25% Z=0.98
4	last 3 before	29	912	31.80		
	first 3 after	77	2516	30.60	4	
2	last 3 before	67	1158	57.86		
	first 3 after	219	4510	48.56	16	+13% Z=0.54
4	last 4 before	40	1044	38.31		
	first 4 after	94	3637	25.85	33	
2	last 4 before	74	1292	57.28		
	first 4 after	305	7045	43.29	24	-12% Z=0.50

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

The ejection rates in the ±4 year comparison are much closer to what was seen in other data files: a 33 percent decrease of ejection risk in the 4 door cars and a 24 percent decrease in the 2 door cars (smaller in relative terms than in the 4 door cars, thus resulting in a negative "net effectiveness" estimate, but about equally large in absolute terms). In short, the sample is far too small to shed new light on ejection, but at least the ±4 year comparison is consistent with the Washington and FARS data.

5.3 <u>Analysis of door integrity in crashes</u>

The NCSS data show that 64 percent of ejections in cars of the last 5 years before SBL were through the side doors. Obviously, any safety improvement that would reduce the likelihood of doors opening in crashes would significantly reduce the risk of ejection. If something was done to doors that reduced door opening in 4 door cars more than in 2 door cars, ejection rates in 4 door cars would decline more swiftly than in 2 door cars. If that "something" happened to coincide with the introduction of SBL, it would result in all the analyses of Chapters 3 and 4 attributing a negative "net effect" on ejections to SBL, when, in fact, it may have been a result of changes to doors.

The combined NCSS and MDAI files include records of 226 cars of the last 4 years before SBL implementation in which at least one door came open during the crash. In other words, door opening occurs about twice as often as occupant ejection, even when all ejection portals are included - thus, NCSS and MDAI are far more likely to produce a statistically meaningful analysis of door opening rates than for ejections. Table 5-2 shows that door opening rates decreased by 23 percent in 4 door cars in the year that SBL was implemented in 2 door cars and continued to decrease by even greater amounts in subsequent years. In 2 door cars, door opening decreased by only 4 percent in the SBL implementation year, with no additional decrease in the next year. Only in the third and fourth years after SBL did fewer doors open and, even then, the reduction lags behind the one for 4 door cars. As a result, Table 5-2 "attributes" a consistent sequence of negative effects on door integrity to SBL: -25, -31, -25 and -37 percent, the last of which is statistically significant.

Of course, there is no intuitive reason to believe that SBL had any effect on doors opening in crashes. Undoubtedly, the effects are due to some other factor that happened to coincide with the implementation of SBL. What is most interesting about Table 5-2 is how closely the door opening rates in MDAI and NCSS parallel the ejection rates in Washington (Tables 3-4 and B-4) and FARS (Tables 4-3 and 4-4, except to the extent that the exposure measure used with FARS causes the gross ejection rates to increase as cars get newer). In all cases, the negative "net effect for SBL" is not due to an actual worsening in 2 door cars, but rather to an immediate improvement in the 4 door cars which is only belatedly achieved in the 2 door cars. Moreover, the magnitude of the effects is similar: FARS and Washington suggest about a 20-25 percent negative net effect on ejections. NCSS and MDAI show a 25-30 percent negative effect on door opening. Since about 64 percent of ejectees in pre-SBL cars were through the doors, the 25-30 percent increase in door opening more or less

TABLE 5-2

NCSS AND MDAI FILES: INCIDENCE OF DOORS OPENING DURING IMPACTS
(Unweighted Data)

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	Cars where at Least 1 Door Opened	N of Cars	Door Opening Rate (%)	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	38	215	17.67		
	first 1 after	44	322	13.66	23	
2	last 1 before	54	293	18.43		
	first 1 after	88	495	17.78	4	-25% Z=0.85
4	last 2 before	75	382	19.63		
	first 2 after	109	757	14.40	27	
2	last 2 before	96	517	18.57		
	first 2 after	213	1194	17.84	4	-31% Z=1.51
4	last 3 before	87	461	18.87		
	first 3 after	157	1300	12.08	36	
2	last 3 before	114	604	18.87		
	first 3 after	373	2465	15.13	20	-25% Z=1.41
4	last 4 before	100	528	18.94		
	first 4 after	187	1895	9.87	48	
2	last 4 before	126	674	18.69		
	first 4 after	526	3951	13.31	29	-37% Z=2.08*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

explains the 20-25 percent increase in ejections and leaves little room for a "true" SBL effect.

Table 5-2 begs the question as to why door opening rates decreased substantially in 4 door cars in 1967-68 but only slightly in 2 door cars. One possibility that must be examined is that major vehicle redesigns or introductions coincided with SBL, biasing the results. In fact, the introduction of the Chevrolet Camaro and Pontiac Firebird and the restyling of the Dodge Charger were the only major model changes that coincided with SBL [26], pp. 122-124. GM restyled their intermediates and compacts one year later; Ford and Chrysler restyled them one or two years earlier. The introduction of Camaro and Firebird could be responsible for some of the relatively poorer door performance of 2 door cars, but not too much since those models only accounted for 8 percent of the 2 door cars sold that year [49]. Most of the effect in Table 5-2, then, would appear due to genuine vehicle modifications rather than biases in the data.

Were 2 door cars modified in a different way from 4 door cars or were they similarly modified, but with different effects? Garrett performed a detailed analysis of door modifications and opening rates in cars of the 1960's [14]. He found that GM, Ford and Chrysler all made significant improvements in door latch designs in 1967-68 (the exact year depending on the make and model), resulting in a 29 percent reduction in door openings, relative to 1965-66 cars, on the Automotive Crash Injury Research (ACIR) file. There were no modifications in door latches between 1964 and 1967 and the door opening rate remained about constant for model years 1964-66. Garrett did not subdivide the door opening rates in his study by 2 door vs. 4 door cars. Recently, however, Garrett stated that identical, simultaneous improvements were made to the door latches of 2 and 4 door cars in 1967-68 and that no substantial further improvements were made for some years after that [15]. Humphrey of GM [21] and Grush of Ford [19] agreed with Garrett's views. It must be concluded that the same modifications were made to the door latches of 2 and 4 door cars, but that they brought about a relatively much greater performance improvement in the 4 door cars. The intuitive support for the conclusion is that the doors of 4 door cars are significantly narrower than in 2 door cars. Wider doors have a greater tendency to bow at the time of impact and separate the latches from the frame. The 1967-68 improvement may have made the latches on the 4 door cars strong enough to resist all but the most severe impacts, while only beginning to solve the problem for 2 door cars. If, in addition, the styling of the late 1960's resulted in even longer doors on 2 door cars (e.g., Camaro), it is plausible that the performance benefit of the 1967-68 improvements was realized primarily on the 4 door cars.

The door opening rates in Table 5-2 are consistent with these ideas. Door opening rates remained constant during the 4 pre-SBL model years, just as in Garrett's ACIR data. At the time of SBL implementation (1967-68), which coincided with the door latch improvements, the rate dropped by about 25 percent in the 4 door cars but much less in the 2 door cars. In the third and fourth year after SBL implementation, the rates drop in both types of cars, partly due, perhaps, to age related biases in the data but also to the side door beams that were introduced in full sized and sporty GM and Ford cars as well as intermediate GM cars at that time [26], p. 108. Side door beams significantly reduce the incidence of doors opening in crashes [26], pp. 318-327.

5.4 <u>Seat performance in crashes of 2 door cars with SBL</u>

One of the noteworthy findings in the sled tests is that seat separation occurred in all three frontal tests at 26.5 mph with dummies in the back seat (see Section 2.2). In one of the three tests, both SBL were sheared off; in the other two, the seat tore loose from the track. In all cases, the net result was that the seat acted like one that did not have SBL. (Seat separation did not occur even at 30 mph with the back seat empty.) The immediate question is whether the sled buck fashioned from a 1981 Chevrolet Citation is representative of the performance of the range of real vehicles in highway crashes.

The MDAI file is unique in that it contains detailed seat performance data on nearly all vehicles (most of which are cars of the late 1960's and early 1970's equipped with the old style of manual SBL). The file contained 3259 2 door cars with SBL that had frontal impacts. The following types of seat separation were documented on MDAI:

108 cases: the left SBL broke
115 cases: the right SBL broke
67 cases: the seat tore loose from one of the tracks
52 cases: the seat and track tore loose from the floor
16 cases: the front seatback tore loose from the seat

Note that breakage of the SBL is the most common cause of seat separation in frontal crashes.

For comparison with the sled tests, the MDAI data need to be tabulated by Delta V range and back seat occupancy. MDAI does not contain estimates of Delta V. It has to be approximated from the Collision Deformation Classification (CDC) [6] of the damaged vehicle. As in NHTSA's evaluation of child safety seats, the approximation consists of two steps [22], pp. 221-222. First, the CRASH program is executed, using the CDC of the case vehicle and assuming the damage is the result of impacting a rigid immobile fixed object [33], pp. 5, 20-22. This first step, however, usually overestimates Delta V in comparison with a reconstruction based on the full CRASH program [22], p. 222, perhaps because CRASH overestimates the extent of damage that occurs in the "average" car with a given CDC. The estimate based on this first step alone will be referred to as the "higher estimate of Delta V" or DV^H. The best estimate (based on regression of Delta V from the full CRASH program with DV^H) is

$$DV_L = 4.645 + .7082\ DV^H$$

henceforth referred to as the "lower estimate of Delta V." As for back seat occupancy, MDAI contains a variable that indicates if any back seat passenger made contact with the front seatback.

Table 5-3 is based on the lower estimate of Delta V, showing the percentage of cars that experienced any of the modes of seat separation documented in MDAI (broken SBL, seat torn loose from tracks or floor, or seatback separated from seat). The results are remarkably parallel to what was found in the sled tests.

TABLE 5-3

MDAI DATA: FRONT SEAT SEPARATION* RATES,
2 DOOR CARS EQUIPPED WITH SBL,
AS A FUNCTION OF DELTA V, IN FRONTAL CRASHES

-LOWER ESTIMATE OF DELTA V**-

Delta V** Range (mph)	N of Cars	n of Cars with Seat Separation*	Separation* Rate (%)
		BACK SEAT UNOCCUPIED	
Less than 10	609	3	0.5
10-14.9	1097	29	2.6
15-19.9	662	42	6.3
20-24.9	286	33	11.5
25-29.9	114	30	26.3
30-39.9	71	22	31.0
40 or more	38	17	44.7
		BACK SEAT OCCUPANT CONTACTED FRONT SEATBACK	
Less than 10	55	3	5.5
10-14.9	90	19	21.1
15-19.9	80	28	35.0
20-29.9	60	28	46.7
30 or more	17	15	88.2

*Note: The front seat "separated" if any of the following occurred: (1) An SBL broke. (2) The seat tore loose from one of the tracks. (3) The seat tore loose from the floor. (4) The front seatback tore loose from the seat.

**The "lower" estimate of Delta V is obtained by running the CDC-only CRASH program, assuming the damage is due to striking a rigid barrier. This number is then multiplied by 0.7082 and added to 4.645.

When the back seat is unoccupied (top half of Table 5-3), seat separation usually does not occur, although it is not uncommon at Delta V above 25 mph. At least one form of seat separation occurred in 6 percent of the cars with frontal Delta V 15-19 mph, 11 percent with Delta V 20-24 mph, 26 percent with Delta V 25-29 mph and in 31 percent of the cars with Delta V in the 30's. Thus, in the 20-30 mph range which is critical for protecting the unrestrained occupant, a moderate percentage (17) of the potential benefit of SBL is lost because the SBL or other components did not hold in place.

The potential for SBL to influence occupant kinematics, however, is far greater when there is somebody in the back seat (see Section 2.2). Here, the lower half of Table 5-3 shows that much of the potential is lost a priori because the SBL or other seat components did not hold. Seat separation occurred in 35 percent of the crashes with Delta V 15-19 mph, 47 percent of the crashes in the critical 20-30 mph range and 88 percent of the crashes with Delta V over 30. Under these circumstances, it is even less surprising that the Washington and FARS accident data showed no casualty reductions for front seat occupants with somebody sitting behind them or for back seat occupants.

The situation is slightly better, though, especially at the lower speeds, when the back seat occupant weighs less than 100 pounds - e.g., a child. In Table 5-4, the frontal crashes in which there are back seat occupants are further subdivided. In the top half, there is only one back seat occupant and that person weighed less than 100 pounds. In the

TABLE 5-4

MDAI DATA: FRONT SEAT SEPARATION* RATES,
BY SIZE OF BACK SEAT OCCUPANT,
2 DOOR CARS EQUIPPED WITH SBL,
AS A FUNCTION OF DELTA V, IN FRONTAL CRASHES

-LOWER ESTIMATE OF DELTA V**-

Delta V** Range (mph)	N of Cars	n of Cars with Seat Separation*	Separation* Rate (%)
BACK SEAT OCCUPANT WEIGHING LESS THAN 100 POUNDS			
Less than 10	12	0	0
10-14.9	11	0	0
15-19.9	13	3	23.1
20-29.9	8	3	37.5
30 or more	2	2	100
BACK SEAT OCCUPANT WEIGHING 100 POUNDS OR MORE			
Less than 10	34	3	8.8
10-14.9	64	19	29.7
15-19.9	59	22	37.2
20-29.9	45	23	51.1
30 or more	13	11	84.6

*Note: The front seat "separated" if any of the following occurred: (1) An SBL broke. (2) The seat tore loose from one of the tracks. (3) The seat tore loose from the floor. (4) The front seatback tore loose from the seat.

**The "lower" estimate of Delta V is obtained by running the CDC-only CRASH program, assuming the damage is due to striking a rigid barrier. This number is then multiplied by 0.7082 and added to 4.645.

lower half, there was a back seat occupant weighing 100 pounds or more. With the lightweight back seat occupants, seat separation did not occur below 15 mph Delta V, whereas 30 percent of the seats were already separating at 10-15 mph when an adult was sitting in the back. At speeds above 15 mph, the separation rate with small back seat occupants is lower than with adults, although higher than when the back seat is unoccupied (top half of Table 5-3). Such results are, of course, consistent with intuition.

Table 5-5 uses the higher estimate of Delta V to analyze seat separation rates. Although the higher estimate was found to be a clear overestimate in files such as NCSS and the National Accident Sampling System it might be more accurate for MDAI if this file's crashes are more severe than average, even for a given CDC. The results in Table 5-5, however, are nearly the same as in Table 5-3, especially in the critical 20-30 mph range of Delta V.

One important caveat is that Tables 5-3, 5-4 and 5-5 are based only on MDAI data, not NCSS. After March 1978, NCSS did collect information on seat performance similar to the MDAI variables. But the seat separation rates in unweighted post-March 1978 data are only about 1/8 as great as in MDAI. Yet unweighted NCSS and MDAI have about the same rates for injury, ejection, and door opening and about the same Delta V distribution. The most plausible conclusion is that the seat separation rates are so much lower in NCSS because MDAI had a more thorough, detailed vehicle examination that identified seat separation with far greater completeness than NCSS.

TABLE 5-5

MDAI DATA: FRONT SEAT SEPARATION* RATES,
2 DOOR CARS EQUIPPED WITH SBL,
AS A FUNCTION OF DELTA V, IN FRONTAL CRASHES

-HIGHER ESTIMATE OF DELTA V**-

Delta V** Range (mph)	N of Cars	n of Cars with Seat Separation*	Separation* Rate (%)
	BACK SEAT UNOCCUPIED		
Less than 10	984	10	1.0
10-14.9	756	22	2.9
15-19.9	571	31	5.4
20-24.9	244	32	13.1
25-29.9	128	16	12.5
30-39.9	121	37	30.6
40 or more	73	28	38.4
	BACK SEAT OCCUPANT CONTACTED FRONT SEATBACK		
Less than 10	82	10	12.2
10-14.9	70	17	24.3
15-19.9	65	18	27.7
20-29.9	47	25	53.2
30 or more	38	23	60.5

*Note: The front seat "separated" if any of the following occurred: (1) An SBL broke. (2) The seat tore loose from one of the tracks. (3) The seat tore loose from the floor. (4) The front seatback tore loose from the seat.

**The "higher" estimate of Delta V is obtained by running the CDC-only CRASH program, assuming the damage is due to striking a rigid barrier.

CHAPTER 6

SUMMARY AND COMPARISON OF FINDINGS

The introduction to the evaluation (Section 1.6), stated several hypotheses as to why seat back locks (SBL) might be beneficial in crashes. It raised some concerns that the SBL actually installed in cars might fall short of the performance of the ideal seat or that they might have negative side effects in some types of crashes. With all the analyses from Chapters 2-5 in hand, it is possible to examine the hypotheses one by one and compare what each of the data sources says about them.

6.1 Do SBL hold seatbacks in place during crashes?

This is the question that has to be asked first. If the answer is "yes," the next question is whether casualties are mitigated. If "no," this is already strong evidence that SBL have limited benefits. The primary concern raised in Section 1.6 is that the force levels experienced in severe crashes, or even in moderately severe crashes if there are back seat occupants, exceed the component strength requirements of Standard 207 - i.e., that SBL might not remain intact. A second issue is whether SBL, even when they remain intact, significantly reduce the impact forces experienced by occupants.

There is a critical difference between crashes where the back seat is unoccupied and those in which unrestrained back seat occupants make contact with the front seatback. When there is nobody in the back seat, SBL usually accomplish their mechanical function of keeping the seatback away from the front seat occupants at the time they contact the steering assembly, instrument panel, etc. Table 6-1 shows that in the MDAI accident data, the SBL or other seating components separated in only 6 percent of frontal crashes with Delta V 15-20 mph and 12 percent with Delta V 20-25 mph. In the 25-40 mph range, about 30 percent of the seats had a component separation, most frequently the SBL not holding the seatback. Table 6-1 also shows that seating components remained intact in 6 sled tests at 24-32 mph Delta V, with the back seat unoccupied. In other words, for the overwhelming majority of serious injuries and a substantial majority of the fatalities, seating components remain intact. Even when seat components remain intact, excessive deflection of the seatback may defeat the action of SBL. The sled tests, however, showed that the SBL "caught" the seatbacks before they had deflected half the distance from their original position to the steering wheel: this was adequate to prevent any contact between the seatback and front seat dummies at the time they were impacting frontal structures in the vehicle.

Although SBL successfully keep seatbacks in place when the back seat is unoccupied, they are less successful in reducing impact forces on front seat occupants. The sled test films, as described in Section 2.2, showed that the seatback in a car without SBL does not make contact with front seat occupants until fairly late into their impacts with the steering assembly and instrument panel. The additional load of the seatback may have added slightly to the loads experienced by the left front dummy's thorax, but over an extended time period and without any

TABLE 6-1

FRONT SEAT SEPARATION* RATES, 2 DOOR CARS EQUIPPED WITH SBL, AS A FUNCTION OF DELTA V, IN FRONTAL CRASHES

	Delta V (mph)	Percent of Cars with Seat Separation*
	BACK SEAT UNOCCUPIED	
MDAI (Table 5-3)	Less than 10	1
	10-14.9	3
	15-19.9	6
	20-24.9	12
	25-29.9	26
	30-39.9	31
	40 or more	45
SLED TESTS (Section 2.2)	24** (2 tests)	0
	28.4** (3 tests)	0
	32** (1 test)	0
	BACK SEAT OCCUPANT CONTACTED FRONT SEATBACK	
MDAI (Table 5-3)	Less than 10	5
	10-14.9	21
	15-19.9	35
	20-29.9	47
	30 or more	88
SLED TESTS (Section 2.2)	16** (1 test)	0
	24** (4 tests)	0
	28.4** (3 tests)	100

*Note: The front seat "separated" if any of the following occurred: (1) An SBL broke. (2) The seat tore loose from one of the tracks. (3) The seat tore loose from the floor. (4) The front seatback tore loose from the seat.

**In the sled tests, Delta V averages 7.2% more than the impact speed.

noticeable spike. The seatback just feebly scrapes against the right front dummy.

When there are back seat occupants, SBL often do not remain intact in the crash. Table 6-1 shows that SBL or another seat component separated in 35 percent of frontal crashes with Delta V 15-20 mph, 47 percent with Delta V 20-30 and 88 percent of crashes with Delta V over 30. Likewise, seat separation occurred in all three sled tests at a Delta V of 28.4 mph. Seat components do <u>not</u> remain intact in the overwhelming majority of fatal crashes and in about half the crashes that would result in serious injuries. What is worse, the sled tests showed that even when seat components remain intact, the back seat dummies deflect the seats just as far forward as when there are no SBL and are just as likely to ramp up the deflected seatback into the front part of the passenger compartment. Although SBL somewhat modify occupant trajectories, they do not reduce the severity of the impacts. (Performance was better, however, especially at low speeds, when the back seat occupant was a child or weighed less than 100 pounds - see Table 5-4).

Based on these considerations, SBL cannot be expected to have much overall effect on occupant injuries, regardless of whether the back seat is occupied.

6.2 Do SBL reduce fatalities and injuries in crashes?

6.2.1 All occupants - all crashes

Table 6-2 presents the overall casualty reduction that was

TABLE 6-2

OVERALL CASUALTY REDUCTION FOR SBL

(2 door vs. 4 door cars,
before vs. after installation of SBL in 2 door cars)

	Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-1)	Fatalities	-15*	-9*	-11*	-10*
FARS (matching make/models; Table 4-2)	Fatalities	-14*	-9*	-11*	-11*
WASHINGTON (Table 3-5)	K + A (serious) inj.	-1	-4	-11*	-12*
	K+A+B (moderate) inj.	-6	-6*	-8*	-9*
	Any injuries	none	-2	-2	-4*
WASHINGTON (matching make/models; Table 3-6)	K + A injuries	+5	-2	-7	-9
	K + A + B injuries	-2	-3	-4	-4
	Any injuries	none	-1	-1	-2
TEXAS (Table 3-10)	K + A injuries	+12*	none	-4	-5
	K + A + B injuries	+6	-1	-6*	-7*
	Any injuries	+3	none	-3	-4*

*Statistically significant effect (two-sided alpha = .05)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

measured for SBL in three accident data files: FARS, Washington State and Texas. Since almost all the results in the table are negative, there is certainly little evidence that SBL reduced casualties. Is there any reason to believe that SBL increased them?

The FARS data provide the most consistently negative results. The sequence of effectiveness estimates (fatality reduction in 2 door cars relative to the control group of 4 door cars, as defined in Sections 3.1 and 4.1) was -15 percent for cars of the first model year with SBL vs. cars of the last year before SBL, -9 percent for the ±2 model year comparison, -11 percent for ±3 model years and -10 percent for ±4 model years. The sequence exhibits no drift in either direction and all results are significantly different from zero (as defined in Sections 3.1.3 and 4.1.3, with two-sided alpha = .05). Even when the analysis is limited to "matching makes and models" (second line of Table 6-2) - i.e., sporty 2 door cars and station wagons are removed from the data - the results are virtually the same. Thus, FARS clearly points to a negative "effect" on the order of 10 percent. The effect, however, can almost entirely be explained by what happened to occupant ejections in the model years that SBL were implemented. Table 6-9 shows that the effectiveness model used in this evaluation attributes a 20-30 percent negative "effect" on ejections. (The reasons for the effect are discussed in Section 6.3.) Since close to 30 percent of fatalities in cars of the 1960's were ejectees, the 20-30 percent relative increase in ejections explains most if not all of the 10 percent net fatality increase. In other words, SBL had little or no effect on the fatality risk of persons who remained inside the car - there is certainly no evidence of a positive effect in FARS.

The results for nonfatal injuries ought to differ from those on fatalities, since only a small proportion of nonfatal injuries are ejectees. Indeed, the sequences of effectiveness estimates for the State data files in Table 6-2, unlike FARS, typically show a trend from little or no effect in the ± 1 model year comparison to significant negative results in the ± 4 year comparison. In Washington, the trend is stronger when all cars are included in the comparison and weak when the data are limited to matching makes and models. In both cases, however, the trend line appears to start from approximately zero effectiveness. The Texas data are a little more perplexing, since they start with a positive effect in the ± 1 year comparison, significant at the .05 but not the .01 level, quickly drop to zero in the ± 2 year estimate, and finally display a more gradual negative trend in the ± 3 and ± 4 year estimates. The most likely conclusion, based on comparison with the other data files as well as the discussion in Section 6.1, is that the positive effect in the ± 1 year comparison is spurious, due to the limited sample size, and is cancelled out by the additional data in the ± 2 year comparison. The remainder of the Texas sequences looks just like the Washington results. The most appropriate conclusion is that SBL had little or no effect on nonfatal injuries.

6.2.2 Frontal crashes

Table 6-3 shows the effectiveness results from FARS and Texas

TABLE 6-3

CASUALTY REDUCTION FOR SBL IN FRONTAL CRASHES

	Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-8, 4-10)	Fatalities	-9	-3	-8*	-8*
	Nonejected fatalities	-6	none	-5	-5
TEXAS (Table 3-10)	K + A injuries	+16*	+6	+2	+1
	K + A + B injuries	+8	+3	-2	-2
	Any injuries	+8*	+3	+1	none
NEW YORK (Table 3-12)	Head minor bleed.	-8	none	-4	-6
	Head pain	-18	-3	-6	-9
	Neck/back pain	-21	-20	-8	-11
	Leg pain	-2	+6	+8	+11
	Head contusion	-1	-13	-9	-15
	Head severe bleed.	+5	+1	-3	-9
	Torso pain	+10	+13	+12	+13

	Effect on	Reduction for SBL (%)
SLED TESTS (Table 2-5)	HIC	+12
	Head g's	+2
	Mean Strain Criterion	+12
	Chest g's	-4
	Chest Severity Index	-3
	Left femur load	none
	Right femur load	-1

*Statistically significant effect (two-sided alpha = .05)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

when the data were limited to frontal crashes as well as the sled test results, all of which are based on simulated frontal crashes. The Washington data could not be subdivided by crash mode. The FARS results are almost identical to those for all crashes, except that they are slightly less negative, because ejection accounts for a smaller (yet substantial) percentage of the frontal fatals than in the other crash modes. The effect for persons who are not ejected is close to zero.

The Texas results for frontal crashes are likewise less negative than for all crashes. Here, however, the difference is not explained by the ejectees, which only account for a small proportion of the nonfatal injuries. Furthermore, unlike the consistently negative FARS results, the Texas sequences start out fairly positive and do not work their way down to zero until the ± 3 or ± 4 year estimate. They are the closest thing to a positive effect for SBL of all the accident data reviewed in this evaluation. Now, if the true effect of SBL were zero, the laws of probability suggest that approximately half of the estimates from all data files should be positive and 1 in 40 should even be positive and (spuriously) significant (two-sided alpha = .05). In that light, the Texas results, none of which are significant at the .01 level, cannot be viewed with great optimism.

The New York data did not show significant changes for any of the more common injury types in frontal crashes.

The sled test data, for all seat positions combined, did not show a statistically significant effect for SBL on any injury criterion - i.e., the observed effects of SBL were small relative to natural test to test variability. The experimental design for the sled tests is described in Section 2.1 and the method for testing statistical significance, based on matched pair comparisons of tests with and without SBL, is documented in Section 2.3.2. Table 6-3 shows positive, but nonsignificant effects of 2-12 percent on the three head injury criteria. Importantly, though, the effects were slightly negative on peak chest g's and sustained chest g's as measured by the Chest Severity Index. Section 1.6 explained that one of the primary potential benefits of SBL could be a reduction of chest injury severity. The reduction was not achieved and the sled tests also showed why (as described in Section 6.1). The sled tests showed virtually no effect on femur loads.

6.2.3 By injury type

The New York State data indicate each person's most serious specific injury and allow effectiveness estimates by injury type (see Section 3.4). Table 6-4 compares the sled tests and the New York results. Whereas the sled tests had generally positive, although nonsignificant results for head injury criteria, the New York estimates on head injuries were consistently negative, sometimes even significantly so, especially concussions, severe bleeding and minor bleeding. Conversely, while the sled tests had slight, nonsignificant negative numbers on chest injuries, the New York data showed modest, nonsignificant positive results. In both cases, the nonsignificant results from the two files cancel each other out, suggesting little or no effect for SBL. Both data

TABLE 6-4

CASUALTY REDUCTION FOR SBL - BY INJURY TYPE

	Body Region	Injury Type	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
NEW YORK (Table 3-11)	HEAD	CONCUSSION	-53	-20	-14	-16
		SEVERE BLEED.	-10	-11	-12	-17*
		minor bleed.	-9	-5	-9*	-9*
		pain	-3	+2	-7	-7
		contusion	+10	-12	-6	-10
		abrasion	-3	-7	-20	-13
	TORSO	INTERNAL	-24	+4	+6	+14
		pain	+1	+2	+3	+4
	LEG	FRACTURE	+14	-8	+11	+1
		pain	+1	+2	+2	+5
		contusion	-12	-16	-9	-6
		minor bleed.	+1	none	-2	-10
		abrasion	-19	-16	-21	-10
	ARM	FRACTURE	+27	+18	+20	+10
		pain	+9	+11	+2	+4
		minor bleed.	-24	-22	-24	-17
		contusion	-13	-24	-31	-24
	Neck/back	pain	-18	-13*	-6	-7
	All over	pain	+52*	+12	-3	none

	Body Region	Injury Crit.	Reduction for SBL (%)
SLED TESTS (Table 2-5)	HEAD	HIC	+12
		Head g's	+2
		MSC	+12
	TORSO	Chest g's	-4
		CSI	-3
	LEG	L femur load	none
		R femur load	-1

*Statistically significant effect (two-sided alpha = .05)
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

sources show little or no effect on leg injuries. The New York results on arm injuries are mixed, with positive numbers on fractures and pain injuries but negative ones on minor bleeding and contusions; all effects are nonsignificant and the best conclusion is that there was little or no effect.

6.2.4 By seat position

FARS, Washington and the sled test data can be subdivided into the three fundamental types of occupants: those sitting in the front seat with nobody sitting behind them, front seat occupants with somebody behind them, and back seat passengers. Table 6-5 shows that front seat occupants with nobody behind them had a consistent, significant fatality increase of about 11 percent in FARS. As described in Section 6.2.1, the fatality increase is almost entirely attributable to the "effect" of SBL on ejections. In Washington, the observed effects are close to zero in the ±1 model year comparison and become gradually worse thereafter, suggesting a vehicle age bias and little or no true effect for SBL. The sled test results are mixed. Nonsignificant improvements on two of the four head injury criteria were offset by comparable aggravation of the other two. Marginal improvement on the chest injury criteria was accompanied by nonsignificant increases in femur loads, suggesting that SBL have little effect on torso injuries. The results are consistent with the discussion in Section 6.1, which suggested that SBL, at best, resulted in a marginal amelioration of chest impacts with the steering assembly and had little or no effect on chest impacts with the instrument panel.

TABLE 6-5

CASUALTY REDUCTION FOR SBL

-FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM-

	Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-5)	Fatalities	-17*	-11*	-13*	-11*
WASHINGTON (Table 3-7)	K + A injuries	none	-6	-11*	-13*
	K + A + B injuries	-5	-9*	-9*	-11*
	Any injuries	+1	-2	-3	-5*

	Effect on	Reduction for SBL (%)
SLED TESTS (Table 2-6)	HIC	-12
	Head g's	-17
	Mean Strain Criterion	+12
	Tot. Lacerat. Index	+14
	Chest g's	+5
	Chest Severity Index	+1
	Left femur load	-18
	Right femur load	-11

*Statistically significant effect (two-sided alpha = .05)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

Table 6-6 presents results on front seat occupants with somebody sitting behind them. The overall effects in the accident data are basically similar to those in Table 6-5, except for the larger variation due to the smaller sample size. In other words, the increase in fatality risk is fairly consistent and close to 10 percent. The sequences for moderate to serious (K + A + B) and overall injury risk appear to converge on zero. The effects for serious injuries, however, are consistently negative, although nonsignificant. The statistical results from the sled tests mirror what was observed in the films - viz., that SBL do change the trajectories of occupants, but without much net effect on injury severity. The head injury readings were generally improved with SBL, although not significantly so, while the chest injury measures worsened. In particular, the peak head g's for the interaction between the rear and front seat occupants were reduced by 28 percent but the peak chest g's for that interaction increased by 25 percent (see Section 2.2 for more discussion).

The sample sizes of back seat occupants were too small for fine-tuned results; nevertheless Table 6-7 makes it clear that SBL had no major effects. The sequences of effectiveness estimates for fatalities and serious injuries shuttle between positive and negative. The results for moderate and minor injuries, after a bad start in the ±1 year comparison, seem to converge on zero. The sled test findings are inconsistent, with zero or negative effects on one of the criteria for each of the three body regions and nonsignificant positive effects for the other criteria for each region.

TABLE 6-6

CASUALTY REDUCTION FOR SBL

-FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM-

	Effect on Risk of	Net Effect of SBL (%)* Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-5)	Fatalities	-20	-5	-8	-11
WASHINGTON (Table 3-7)	K + A injuries	-23	-10	-15	-13
	K + A + B injuries	-7	+6	+2	+2
	Any injuries	-10	-4	-2	-2

	Effect on	Reduction for SBL (%)*
SLED TESTS (Table 2-7)	HIC	+20
	Head g's from:	
	any contact	+2
	1st contact	+1
	later contacts	+28
	Mean Strain Criterion	+19
	Tot. Lacerat. Index	-2
	Chest g's from:	
	any contact	-12
	1st contact	+2
	later contacts	-25
	Chest Severity Index	-32
	Left femur load	+10
	Right femur load	+17

*Note: positive numbers indicate favorable results for SBL; negative numbers indicate unfavorable results for SBL. None of the observed effects was statistically significant (two-sided alpha = .05).

TABLE 6-7

CASUALTY REDUCTION FOR SBL

-BACK SEAT OCCUPANTS-

	Effect on Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-5)	Fatalities	+2	+7	+5	-7
WASHINGTON (Table 3-7)	K + A injuries	-7	+11	-16	-14
	K + A + B injuries	-24	-3	-9	-4
	Any injuries	-12	+1	none	-2

	Effect on	Reduction for SBL (%)
SLED TESTS (Table 2-8)	HIC	+21
	Head g's	+12
	Mean Strain Criterion	none
	Chest g's	-5
	Chest Severity Index	+20
	Left femur load	+8
	Right femur load	-24*

*Statistically significant effect (two-sided alpha = .05)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

In the special case where the back seat occupant is a child up to 12 years old, impact forces on the front seatback are less severe due to the child's smaller mass and seat separation is less likely to occur - see Table 5-4. Nevertheless, Washington (Table 3-9) and FARS (Table 4-14) data do not associate with SBL any casualty reductions for the children or for the persons sitting in front of them. Both these analyses, however, are based on samples too small to be statistically meaningful.

6.2.5 Restrained occupants

The sled tests showed that SBL allow a substantial amount of forward deflection of the seatback in frontal crashes. Seatbacks deflected half the distance from their original position to the steering wheel even when there was no back seat dummy adding its load to the momentum of the seatback. It is reasonable to expect that SBL would have little benefit for the belted front seat occupant, who remains within the area where the seatback is displaced before it is caught by the SBL. Indeed, Table 6-8 shows no benefits for SBL. Fatality reduction, after a positive start, converges on zero: since none of the other FARS sequences showed a year to year trend against SBL, it should be concluded that the sequence in Table 6-8 reflects a zero effect and small sample sizes in the first two estimates, rather than a positive effect and a trend against SBL. The Washington results for serious and moderate injuries are consistently negative, although nonsignificant. The results for overall injury reduction are close to zero throughout the sequence.

TABLE 6-8

CASUALTY REDUCTION FOR SBL

-BELTED OCCUPANTS-

(2 door vs. 4 door cars,
before vs. after installation of SBL in 2 door cars)

	Effect on Risk of	Net Effect of SBL (%)* Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-7)	Fatalities	+26	+20	+3	+1
WASHINGTON (Table 3-8)	K + A injuries	-16	-6	-25	-21
	K + A + B injuries	-19	-11	-11	-8
	Any injuries	+2	none	-1	-1

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05).

6.2.6 Summary

This preliminary evaluation analyzes numerous sled tests and over a million accident cases, but none of the data showed significant benefits for SBL. Statistically, it is easy to prove definitively that a safety device is effective but difficult to prove that it is not. That is because statistical methods typically test a null hypothesis that a safety device is not effective. If the statistically significant positive effects are found, the null hypothesis is rejected - i.e., there is convincing evidence that the safety device is effective. But the lack of statistically significant positive results is not, by itself, convincing evidence that the null hypothesis is true and the device is not effective. For that reason, this study, none of whose results show effectiveness, is called a "preliminary" evaluation. There might still be some limited, narrowly defined portion of the crash environment where SBL are, in fact, beneficial, but there are simply not enough data of that type of crash for a statistically meaningful effectiveness analysis. Specifically, it seems logical that SBL might be beneficial for children riding in the back seat in moderate speed frontal crashes: the SBL may withstand the relatively light impact load of a child (see Table 5-4) and the seatback may retain the child within the safer rear half of the passenger compartment, whereas in a car without SBL, the child might be propelled over the folded seatback and contact the windshield, header, instrument panel or a front seat occupant. Even though the analyses of this evaluation do not show any fatality or injury reductions with SBL for child back seat occupants, the sample size for this limited crash situation is too small for the results to be convincing evidence that, in fact, SBL are not effective there. Similarly, it seems logical that SBL might account for a modest reduction of nonfatal injuries in low to moderate speed frontal crashes (Delta V 15 mph or so), especially when there are adults in the back seat; as above, the available data did not show a significant positive effect but do not preclude the possibility that there is, in fact, a modest positive effect. These crash situations could be possible topics for further study. Nevertheless, the data make a strong case that SBL have little or no overall effect on fatalities and injuries.

6.3 Do SBL affect the risk of occupant ejection?

Without doubt, the most decisive finding in the accident data was that the risk of occupant ejection fell dramatically in 4 door cars in the model years that SBL were introduced in 2 door cars, but the risk did not decrease in the 2 door cars until several model years later. Since the effectiveness measure used with the accident data is based on the change in 2 door cars relative to the change in 4 door cars, large, significant negative "effects" were consistently generated for SBL. Obviously, the big reduction of ejection in 4 door cars had nothing to do with SBL. But the failure to achieve a similar reduction in 2 door cars is conceivably due to a negative effect of SBL in 2 door cars which masks the positive effect seen in the 4 door cars. Section 1.6 presented a hypothesis as to why SBL could increase ejection risk for front seat occupants: without a folded seatback blocking the way, the occupant has an easier path to an open door. Intuitively, though, such an effect, if any, would not be large.

How large are the observed "effects" for SBL? Table 6-9 shows that the effect is always statistically significant in FARS and is *consistently near -25 percent, for* all occupants. For front seat occupants alone, it approaches -30 percent and perhaps even -35 percent for front seat occupants *with somebody sitting behind them.* When the data are separately analyzed by car size or by company (as in Table 4-13), though, there is a suggestion that the preceding results may have an additional bias against SBL due to certain market shifts and that the effect for front seat occupants may be in the -20 to -25 percent range. The Washington data show a consistent, significant -30 percent effect for SBL; however, when the data set is limited to matching makes and models, the effect is closer to -20 percent. The NCSS-MDAI data, after a completely anomalous start, rapidly converge to a similar value. The net effect on ejections seems to be in the -20 to -30 percent range.

A critically important finding in the NCSS and MDAI data, however, is that the likelihood of doors opening in crashes decreased sharply in 4 door cars in the model years that SBL were introduced in 2 door cars, but it did not drop in 2 door cars until several years later - exactly what was seen in the ejection rates. The lower part of Table 6-9 shows that the change in 2 door cars relative to the change in 4 door cars was consistently on the order of -30 percent. The likelihood of doors opening in crashes presumably has nothing to do with SBL but it is closely related to the risk of occupant ejection. Section 5.3 *examined door* modifications of the 1960's and concluded that major door latch improvements in 1967-68 (nearly coinciding with the implementation of SBL) are

TABLE 6-9

OBSERVED "EFFECTS" OF SBL ON OCCUPANT EJECTION AND ON DOORS OPENING DURING IMPACTS

(2 door vs. 4 door cars, before vs. after installation of SBL in 2 door cars)

		Net "Effect" of SBL (%)**			
		Number of Model Years before/after SBL Installation in 2 Door Cars			
	Type of Occupant	±1	±2	±3	±4
	EJECTIONS				
FARS (Table 4-6)	All ejectees	-42*	-26*	-24*	-23*
	Front seat, nobody behind them	-38*	-30*	-28*	-25*
	Front seat, somebody behind them	-77*	-37*	-30	-35*
	Back seat	-43	+4	+1	-13
WASHINGTON (Table 3-4)	All ejectees	-41*	-30*	-25*	-35*
(Table 3-6)	Matching make/models	-12	-17	-10	-20
NCSS-MDAI (Table 5-1)	All ejectees	+57	+25	+13	-12
	DOORS OPENING DURING IMPACTS				
	Vehicle Type				
NCSS-MDAI (Table 5-2)	All vehicles	-25	-31	-25	-37*

*Statistically significant effect (two-sided alpha = .05)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

responsible for the dramatic reduction of door opening in 4 door cars. These same improvements were made in 2 door cars but were apparently not nearly as effective. The intuitive support for the conclusion is that the doors of 4 door cars are significantly narrower than in 2 door cars. Wider doors have a greater tendency to bow at the time of impact and separate the latches from the frame. The 1967-68 improvement may have made the latches on the 4 door cars strong enough to resist all but the most severe impacts, while only beginning to solve the problem for 2 door cars.

If the effect of the latch improvements on door opening in 2 door cars relative to 4 door cars is -30 percent, it would explain a 20 percent relative increase in ejection risk, since two-thirds of the ejections in cars of the 1960's were through the doors. Thus, if the observed "effect" of SBL on ejections is close to 20 percent, as many of the data suggest, it could be attributed entirely to the door latch modifications and actually have nothing to do with SBL. But if the "effect" of SBL on ejections is higher than 20 percent - as it may be in the FARS data on front seat occupants with somebody sitting behind them - the possibility of a small but genuine negative effect for SBL cannot be ruled out.

Table 6-9 shows that the "effect" of SBL on the ejection of back seat occupants may be converging on -10 to -15 percent in FARS. If this number is slightly less negative than the effect on ejection that would be attributed to the door latch modifications, it could indicate a small but genuine positive effect for SBL, possibly canceling out part of the negative effect for the front seat occupants.

6.4 Do SBL affect fatality risk in car fires?

Section 1.6 raised a concern that the old style of manually operated SBL could impede the egress of back seat passengers from a 2 door car in emergency situations such as vehicle fires. But SBL might have modest benefits for front seat occupants in post-crash fires because it would keep folded over seatbacks out of their way. FARS is the only data file that contains a large number of cases involving vehicle fires and, even in FARS, the sample is not large enough for statistically significant results. Nevertheless, there are some consistent trends in Table 6-10.

Table 6-10 shows a consistently negative, although nonsignificant, effect for manual SBL on the likelihood of a back seat occupant dying in a vehicle that caught fire, as was feared in Section 1.6. The effect seems to be converging to about -30 percent, but it is important to note that none of the estimates are statistically significant, even at the .1 level. Intuitively, this effect would not be expected in domestic cars of the 1980's with automatic inertial SBL, since the back seat occupant would be able to fold the seatback without first having to disengage the SBL.

Table 6-10, however, also shows a highly positive, although nonsignificant effect of SBL for front seat occupants with somebody sitting behind them: on the order of 50 percent. The estimate is based on

TABLE 6-10

EFFECT OF SBL ON FATALITY RISK
IN CRASHES INVOLVING FIRES*

(2 door vs. 4 door cars,
before vs. after installation of SBL in 2 door cars)

	Effect on Fire Crash Fatality* Risk of	Net Effect of SBL (%)** Number of Model Years before/after SBL Installation in 2 Door Cars ±1	±2	±3	±4
FARS (Table 4-11)	All occupants	-21	none	+4	+6
	Front seat occ., nobody behind them	-28	-3	+2	+4
	Front seat occ., somebody behind them	+40	+68	+50	+57
	Back seat occupants	-23	-64	-34	-32

*Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (2-sided alpha = .05).

small samples, especially for pre-SBL cars, and far exceeds the benefit that could intuitively be expected. The net effect for all seating positions combined is close to zero. The most reasonable conclusion, based on Table 6-10, would appear to be that SBL have had little net effect on fire fatalities and that a possible negative effect for back seat occupants may have been offset by slightly easier egress for the far more numerous front seat occupants. Of course, the conclusion applies only to the old type of manual SBL. For current automatic SBL, the effect should be zero since the seatback moves freely, like in a pre-SBL car, except during the moment of impact.

APPENDIX A

SLED TEST RESULTS

SLED TEST RESULTS 10:58 THURSDAY, JULY 10, 1986

CONTENTS OF SAS DATA SET WORK.MCR

TRACKS USED=1 SUBEXTENTS=1 OBSERVATIONS=64 CREATED BY OS JOB KHEWUR1 ON CPUID 20-3090-170403

AT 10:58 THURSDAY, JULY 10, 1986 BY SAS RELEASE 82.4 DSNAME=SYS86191.T105833.RA000.KHEWUR1.R0000001 BLKSIZE=23396

LRECL=172 OBSERVATIONS PER TRACK=272 GENERATED BY DATA

ALPHABETIC LIST OF VARIABLES

#	VARIABLE	TYPE	LENGTH	POSITION	FORMAT	INFORMAT	LABEL
13	CHEST	NUM	8	100	DATAF5.		PEAK CHEST G'S FROM ANY CONTACT
14	CHESTE	NUM	8	108	DATAF5.		PEAK CHEST G'S FROM 1ST CONTACT
15	CHESTL	NUM	8	116	DATAF5.		PEAK CHEST G'S FROM LATER CONTACTS
9	CSI	NUM	8	68	DATAF5.		CHEST SEVERITY INDEX
3	DV	NUM	8	20			DELTA V (MPH)
10	HEAD	NUM	8	76			PEAK HEAD G'S FROM ANY CONTACT
11	HEADE	NUM	8	84	DATAF5.		PEAK HEAD G'S FROM 1ST CONTACT
12	HEADL	NUM	8	92	DATAF5.		PEAK HEAD G'S FROM LATER CONTACTS
8	HIC	NUM	8	60			HEAD INJURY CRITERION
16	LFEM	NUM	8	124	DATAF5.		LEFT FEMUR LOAD (POUNDS)
6	LOCKED	NUM	8	44	LOCKEDF8.		WITH OR WITHOUT SEAT BACK LOCKS
7	LR	NUM	8	52	LRF5.		LEFT OR RIGHT SIDE
19	MSC	NUM	8	148			MEAN STRAIN CRITERION
5	PDOF	NUM	8	36	PDOFF13.		PRINCIPAL DIRECTION OF FORCE
17	RFEM	NUM	8	132			RIGHT FEMUR LOAD (POUNDS)
21	SEATPOS	NUM	8	164	SEATPOSF20.		SEAT POSITION
4	SLEDG	NUM	8	28			SLED G'S
2	SPEED	NUM	8	12			ACTUAL IMPACT SPEED (MPH)
20	TARGET	NUM	8	156			TARGETED IMPACT SPEED (MPH)
1	TESTNO	NUM	8	4			CONTRACTOR'S TEST NUMBER
18	TLI	NUM	8	140	DATAF5.		TOTAL LACERATION INDEX

SLED TEST RESULTS   10:58 THURSDAY, JULY 10, 1986

OBS	TESTNO	LOCKED	TARGET	SPEED	DV	SLEDG	PDOF	SEATPOS
1	2918	NO SBL	22.5	22.2	24.00	11.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
2	2918	NO SBL	22.5	22.2	24.00	11.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
3	2921	NO SBL	15.0	14.8	16.40	9.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
4	2921	NO SBL	15.0	14.8	16.40	9.0	12:00 FRONTAL	BACK SEAT PASSENGER
5	2924	WITH SBL	15.0	14.9	16.80	8.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
6	2924	WITH SBL	15.0	14.9	16.80	8.5	12:00 FRONTAL	BACK SEAT PASSENGER
7	2927	NO SBL	30.0	29.6	31.60	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND
8	2927	NO SBL	30.0	29.6	31.60	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND
9	2935	WITH SBL	26.5	25.7	28.20	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
10	2935	WITH SBL	26.5	25.7	28.20	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
11	2938	WITH SBL	26.5	26.9	28.90	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
12	2938	WITH SBL	26.5	26.9	28.90	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
13	2941	NO SBL	26.5	26.5	28.50	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND
14	2941	NO SBL	26.5	26.5	28.50	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND
15	2944	NO SBL	26.5	26.6	28.10	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
16	2944	NO SBL	26.5	26.6	28.10	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
17	2947	NO SBL	26.5	26.3	27.80	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
18	2947	NO SBL	26.5	26.3	27.80	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
19	2950	WITH SBL	26.5	26.5	26.70	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
20	2950	WITH SBL	26.5	26.5	26.70	14.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
21	2957	WITH SBL	26.5	26.5	28.30	13.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
22	2957	WITH SBL	26.5	26.5	28.30	13.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
23	2957	WITH SBL	26.5	26.5	28.30	13.0	12:00 FRONTAL	BACK SEAT PASSENGER
24	2957	WITH SBL	26.5	26.5	28.30	13.0	12:00 FRONTAL	BACK SEAT PASSENGER
25	2962	WITH SBL	26.5	26.5	27.90	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
26	2962	WITH SBL	26.5	26.5	27.90	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND

OBS	LR	HIC	HEAD	HEADE	HEADL	MSC	TLI	CHEST	CHESTE	CHESTL	CSI	LFEM	RFEM
1	LEFT	213	43.5	N. A.	N. A.	0.005384	6.3	41.2	N. A.	N. A.	178	1152	1178
2	RIGHT	146	50.3	N. A.	N. A.	0.003255	7.7	28.8	N. A.	N. A.	148	497	513
3	LEFT	131	44.1	44.1	30	0.002247	0	34.5	34.5	18	127	904	503
4	LEFT	56	30.0	N. A.	N. A.	0.001757	N. A.	22.3	N. A.	N. A.	40	335	272
5	LEFT	85	32.3	32.3	18	0.001458	0	23.3	23.3	3	64	530	719
6	LEFT	33	20.7	N. A.	N. A.	0.001773	N. A.	12.8	N. A.	N. A.	UNK.	223	487
7	LEFT	533	65.8	N. A.	N. A.	0.004218	5	54.8	N. A.	N. A.	367	865	1428
8	RIGHT	1958	76.1	N. A.	N. A.	0.018813	10.3	79.2	N. A.	N. A.	733	2213	1745
9	LEFT	477	66.8	N. A.	N. A.	0.005010	3.7	53.9	N. A.	N. A.	305	1745	1935
10	RIGHT	218	54.9	N. A.	N. A.	0.002955	5.3	50.9	N. A.	N. A.	308	1349	1276
11	LEFT	351	74.2	N. A.	N. A.	0.005365	5.4	51	N. A.	N. A.	355	1965	998
12	RIGHT	298	60.1	N. A.	N. A.	0.002931	5.6	75.8	N. A.	N. A.	595	2323	2251
13	LEFT	321	56.0	N. A.	N. A.	0.003657	5.1	47.7	N. A.	N. A.	288	2062	1536
14	RIGHT	459	57.6	N. A.	N. A.	0.008210	5.2	70.1	N. A.	N. A.	679	1418	2921
15	LEFT	433	78.9	N. A.	N. A.	0.004447	4.8	67.7	N. A.	N. A.	498	1803	1079
16	RIGHT	345	56.1	N. A.	N. A.	0.003827	8.5	67.8	N. A.	N. A.	317	2779	1873
17	LEFT	543	66.8	N. A.	N. A.	0.003477	3.9	67.7	N. A.	N. A.	482	2622	725
18	RIGHT	428	59.7	N. A.	N. A.	0.009045	1.9	73.5	N. A.	N. A.	578	3668	2983
19	LEFT	762	95.3	N. A.	N. A.	0.003367	4.9	54.7	N. A.	N. A.	400	2831	530
20	RIGHT	376	59.4	N. A.	N. A.	0.003070	5.7	55.6	N. A.	N. A.	410	2322	2133
21	LEFT	576	64.4	64.4	55	0.004217	3.4	72.6	72.6	42	735	1629	721
22	RIGHT	327	42.4	42.4	0	0.005867	4.8	74.1	74.1	0	552	2702	1535
23	LEFT	237	71.1	N. A.	N. A.	0.003598	N. A.	45.9	N. A.	N. A.	179	924	1035
24	RIGHT	112	46.6	N. A.	N. A.	0.002983	N. A.	12.4	N. A.	N. A.	21	669	610
25	LEFT	397	64.7	64.7	45	0.004355	5.2	73.8	50	73.8	862	2564	562
26	RIGHT	4307	80.5	80.5	20	0.024524	5.3	78.1	78.1	65	980	3459	2901

OBS	TESTNO	LOCKED	TARGET	SPEED	DV	SLEDG	PDCF	SEATPOS
27	2962	WITH SBL	26.5	26.5	27.90	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
28	2962	WITH SBL	26.5	26.5	27.90	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
29	2967	NO SBL	26.5	26.5	28.20	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
30	2967	NO SBL	26.5	26.5	28.20	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
31	2967	NO SBL	26.5	26.5	28.20	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
32	2967	NO SBL	26.5	26.5	28.20	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
33	2972	NO SBL	26.5	26.8	30.40	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
34	2972	NO SBL	26.5	26.8	30.40	13.5	12:00 FRONTAL	FRONT,SOMEONE BEHIND
35	2972	NO SBL	26.5	26.8	30.40	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
36	2972	NO SBL	26.5	26.8	30.40	13.5	12:00 FRONTAL	BACK SEAT PASSENGER
37	2977	NO SBL	26.5	26.2	27.90	14.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
38	2977	NO SBL	26.5	26.2	27.90	14.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
39	2977	NO SBL	26.5	26.2	27.90	14.0	12:00 FRONTAL	BACK SEAT PASSENGER
40	2977	NO SBL	26.5	26.2	27.90	14.0	12:00 FRONTAL	BACK SEAT PASSENGER
41	2982	WITH SBL	26.5	26.5	28.50	14.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
42	2982	WITH SBL	26.5	26.5	28.50	14.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
43	2982	WITH SBL	26.5	26.5	28.50	14.0	12:00 FRONTAL	BACK SEAT PASSENGER
44	2982	WITH SBL	26.5	26.5	28.50	14.0	12:00 FRONTAL	BACK SEAT PASSENGER
45	2994	WITH SBL	22.5	22.2	23.40	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
46	2994	WITH SBL	22.5	22.2	23.40	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
47	2994	WITH SBL	22.5	22.2	23.40	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
48	2994	WITH SBL	22.5	22.2	23.40	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
49	2995	WITH SBL	22.5	22.7	24.03	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
50	2995	WITH SBL	22.5	22.7	24.03	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
51	2995	WITH SBL	22.5	22.7	24.03	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
52	2995	WITH SBL	22.5	22.7	24.03	11.0	12:00 FRONTAL	BACK SEAT PASSENGER

OBS	LR	HIC	HEAD	HEADF	HEADL	HSC	TLI	CHEST	CHESTF	CHESTL	CSI	LFEM	RFEM
27	LEFT	1167	89.1	N. A.	N. A.	0.010712	N. A.	37.8	N. A.	N. A.	148	535	551
28	RIGHT	495	91.7	N. A.	N. A.	0.017079	N. A.	46.1	N. A.	N. A.	169	649	632
29	LEFT	640	75.7	73.7	35	0.006588	4.8	75.5	60	75.5	1113	4039	650
30	RIGHT	934	64.4	64.4	60	0.012768	5.4	90	80	12	681	3647	3320
31	LEFT	4363	130.5	N. A.	N. A.	0.013244	N. A.	69.8	N. A.	N. A.	346	363	542
32	RIGHT	1320	70.3	N. A.	N. A.	0.014075	N. A.	24.6	N. A.	N. A.	85	713	705
33	LEFT	226	48.3	48	10	0.005399	4.5	50.3	50.3	22	310	1866	987
34	RIGHT	819	103.0	103	70	0.007115	6.1	53.2	53.2	35	451	2875	2036
35	LEFT	521	93.4	N. A.	N. A.	0.005443	N. A.	42.7	N. A.	N. A.	311	1164	597
36	RIGHT	1200	135.5	N. A.	N. A.	0.006705	N. A.	25.2	N. A.	N. A.	126	674	539
37	LEFT	450	77.3	77.3	50	0.007514	4.3	59.5	59.5	52	436	2056	767
38	RIGHT	2723	107.6	100	107.6	0.016422	6.3	55.8	55.8	40	444	2459	2933
39	LEFT	313	76.3	N. A.	N. A.	0.003851	N. A.	38.9	N. A.	N. A.	211	1120	728
40	RIGHT	1327	164.5	N. A.	N. A.	0.016311	N. A.	29.6	N. A.	N. A.	350	560	628
41	LEFT	326	43.2	43.2	44	0.003696	6	56.7	56.7	55	902	1450	777
42	RIGHT	324	71.3	71.3	39	0.005660	6	60.3	60.3	0	481	2775	2279
43	LEFT	184	61.5	N. A.	N. A.	0.004123	N. A.	42.6	N. A.	N. A.	188	233	1332
44	RIGHT	534	102.8	N. A.	N. A.	0.009472	N. A.	42	N. A.	N. A.	261	UNK.	1022
45	LEFT	293	51.8	51.8	35	0.003632	1	41.7	41.7	27	274	872	642
46	RIGHT	376	80.6	80.6	35	0.003286	5.1	35.9	20	35.9	152	1103	901
47	LEFT	321	63.0	N. A.	N. A.	0.003590	N. A.	34.6	N. A.	N. A.	134	579	621
48	RIGHT	613	52.5	N. A.	N. A.	0.003186	N. A.	23.2	N. A.	N. A.	36	402	598
49	LEFT	365	93.6	93.6	30	0.006825	3.8	80.3	35	80.3	941	1513	581
50	RIGHT	477	86.3	86.3	55	0.005032	5.2	24.9	24.9	20	191	1829	485
51	LEFT	734	90.5	N. A.	N. A.	0.007263	N. A.	32.7	N. A.	N. A.	113	527	506
52	RIGHT	739	73.5	N. A.	N. A.	0.010549	N. A.	29.9	N. A.	N. A.	64	510	491

SLED TEST RESULTS

10:58 THURSDAY, JULY 10, 1986

OBS	TESTNO	LOCKED	TARGET	SPEED	DV	SLEDG	PDOF	SEATPOS
53	2996	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
54	2996	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
55	2996	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
56	2996	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
57	3002	WITH SBL	22.5	22.4	24.2	12.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
58	3002	WITH SBL	22.5	22.4	24.2	12.0	12:00 FRONTAL	FRONT, NOBODY BEHIND
59	3003	WITH SBL	22.5	22.7	24.6	11.0	1:00 OBLIQUE	FRONT, NOBODY BEHIND
60	3003	WITH SBL	22.5	22.7	24.6	11.0	1:00 OBLIQUE	FRONT, NOBODY BEHIND
61	3004	NO SBL	22.5	22.5	24.7	11.0	1:00 OBLIQUE	FRONT, NOBODY BEHIND
62	3004	NO SBL	22.5	22.5	24.7	11.0	1:00 OBLIQUE	FRONT, NOBODY BEHIND
63	3008	NO SBL	22.5	23.3	24.6	10.0	1:00 OBLIQUE	FRONT,SOMEONE BEHIND
64	3008	NO SBL	22.5	23.3	24.6	10.0	1:00 OBLIQUE	FRONT,SOMEONE BEHIND
65	3008	NO SBL	22.5	23.3	24.6	10.0	1:00 OBLIQUE	BACK SEAT PASSENGER
66	3008	NO SBL	22.5	23.3	24.6	10.0	1:00 OBLIQUE	BACK SEAT PASSENGER
67	3009	WITH SBL	22.5	23.1	24.4	11.0	1:00 OBLIQUE	FRONT,SOMEONE BEHIND
68	3009	WITH SBL	22.5	23.1	24.4	11.0	1:00 OBLIQUE	FRONT,SOMEONE BEHIND
69	3009	WITH SBL	22.5	23.1	24.4	11.0	1:00 OBLIQUE	BACK SEAT PASSENGER
70	3009	WITH SBL	22.5	23.1	24.4	11.0	1:00 OBLIQUE	BACK SEAT PASSENGER
71	3016	WITH SBL	22.5	23.3	24.7	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
72	3016	WITH SBL	22.5	23.3	24.7	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
73	3016	WITH SBL	22.5	23.3	24.7	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
74	3016	WITH SBL	22.5	23.3	24.7	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
75	3017	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
76	3017	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
77	3017	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
78	3017	NO SBL	22.5	22.5	23.5	11.0	12:00 FRONTAL	BACK SEAT PASSENGER

OBS	LR	HIC	HEAD	HEADE	HEADL	MSC	TLI	CHEST	CHESTE	CHESTL	CSI	LFEM	RFEM
53	LEFT	457	58.3	58.3	45	0.003529	1	53.4	30	53.4	338	1276	712
54	RIGHT	474	85.3	85.3	25	0.005163	5	27.8	27.8	19	144	1922	1364
55	LEFT	392	78.3	N. A.	N. A.	0.004667	N. A.	46.5	N. A.	N. A.	159	398	616
56	RIGHT	136	43.1	N. A.	N. A.	0.002298	N. A.	20.6	N. A.	N. A.	59	268	463
57	LEFT	234	52.5	N. A.	N. A.	0.006135	5.3	46.5	N. A.	N. A.	191	2925	780
58	RIGHT	546	93.6	N. A.	N. A.	0.004564	5.9	29.5	N. A.	N. A.	140	1355	2436
59	LEFT	235	55.7	N. A.	N. A.	0.003058	2.3	29	N. A.	N. A.	130	3445	515
60	RIGHT	394	87.6	N. A.	N. A.	0.005044	6.1	40.2	N. A.	N. A.	195	3136	1798
61	LEFT	277	56.6	N. A.	N. A.	0.004867	5.2	39	N. A.	N. A.	189	3841	323
62	RIGHT	234	61.0	N. A.	N. A.	0.002986	6.1	36.6	N. A.	N. A.	176	1738	2148
63	LEFT	227	52.6	52.6	20	0.004458	0	36.7	36.7	28	202	2108	509
64	RIGHT	337	91.6	91.6	70	0.006255	5.3	46.4	46.4	10	275	3524	2356
65	LEFT	436	42.5	N. A.	N. A.	0.009942	N. A.	17.7	N. A.	N. A.	44	812	503
66	RIGHT	455	77.8	N. A.	N. A.	0.006073	N. A.	16.6	N. A.	N. A.	62	375	429
67	LEFT	185	52.3	52.3	22	0.003013	1.3	59.7	35	59.7	1012	4403	567
68	RIGHT	413	65.4	65.4	0	0.006404	4.4	39	39	7	231	4173	3378
69	LEFT	663	84.2	N. A.	N. A.	0.008043	N. A.	33.1	N. A.	N. A.	67	508	516
70	RIGHT	357	67.1	N. A.	N. A.	0.003958	N. A.	27.8	N. A.	N. A.	93	468	476
71	LEFT	736	111.3	111.3	25	0.008928	4.8	52.6	38	52.6	329	1344	440
72	RIGHT	253	72.8	72.8	15	0.004644	5.7	72.8	45	72.8	320	2692	2156
73	LEFT	701	104.3	N. A.	N. A.	0.007868	N. A.	UNK.	N. A.	N. A.	UNK.	589	619
74	RIGHT	1386	62.8	N. A.	N. A.	0.014832	N. A.	32.8	N. A.	N. A.	79	290	602
75	LEFT	139	39.6	39.6	17	0.002561	0	45.7	40	45.7	300	2191	624
76	RIGHT	1111	79.3	79.3	50	0.013263	5.9	49.1	49.1	19	257	3814	3195
77	LEFT	627	96.1	N. A.	N. A.	0.006070	N. A.	35.9	N. A.	N. A.	136	339	613
78	RIGHT	1446	66.6	N. A.	N. A.	0.014676	N. A.	21.6	N. A.	N. A.	62	438	422

SLED TEST RESULTS 10:58 THURSDAY, JULY 10, 1986

OBS	TESTNO	LOCKED	TARGET	SPEED	DV	SLEDG	PDOF	SEATPOS
79	3018	NO SBL	22.5	22.5	24.4	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
80	3018	NO SBL	22.5	22.5	24.4	11.0	12:00 FRONTAL	FRONT,SOMEONE BEHIND
81	3018	NO SBL	22.5	22.5	24.4	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
82	3018	NO SBL	22.5	22.5	24.4	11.0	12:00 FRONTAL	BACK SEAT PASSENGER
83	3021	WITH SBL	30.0	29.1	30.1	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND
84	3021	WITH SBL	30.0	29.1	30.1	14.5	12:00 FRONTAL	FRONT, NOBODY BEHIND

OBS	LR	HIC	HEAD	HEADE	HEADL	MSC	TLI	CHEST	CHESTE	CHESTL	CSI	LFEM	RFEM
79	LEFT	167	33.0	33	18	0.002383	6	37.1	37.1	24	167	1280	359
80	RIGHT	3068	67.0	67	0	0.020120	5.8	48.9	48.9	20	294	2899	2120
81	LEFT	113	41.6	N. A.	N. A.	0.002053	N. A.	29.3	N. A.	N. A.	114	457	658
82	RIGHT	413	72.5	N. A.	N. A.	0.004326	N. A.	20.7	N. A.	N. A.	71	404	417
83	LEFT	696	61.8	N. A.	N. A.	0.003621	5.1	68.8	N. A.	N. A.	587	1841	738
84	RIGHT	1629	95.2	N. A.	N. A.	0.006699	5.2	84.6	N. A.	N. A.	1310	3859	5129

APPENDIX B

DETAILED STATE DATA TABULATIONS

TABLE B-1

WASHINGTON STATE 1973-77: K + A INJURY RATES, ALL OCCUPANTS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	359	10,667	3.37		
	first 1 after	291	11,379	2.56	24	
2	last 1 before	505	13,505	3.74		
	first 1 after	423	15,644	2.70	28	+5% Z=0.49
4	last 2 before	740	21,547	3.43		
	first 2 after	617	23,935	2.58	25	
2	last 2 before	999	26,385	3.79		
	first 2 after	993	34,165	2.91	23	-2% Z=0.32
4	last 3 before	954	26,752	3.57		
	first 3 after	723	28,548	2.53	29	
2	last 3 before	1256	32,318	3.89		
	first 3 after	1320	44,543	2.96	24	-7% Z=1.14
4	last 4 before	1165	31,419	3.71		
	first 4 after	832	33,483	2.48	33	
2	last 4 before	1516	37,730	4.02		
	first 4 after	1526	51,859	2.94	27	-9% Z=1.55

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-2

WASHINGTON STATE 1973-77: K + A + B INJURY RATES,
ALL OCCUPANTS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models
that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	1350	10,667	12.66		
	first 1 after	1205	11,379	10.59	16	
2	last 1 before	1995	13,505	14.77		
	first 1 after	1979	15,644	12.65	14	-2% Z=0.48
4	last 2 before	2830	21,547	13.13		
	first 2 after	2485	23,935	10.38	21	
2	last 2 before	4045	26,385	15.33		
	first 2 after	4279	34,165	12.52	18	-3% Z=0.99
4	last 3 before	3592	26,752	13.43		
	first 3 after	2949	28,548	10.33	23	
2	last 3 before	5042	32,318	15.60		
	first 3 after	5534	44,543	12.42	20	-4% Z=1.15
4	last 4 before	4351	31,419	13.85		
	first 4 after	3445	33,483	10.29	26	
2	last 4 before	6022	37,730	15.96		
	first 4 after	6393	51,859	12.33	23	-4% Z=1.41

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-3

WASHINGTON STATE 1973-77: OVERALL INJURY RATES, ALL OCCUPANTS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	2,697	10,667	25.28		
	first 1 after	2,645	11,379	23.24	8	
2	last 1 before	3,694	13,505	27.35		
	first 1 after	3,934	15,644	25.15	8	none Z=0.00
4	last 2 before	5,569	21,547	25.84		
	first 2 after	5,453	23,935	22.78	12	
2	last 2 before	7,290	26,385	27.63		
	first 2 after	8,421	34,165	24.65	11	-1% Z=0.55
4	last 3 before	6,944	26,752	25.96		
	first 3 after	6,472	28,548	22.67	13	
2	last 3 before	8,953	32,318	27.70		
	first 3 after	10,917	44,543	24.51	12	-1% Z=0.65
4	last 4 before	8,294	31,419	26.40		
	first 4 after	7,551	33,483	22.55	15	
2	last 4 before	10,533	37,730	27.92		
	first 4 after	12,665	51,859	24.42	13	-2% Z=1.31

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-4

WASHINGTON STATE 1973-77: EJECTEES PER 1000 OCCUPANTS, ALL SEATING POSITIONS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	N of Occ.	Ejectees per 1000 Occ.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	71	10,667	6.66		
	first 1 after	50	11,379	4.39	34	
2	last 1 before	130	13,505	9.63		
	first 1 after	111	15,644	7.10	26	-12% Z=0.49
4	last 2 before	146	21,547	6.78		
	first 2 after	89	23,935	3.72	45	
2	last 2 before	295	26,385	11.18		
	first 2 after	246	34,165	7.20	36	-17% Z=1.00
4	last 3 before	195	26,752	7.29		
	first 3 after	112	28,548	3.92	46	
2	last 3 before	366	32,318	11.33		
	first 3 after	299	44,543	6.71	41	-10% Z=0.68
4	last 4 before	240	31,419	7.64		
	first 4 after	126	33,483	3.76	51	
2	last 4 before	434	37,730	11.50		
	first 4 after	354	51,859	6.83	41	-20% Z=1.42

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-5

WASHINGTON STATE 1973-77: K + A INJURY RATES,
FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	506	20,853	2.43		
	first 1 after	456	21,053	2.17	11	
2	last 1 before	700	26,067	2.69		
	first 1 after	712	29,691	2.40	11	none Z=0.00
4	last 2 before	1106	42,522	2.60		
	first 2 after	943	43,336	2.18	16	
2	last 2 before	1436	50,204	2.86		
	first 2 after	1554	61,500	2.52	12	-6% Z=0.96
4	last 3 before	1681	62,140	2.71		
	first 3 after	1314	61,866	2.12	21	
2	last 3 before	2067	70,729	2.92		
	first 3 after	2414	94,632	2.55	13	-11% Z=2.26*
4	last 4 before	2200	77,403	2.84		
	first 4 after	1642	78,682	2.09	27	
2	last 4 before	2515	82,637	3.04		
	first 4 after	3058	120,943	2.53	17	-13% Z=2.95*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-6

WASHINGTON STATE 1973-77: K + A + B INJURY RATES, FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2,166	20,853	10.39		
	first 1 after	1,935	21,053	9.19	12	
2	last 1 before	3,121	26,067	11.97		
	first 1 after	3,311	29,691	11.15	7	-5% Z=1.34
4	last 2 before	4,713	42,522	11.08		
	first 2 after	3,936	43,336	9.08	18	
2	last 2 before	6,329	50,204	12.61		
	first 2 after	6,898	61,500	11.22	11	-9% Z=3.11*
4	last 3 before	7,060	62,140	11.36		
	first 3 after	5,563	61,866	8.99	21	
2	last 3 before	9,104	70,729	12.87		
	first 3 after	10,542	94,632	11.14	13	-9% Z=4.09*
4	last 4 before	9,079	77,403	11.73		
	first 4 after	7,003	78,682	8.90	24	
2	last 4 before	10,855	82,637	13.14		
	first 4 after	13,424	120,943	11.10	16	-11% Z=5.50*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-7

WASHINGTON STATE 1973-77: OVERALL INJURY RATES,
FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	4,493	20,853	21.55		
	first 1 after	4,342	21,053	20.62	4	
2	last 1 before	6,178	26,067	23.70		
	first 1 after	6,678	29,691	22.49	5	+1% Z=0.35
4	last 2 before	9,501	42,522	22.34		
	first 2 after	8,809	43,336	20.33	9	
2	last 2 before	12,142	50,204	24.19		
	first 2 after	13,828	61,500	22.48	7	-2% Z=1.26
4	last 3 before	13,990	62,140	22.51		
	first 3 after	12,480	61,866	20.17	10	
2	last 3 before	17,226	70,729	24.35		
	first 3 after	21,235	94,632	22.44	8	-3% Z=1.95
4	last 4 before	17,763	77,403	22.95		
	first 4 after	15,746	78,682	20.01	13	
2	last 4 before	20,275	82,637	24.54		
	first 4 after	27,219	120,943	22.51	8	-5% Z=3.94

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-8

WASHINGTON STATE 1973-77: K + A INJURY RATES, FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	54	990	5.45		
	first 1 after	34	1053	3.23	41	
2	last 1 before	81	1162	6.97		
	first 1 after	69	1354	5.10	27	-23% Z=0.79
4	last 2 before	112	2018	5.55		
	first 2 after	78	2116	3.68	34	
2	last 2 before	163	2264	7.20		
	first 2 after	149	2820	5.28	27	-10% Z=0.55
4	last 3 before	163	2971	5.49		
	first 3 after	112	3076	3.64	34	
2	last 3 before	222	3268	6.79		
	first 3 after	221	4249	5.20	23	-15% Z=0.94
4	last 4 before	197	3623	5.44		
	first 4 after	139	3975	3.50	36	
2	last 4 before	261	3812	6.85		
	first 4 after	266	5351	4.97	27	-13% Z=0.88

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-9

WASHINGTON STATE 1973-77: K + A + B INJURY RATES,
FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	163	990	16.46		
	first 1 after	134	1053	12.73	23	
2	last 1 before	262	1162	22.55		
	first 1 after	252	1354	18.61	17	-7% Z=0.48
4	last 2 before	337	2018	16.70		
	first 2 after	297	2116	14.04	16	
2	last 2 before	532	2264	23.50		
	first 2 after	525	2820	18.62	21	+6% Z=0.63
4	last 3 before	510	2971	17.17		
	first 3 after	430	3076	13.98	19	
2	last 3 before	743	3268	22.74		
	first 3 after	769	4249	18.10	20	+2% Z=0.29
4	last 4 before	621	3623	17.14		
	first 4 after	555	3975	13.96	19	
2	last 4 before	855	3812	22.43		
	first 4 after	954	5351	17.83	21	+2% Z=0.35

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-10

WASHINGTON STATE 1973-77: OVERALL INJURY RATES, FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	300	990	30.30		
	first 1 after	277	1053	26.31	13	
2	last 1 before	398	1162	34.25		
	first 1 after	443	1354	32.72	4	-10% Z=1.03
4	last 2 before	615	2018	30.48		
	first 2 after	571	2116	26.98	11	
2	last 2 before	810	2264	35.78		
	first 2 after	930	2820	32.98	8	-4% Z=0.62
4	last 3 before	906	2971	30.49		
	first 3 after	825	3076	26.82	12	
2	last 3 before	1155	3268	35.34		
	first 3 after	1344	4249	31.63	11	-2% Z=0.33
4	last 4 before	1111	3623	30.67		
	first 4 after	1071	3975	26.94	12	
2	last 4 before	1343	3812	35.23		
	first 4 after	1697	5351	31.71	10	-2% Z=0.50

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-11

WASHINGTON STATE 1973-77: K + A INJURY RATES, BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	45	1100	4.09		
	first 1 after	32	1195	2.68	35	
2	last 1 before	78	1312	5.95		
	first 1 after	62	1488	4.17	30	-7% Z=0.24
4	last 2 before	87	2247	3.87		
	first 2 after	78	2403	3.25	16	
2	last 2 before	153	2563	5.97		
	first 2 after	139	3115	4.46	25	+11% Z=0.60
4	last 3 before	136	3296	4.13		
	first 3 after	98	3469	2.83	32	
2	last 3 before	207	3663	5.65		
	first 3 after	210	4664	4.50	20	-16% Z=0.93
4	last 4 before	171	4029	4.24		
	first 4 after	128	4473	2.86	33	
2	last 4 before	234	4275	5.47		
	first 4 after	248	5881	4.22	23	-14% Z=0.91

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-12

WASHINGTON STATE 1973-77: K + A + B INJURY RATES,
BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	183	1100	16.64		
	first 1 after	137	1195	11.46	31	
2	last 1 before	249	1312	18.98		
	first 1 after	241	1488	16.20	15	-24% Z=1.57
4	last 2 before	369	2247	16.42		
	first 2 after	307	2403	12.78	22	
2	last 2 before	518	2563	20.21		
	first 2 after	505	3115	16.21	20	-3% Z=0.33
4	last 3 before	554	3296	16.81		
	first 3 after	423	3469	12.19	27	
2	last 3 before	732	3663	19.98		
	first 3 after	736	4664	15.78	21	-9% Z=1.09
4	last 4 before	693	4029	17.20		
	first 4 after	569	4473	12.72	26	
2	last 4 before	854	4275	19.98		
	first 4 after	907	5881	15.42	23	-4% Z=0.62

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-13

WASHINGTON STATE 1973-77: OVERALL INJURY RATES, BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	329	1100	29.91		
	first 1 after	291	1195	24.35	19	
2	last 1 before	414	1312	31.55		
	first 1 after	430	1488	28.90	8	-12% Z=1.28
4	last 2 before	658	2247	29.28		
	first 2 after	609	2403	25.34	13	
2	last 2 before	845	2563	32.97		
	first 2 after	881	3115	28.28	14	+1% Z=0.14
4	last 3 before	983	3296	29.82		
	first 3 after	883	3469	25.45	15	
2	last 3 before	1194	3663	32.60		
	first 3 after	1302	4664	27.92	14	none Z=0.07
4	last 4 before	1234	4029	30.63		
	first 4 after	1147	4473	25.64	16	
2	last 4 before	1404	4275	32.84		
	first 4 after	1648	5881	28.02	15	-2% Z=0.40

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-14

WASHINGTON STATE 1973-77: K + A INJURY RATES, BELTED OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	54	3,688	1.46		
	first 1 after	49	4,056	1.21	17	
2	last 1 before	72	4,310	1.67		
	first 1 after	85	5,298	1.60	4	-16% Z=0.60
4	last 2 before	113	7,256	1.56		
	first 2 after	112	8,504	1.32	15	
2	last 2 before	150	8,233	1.82		
	first 2 after	180	11,073	1.63	11	-6% Z=0.31
4	last 3 before	165	10,076	1.64		
	first 3 after	170	12,628	1.35	18	
2	last 3 before	188	11,094	1.69		
	first 3 after	306	17,516	1.75	-3	-25% Z=1.59
4	last 4 before	193	11,777	1.64		
	first 4 after	225	16,633	1.35	17	
2	last 4 before	209	12,146	1.72		
	first 4 after	388	23,084	1.68	2	-21% Z=1.30

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-15

WASHINGTON STATE 1973-77: K + A + B INJURY RATES, BELTED OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	322	3,688	8.73		
	first 1 after	321	4,056	7.91	9	
2	last 1 before	420	4,310	9.74		
	first 1 after	555	5,298	10.48	-8	-19% Z=1.74
4	last 2 before	685	7,256	9.44		
	first 2 after	674	8,504	7.92	16	
2	last 2 before	884	8,233	10.74		
	first 2 after	1103	11,073	9.96	7	-11% Z=1.47
4	last 3 before	985	10,076	9.78		
	first 3 after	1050	12,628	8.31	15	
2	last 3 before	1205	11,094	10.86		
	first 3 after	1799	17,516	10.27	5	-11% Z=1.91
4	last 4 before	1155	11,777	9.81		
	first 4 after	1366	16,633	8.21	16	
2	last 4 before	1365	12,146	11.24		
	first 4 after	2351	23,084	10.18	9	-8% Z=1.57

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-16

WASHINGTON STATE 1973-77: OVERALL INJURY RATES, BELTED OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	784	3,688	21.26		
	first 1 after	881	4,056	21.72	-2	
2	last 1 before	1015	4,310	23.54		
	first 1 after	1254	5,298	23.66	-1	+2% Z=0.29
4	last 2 before	1625	7,256	22.40		
	first 2 after	1821	8,504	21.41	4	
2	last 2 before	1991	8,233	24.18		
	first 2 after	2544	11,073	22.97	5	none Z=0.16
4	last 3 before	2292	10,076	22.75		
	first 3 after	2727	12,628	21.59	5	
2	last 3 before	2707	11,094	24.40		
	first 3 after	4113	17,516	23.48	4	-1% Z=0.41
4	last 4 before	2683	11,777	22.78		
	first 4 after	3570	16,633	21.46	6	
2	last 4 before	3035	12,146	24.99		
	first 4 after	5464	23,084	23.67	5	-1% Z=0.18

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-17

TEXAS 1972-74: K + A INJURY RATES,
ALL DRIVERS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	814	48,362	1.68		
	first 1 after	771	48,704	1.58	6	
2	last 1 before	1060	50,374	2.10		
	first 1 after	1038	59,932	1.73	18	+12% Z=2.02*
4	last 2 before	1824	96,243	1.89		
	first 2 after	1543	104,156	1.48	22	
2	last 2 before	2115	96,173	2.20		
	first 2 after	2290	132,753	1.73	22	none Z=0.08
4	last 3 before	2798	139,221	2.01		
	first 3 after	2199	156,389	1.41	30	
2	last 3 before	3027	131,212	2.31		
	first 3 after	3602	214,049	1.68	27	-4% Z=1.11
4	last 4 before	3686	177,570	2.08		
	first 4 after	2871	207,986	1.38	34	
2	last 4 before	3702	153,825	2.41		
	first 4 after	4873	291,275	1.67	30	-5% Z=1.35

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-18

TEXAS 1972-74: K + A + B INJURY RATES,
ALL DRIVERS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2,873	48,362	5.94		
	first 1 after	2,654	48,704	5.45	8	
2	last 1 before	3,597	50,374	7.14		
	first 1 after	3,684	59,932	6.15	14	+6% Z=1.83
4	last 2 before	6,091	96,243	6.33		
	first 2 after	5,416	104,156	5.20	18	
2	last 2 before	7,068	96,173	7.35		
	first 2 after	8,100	132,753	6.10	17	-1% Z=0.43
4	last 3 before	9,123	139,221	6.55		
	first 3 after	7,753	156,389	4.96	24	
2	last 3 before	9,878	131,212	7.53		
	first 3 after	12,964	214,049	6.06	20	-6% Z=3.08*
4	last 4 before	12,076	177,570	6.80		
	first 4 after	10,101	207,986	4.86	29	
2	last 4 before	11,917	153,825	7.75		
	first 4 after	17,331	291,275	5.95	23	-7% Z=4.15*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-19

TEXAS 1972-74: OVERALL INJURY RATES, ALL DRIVERS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	4,854	48,362	10.04		
	first 1 after	4,629	48,704	9.50	5	
2	last 1 before	5,609	50,374	11.13		
	first 1 after	6,108	59,932	10.19	8	+3* Z=1.29
4	last 2 before	9,947	96,243	10.34		
	first 2 after	9,562	104,156	9.18	11	
2	last 2 before	10,931	96,173	11.37		
	first 2 after	13,404	132,753	10.10	11	none Z=0.01
4	last 3 before	14,681	139,221	10.55		
	first 3 after	13,818	156,389	8.84	16	
2	last 3 before	15,274	131,212	11.64		
	first 3 after	21,491	214,049	10.04	14	-3% Z=1.91
4	last 4 before	19,190	177,570	10.81		
	first 4 after	18,074	207,986	8.69	20	
2	last 4 before	18,216	153,825	11.84		
	first 4 after	28,822	291,275	9.90	16	-4% Z=2.86*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-20

TEXAS 1972-74: K + A INJURY RATES,
DRIVERS IN FRONTAL CRASHES

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	518	19,837	2.61		
	first 1 after	494	19,650	2.51	4	
2	last 1 before	623	21,830	2.85		
	first 1 after	590	25,470	2.32	19	+16% Z=2.03*
4	last 2 before	1167	40,324	2.89		
	first 2 after	970	41,292	2.35	19	
2	last 2 before	1275	42,321	3.01		
	first 2 after	1291	55,933	2.31	23	+6% Z=1.00
4	last 3 before	1801	58,819	3.06		
	first 3 after	1361	61,150	2.23	27	
2	last 3 before	1837	58,179	3.16		
	first 3 after	2006	89,442	2.24	29	+2% Z=0.48
4	last 4 before	2384	75,946	3.14		
	first 4 after	1760	80,771	2.18	31	
2	last 4 before	2278	68,639	3.32		
	first 4 after	2733	121,184	2.26	32	+1% Z=0.51

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-21

TEXAS 1972-74: K + A + B INJURY RATES,
DRIVERS IN FRONTAL CRASHES

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	1742	19,837	8.78		
	first 1 after	1603	19,650	8.16	7	
2	last 1 before	2139	21,830	9.80		
	first 1 after	2138	25,470	8.39	19	+8% Z=1.83
4	last 2 before	3731	40,324	9.25		
	first 2 after	3255	41,292	7.88	15	
2	last 2 before	4281	42,321	10.12		
	first 2 after	4678	55,933	8.36	17	+3% Z=0.98
4	last 3 before	5633	58,819	9.58		
	first 3 after	4641	61,150	7.59	21	
2	last 3 before	6017	58,179	10.34		
	first 3 after	7393	89,442	8.27	20	-2% Z=0.33
4	last 4 before	7507	75,946	9.88		
	first 4 after	5961	80,771	7.38	25	
2	last 4 before	7322	68,639	10.67		
	first 4 after	9888	121,184	8.16	24	-2% Z=1.08

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE B-22

TEXAS 1972-74: OVERALL INJURY RATES, DRIVERS IN FRONTAL CRASHES

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Injuries	N of Persons	Injuries per 100 Persons	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2,472	19,837	12.46		
	first 1 after	2,356	19,650	11.99	4	
2	last 1 before	2,943	21,830	13.48		
	first 1 after	3,055	25,470	11.99	11	+8% Z=2.16*
4	last 2 before	5,186	40,324	12.86		
	first 2 after	4,783	41,292	11.58	10	
2	last 2 before	5,860	42,321	13.85		
	first 2 after	6,747	55,933	12.06	13	+3% Z=1.32
4	last 3 before	7,739	58,819	13.16		
	first 3 after	6,908	61,150	11.30	14	
2	last 3 before	8,247	58,179	14.18		
	first 3 after	10,752	89,442	12.02	15	+1% Z=0.59
4	last 4 before	10,245	75,946	13.49		
	first 4 after	8,927	80,771	11.05	18	
2	last 4 before	9,949	68,639	14.49		
	first 4 after	14,440	121,184	11.92	18	none Z=0.18

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE B-23

NEW YORK STATE 1974: INJURY RATES BY INJURY TYPE, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
<u>LAST YEAR</u> BEFORE VS. <u>FIRST YEAR</u> AFTER INSTALLATION OF SBL IN 2 DOOR CARS

			4 Door Cars			2 Door Cars				
Body Region	Injury Type	Overall n of Occurrences	PRE (9682 Occ.) Inj. Rate*	POST (10991 Occ.) Inj. Rate*	Gross Red. (%)	PRE (7721 Occ.) Inj. Rate*	POST (9881 Occ.) Inj Rate*	Gross Red. (%)	NET RED. FOR SBL (%)**	Z Test
Head	minor bleed.	2780	75.50	59.87	21	85.35	74.08	13	-9	1.23
Neck/back	pain	2029	53.19	50.59	5	50.90	57.18	-12	-18	1.90
Head	pain	1539	39.25	39.76	-1	40.15	41.70	-4	-3	.25
Leg	pain	942	26.93	22.84	12	26.94	23.38	13	+1	.18
Head	contusion	787	20.66	18.38	11	24.61	19.73	20	+10	.74
Arm	pain	683	19.11	18.65	2	17.74	15.79	11	+9	.60
Torso	pain	613	15.29	18.01	-18	13.86	16.19	-17	+1	.05
HEAD	SEVERE BLEED.	545	14.46	11.55	20	16.97	14.88	12	-10	.60
Leg	contusion	327	8.78	7.28	17	9.58	8.91	7	-12	.52
Arm	minor bleed.	288	7.64	5.73	25	8.94	8.30	7	-24	.90
Head	abrasion	266	6.09	7.19	-18	6.48	7.89	-22	-3	.12
HEAD	CONCUSSION	238	5.78	4.91	15	6.22	8.10	-30	-53	1.63
Leg	minor bleed.	189	5.06	3.91	23	6.35	4.86	23	+1	.03
All over	pain	191	4.85	5.82	-20	5.96	3.44	42	+52	2.49#
Arm	contusion	145	4.44	3.37	24	4.02	3.44	14	-13	.36
Leg	abrasion	136	4.13	3.18	23	3.63	3.34	8	-19	.52
LEG	FRACTURE	237	2.89	3.64	-26	3.76	4.05	-8	+14	.45
ARM	FRACTURE	104	1.96	2.09	-7	4.02	3.14	22	+27	.78
TORSO	INTERNAL	98	2.79	1.91	31	3.11	2.63	15	-24	.52

*Injury rate per 1000 occupants
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.
#Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

TABLE B-24

NEW YORK STATE 1974: INJURY RATES BY INJURY TYPE, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, LAST 2 YEARS BEFORE VS. FIRST 2 YEARS AFTER INSTALLATION OF SBL IN 2 DOOR CARS

			4 Door Cars			2 Door Cars				
Body Region	Injury Type	Overall n of Occurrences	PRE (18182 Occ.) Inj. Rate*	POST (23170 Occ.) Inj. Rate*	Gross Red. (%)	PRE (14511 Occ.) Inj. Rate*	POST (21952 Occ.) Inj Rate*	Gross Red. (%)	NET RED. FOR SBL (%)**	Z Test
Head	minor bleed.	5594	75.18	57.96	23	89.45	72.25	19	-5	.89
Neck/back	pain	4128	52.47	52.91	-1	49.20	56.21	-14	-13	2.01#
Head	pain	3094	39.21	39.71	-1	40.18	40.00	none	+2	.24
Leg	pain	1871	25.30	22.53	11	26.46	23.00	13	+2	.26
Head	contusion	1621	22.27	18.00	19	23.22	21.05	9	-12	1.16
Arm	pain	1356	17.71	18.17	-3	17.71	16.22	8	+11	1.04
Torso	pain	1204	15.56	16.31	-5	14.61	15.08	-3	+2	.13
HEAD	SEVERE BLEED.	1169	17.60	10.01	43	21.71	13.76	37	-11	.92
Leg	contusion	652	9.07	7.21	21	9.23	8.47	8	-16	.91
Arm	minor bleed.	583	7.15	5.65	21	9.03	8.70	4	-22	1.18
Head	abrasion	563	7.20	6.56	9	7.79	7.61	2	-7	.41
HEAD	CONCUSSION	486	5.83	5.05	13	7.03	7.33	-4	-20	1.01
Leg	minor bleed.	403	5.61	4.19	25	6.62	4.92	26	none	.02
All over	pain	390	5.39	5.44	-1	4.89	4.33	12	+12	.63
Arm	contusion	300	4.62	3.54	23	3.79	3.60	5	-24	.92
Leg	abrasion	282	4.29	3.11	28	4.00	3.37	16	-16	.63
LEG	FRACTURE	269	3.63	3.19	12	3.65	3.46	5	-8	.31
ARM	FRACTURE	205	2.47	2.33	6	3.38	2.60	23	+18	.73
TORSO	INTERNAL	199	2.36	2.37	none	2.83	2.73	3	+4	.14

*Injury rate per 1000 occupants

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

TABLE B-25

NEW YORK STATE 1974: INJURY RATES BY INJURY TYPE, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
LAST 3 YEARS BEFORE VS. FIRST 3 YEARS AFTER INSTALLATION OF SBL IN 2 DOOR CARS

			4 Door Cars			2 Door Cars				
Body Region	Injury Type	Overall n of Occurrences	PRE (22900 Occ.) Inj. Rate*	POST (34673 Occ.) Inj. Rate*	Gross Red. (%)	PRE (18424 Occ.) Inj. Rate*	POST (36712 Occ.) Inj Rate*	Gross Red. (%)	NET RED. FOR SBL (%)**	Z Test
Head	minor bleed.	7905	76.55	55.63	27	88.80	70.47	21	-9	1.98#
Neck/back	pain	5957	51.97	53.27	-3	50.21	54.34	-8	-6	1.03
Head	pain	4509	39.48	39.74	-1	39.62	40.78	-3	-2	.37
Leg	pain	2662	25.46	22.27	13	26.22	22.44	14	+2	.28
Head	contusion	2383	21.66	18.26	16	24.48	21.87	11	-6	.70
Arm	pain	1987	18.73	17.68	6	18.07	16.67	8	+2	.25
Torso	pain	1774	16.33	16.67	-2	15.03	14.85	1	+3	.33
HEAD	SEVERE BLEED.	1698	18.69	9.58	49	23.77	13.62	43	-12	1.14
Leg	contusion	974	8.86	7.70	13	9.50	8.96	6	-9	.62
Arm	minor bleed.	832	7.34	5.02	32	9.88	8.39	15	-24	1.52
Head	abrasion	820	7.38	6.32	14	7.71	7.90	-2	-20	1.24
HEAD	CONCUSSION	693	5.72	4.96	13	7.11	7.05	1	-14	.85
Leg	minor bleed.	578	5.68	4.33	24	6.35	4.93	22	-2	.11
All over	pain	552	4.93	5.19	-5	4.45	4.82	-8	-3	.16
Arm	contusion	432	4.67	3.37	28	3.91	3.70	5	-31	1.37
Leg	abrasion	392	4.24	2.88	32	4.01	3.30	18	-21	.94
LEG	FRACTURE	367	3.58	3.26	9	3.58	2.89	19	+11	.56
ARM	FRACTURE	290	2.23	2.28	-2	3.31	2.70	19	+20	.93
TORSO	INTERNAL	286	2.36	2.36	none	2.82	2.67	5	+6	.22

*Injury rate per 1000 occupants
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.
#Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

TABLE B-26

NEW YORK STATE 1974: INJURY RATES BY INJURY TYPE, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS,
LAST 4 YEARS BEFORE VS. FIRST 4 YEARS AFTER INSTALLATION OF SBL IN 2 DOOR CARS

			4 Door Cars			2 Door Cars				
Body Region	Injury Type	Overall n of Occurrences	PRE (25387 Occ.) Inj. Rate*	POST (46177 Occ.) Inj. Rate*	Gross Red. (%)	PRE (20269 Occ.) Inj. Rate*	POST (51029 Occ.) Inj Rate*	Gross Red. (%)	NET RED. FOR SBL (%)**	Z Test
Head	minor bleed.	9709	77.01	54.05	30	88.41	67.92	23	-9	2.21#
Neck/back	pain	7572	51.84	52.84	-2	50.18	54.85	-9	-7	1.43
Head	pain	5717	39.27	38.72	1	39.57	41.74	-5	-7	1.20
Leg	pain	3318	24.78	22.15	11	26.10	22.28	15	+5	.64
Head	contusion	3023	22.33	17.78	20	25.21	22.03	13	-10	1.23
Arm	pain	2447	18.40	17.04	7	18.21	16.15	11	+4	.51
Torso	pain	2233	16.39	16.33	none	15.44	14.70	5	+4	.50
HEAD	SEVERE BLEED.	2104	19.46	9.29	52	24.17	13.54	44	-17	1.82
Leg	contusion	1244	8.86	7.77	12	9.72	9.07	7	-6	.52
Arm	minor bleed.	1041	7.56	5.28	30	9.77	7.98	18	-17	1.21
Head	abrasion	1017	7.52	6.13	19	8.09	7.43	8	-13	.90
HEAD	CONCUSSION	863	5.83	4.74	19	7.25	6.84	6	-16	1.03
Leg	minor bleed.	729	5.63	4.22	25	6.27	5.17	17	-10	.62
All over	pain	694	4.73	4.92	-4	4.74	4.92	-4	none	.01
Arm	contusion	559	4.65	3.44	26	4.19	3.86	8	-24	1.23
Leg	abrasion	495	4.21	2.97	30	4.19	3.25	22	-10	.51
LEG	FRACTURE	458	3.51	3.01	14	3.60	3.08	15	+1	.01
ARM	FRACTURE	357	2.21	2.14	3	3.11	2.72	12	+10	.45
TORSO	INTERNAL	336	2.32	2.10	10	3.01	2.33	23	+14	.69

*Injury rate per 1000 occupants
**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.
#Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

APPENDIX C

DETAILED FARS DATA TABULATIONS

TABLE C-1

FARS 1975-85: FATALITY RATES PER MILLION "EXPOSURE"# YEARS, FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Exposure Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	2113	11.328	188.0		
	first 1 after	2147	13.026	164.8	12	
2	last 1 before	2413	9.690	249.0		
	first 1 after	3195	12.527	255.0	-2	-17% Z=3.80*
4	last 2 before	3640	22.180	164.1		
	first 2 after	4783	29.007	164.9	none	
2	last 2 before	4177	18.032	231.6		
	first 2 after	7248	28.138	257.6	-11	-11% Z=3.46*
4	last 3 before	4192	27.466	152.6		
	first 3 after	6217	35.913	173.1	-13	
2	last 3 before	4892	22.547	217.0		
	first 3 after	10516	37.676	279.1	-29	-13% Z=4.76*
4	last 4 before	4555	32.110	141.9		
	first 4 after	7980	43.930	181.7	-28	
2	last 4 before	5219	25.079	208.1		
	first 4 after	13388	45.254	295.8	-42	-11% Z=4.23*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with nobody behind them (in Washington State - see Tables 3-1 and B-5).

TABLE C-2

FARS 1975-85: FATALITY RATES PER MILLION "EXPOSURE"** YEARS,
FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Exposure Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	216	0.659	327.8		
	first 1 after	238	0.777	306.1	7	
2	last 1 before	274	0.550	498.4		
	first 1 after	377	0.676	557.6	-12	-20% Z=1.47
4	last 2 before	355	1.307	271.7		
	first 2 after	513	1.663	308.4	-14	
2	last 2 before	474	1.015	467.0		
	first 2 after	834	1.497	557.2	-19	-5% Z=0.55
4	last 3 before	389	1.616	240.7		
	first 3 after	654	2.091	312.7	-30	
2	last 3 before	559	1.298	430.8		
	first 3 after	1182	1.957	604.0	-40	-8% Z=0.93
4	last 4 before	433	1.857	233.2		
	first 4 after	856	2.597	329.7	-41	
2	last 4 before	592	1.443	410.2		
	first 4 after	1481	2.295	645.3	-57	-11% Z=1.39

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

**"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with somebody behind them (in Washington State - see Tables 3-1 and B-8).

TABLE C-3

FARS 1975-85: FATALITY RATES PER MILLION "EXPOSURE"** YEARS, BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Exposure Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	134	0.734	182.5		
	first 1 after	201	0.885	227.0	-24	
2	last 1 before	176	0.619	284.4		
	first 1 after	255	0.739	345.2	-21	+2% Z=0.16
4	last 2 before	237	1.448	163.7		
	first 2 after	442	1.882	234.9	-43	
2	last 2 before	312	1.152	270.9		
	first 2 after	597	1.645	362.9	-34	+7% Z=0.64
4	last 3 before	264	1.784	147.9		
	first 3 after	565	2.351	240.3	-62	
2	last 3 before	373	1.456	256.2		
	first 3 after	852	2.149	396.5	-55	+5% Z=0.50
4	last 4 before	298	2.046	145.6		
	first 4 after	712	2.903	245.3	-68	
2	last 4 before	389	1.619	240.3		
	first 4 after	1090	2.519	432.7	-80	-7% Z=0.74

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

**"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the back seat (in Washington State - see Tables 3-1 and B-11).

TABLE C-4

FARS 1975-85: EJECTEES# PER MILLION "EXPOSURE"## YEARS, FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Exposure Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	456	11.328	40.6		
	first 1 after	410	13.026	31.5	22	
2	last 1 before	784	9.690	80.9		
	first 1 after	1088	12.527	86.9	-7	-38% Z=3.94*
4	last 2 before	808	22.180	36.4		
	first 2 after	940	29.007	32.4	11	
2	last 2 before	1345	18.032	74.6		
	first 2 after	2429	28.138	86.3	-16	-30% Z=4.48*
4	last 3 before	957	27.466	34.8		
	first 3 after	1265	35.913	35.2	-1	
2	last 3 before	1628	22.547	72.2		
	first 3 after	3514	37.676	93.3	-29	-28% Z=4.69*
4	last 4 before	1071	32.110	33.4		
	first 4 after	1622	43.930	36.9	-11	
2	last 4 before	1756	25.079	70.0		
	first 4 after	4393	45.254	97.1	-39	-25% Z=4.65*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

##"<u>Exposure years</u>" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with nobody behind them (in Washington State - see Tables 3-1 and B-5).

TABLE C-5

FARS 1975-85: EJECTEES# PER MILLION "EXPOSURE"## YEARS, FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Exposure Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	73	0.659	110.8		
	first 1 after	54	0.777	69.5	37	
2	last 1 before	120	0.550	218.3		
	first 1 after	164	0.676	242.6	-11	-77% Z=2.66*
4	last 2 before	111	1.307	84.9		
	first 2 after	121	1.663	72.7	14	
2	last 2 before	207	1.015	203.9		
	first 2 after	359	1.497	239.9	-17	-37% Z=2.01*
4	last 3 before	124	1.616	76.7		
	first 3 after	166	2.091	79.4	-3	
2	last 3 before	248	1.298	191.1		
	first 3 after	504	1.957	257.5	-35	-30% Z=1.87
4	last 4 before	140	1.857	75.4		
	first 4 after	217	2.597	83.6	-11	
2	last 4 before	261	1.443	180.8		
	first 4 after	619	2.295	269.7	-49	-35% Z=2.27*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

##"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with somebody behind them (in Washington State - see Tables 3-1 and B-8).

TABLE C-6

FARS 1975-85: EJECTEES# PER MILLION "EXPOSURE"## YEARS, BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Exposure Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	68	0.734	92.6		
	first 1 after	52	0.885	58.7	37	
2	last 1 before	100	0.619	161.6		
	first 1 after	108	0.739	146.2	10	-43% Z=1.55
4	last 2 before	100	1.448	69.1		
	first 2 after	129	1.882	68.5	1	
2	last 2 before	175	1.152	152.0		
	first 2 after	238	1.645	144.7	5	+4% Z=0.25
4	last 3 before	110	1.784	61.6		
	first 3 after	164	2.351	69.8	-13	
2	last 3 before	208	1.456	142.9		
	first 3 after	343	2.149	159.6	-12	+1% Z=0.08
4	last 4 before	130	2.046	63.5		
	first 4 after	209	2.903	72.0	-13	
2	last 4 before	217	1.619	134.1		
	first 4 after	433	2.519	171.9	-28	-13% Z=0.89

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

##"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the back seat (in Washington State - see Tables 3-1 and B-11).

TABLE C-7

FARS 1975-85: FATALITY RATES IN CRASHES INVOLVING FIRES**, PER MILLION VEHICLE YEARS, ALL OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Fire Crash Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	71	12.632	5.62		
	first 1 after	91	14.688	6.20	-10	
2	last 1 before	84	10.858	7.74		
	first 1 after	144	13.942	10.33	-34	-21% Z=0.92
4	last 2 before	111	24.934	4.45		
	first 2 after	201	32.552	6.18	-39	
2	last 2 before	149	20.198	7.38		
	first 2 after	319	31.280	10.20	-38	none Z=0.02
4	last 3 before	126	30.866	4.08		
	first 3 after	274	40.356	6.79	-66	
2	last 3 before	171	25.300	6.76		
	first 3 after	452	41.782	10.82	-60	+4% Z=0.27
4	last 4 before	137	36.013	3.80		
	first 4 after	369	49.249	7.47	-96	
2	last 4 before	180	28.141	6.40		
	first 4 after	591	50.068	11.80	-85	+6% Z=0.47

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

**Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

TABLE C-8

FARS 1975-85: FATALITY RATES IN CRASHES INVOLVING FIRES**,
PER MILLION "EXPOSURE"# YEARS,
FRONT SEAT OCCUPANTS WITH NOBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Fire Crash Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	64	11.328	5.70		
	first 1 after	69	13.026	5.30	7	
2	last 1 before	73	9.690	7.53		
	first 1 after	112	12.527	8.94	-19	-28% Z=1.06
4	last 2 before	101	22.180	4.55		
	first 2 after	168	29.007	5.79	-27	
2	last 2 before	129	18.032	7.15		
	first 2 after	263	28.138	9.35	-31	-3% Z=0.16
4	last 3 before	114	27.466	4.15		
	first 3 after	233	35.913	6.49	-56	
2	last 3 before	147	22.547	6.52		
	first 3 after	374	37.676	9.93	-52	+2% Z=0.18
4	last 4 before	125	32.110	3.89		
	first 4 after	307	43.930	6.99	-80	
2	last 4 before	155	25.079	6.18		
	first 4 after	480	45.254	10.61	-72	+4% Z=0.32

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05).

**Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

#"Exposure years" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with nobody behind them (in Washington State - see Tables 3-1 and B-5).

TABLE C-9

FARS 1975-85: FATALITY RATES IN CRASHES INVOLVING FIRES**,
PER MILLION "EXPOSURE"# YEARS,
FRONT SEAT OCCUPANTS WITH SOMEBODY SITTING BEHIND THEM

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Fire Crash Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	2	0.659	3.04		
	first 1 after	12	0.777	15.44	-408	
2	last 1 before	4	0.550	7.28		
	first 1 after	15	0.676	22.19	-205	+40% Z=0.54
4	last 2 before	3	1.307	2.30		
	first 2 after	22	1.663	13.23	-476	
2	last 2 before	8	1.015	7.88		
	first 2 after	22	1.497	14.70	-87	+68% Z=1.57
4	last 3 before	4	1.616	2.48		
	first 3 after	25	2.091	11.95	-383	
2	last 3 before	9	1.298	6.94		
	first 3 after	33	1.957	16.86	-143	+50% Z=1.06
4	last 4 before	4	1.857	2.15		
	first 4 after	38	2.597	14.64	-579	
2	last 4 before	10	1.443	6.93		
	first 4 after	46	2.295	20.04	-189	+57% Z=1.38

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05).

**Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

#"<u>Exposure years</u>" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the front seat with somebody behind them (in Washington State - see Tables 3-1 and B-8).

TABLE C-10

FARS 1975-85: FATALITY RATES IN CRASHES INVOLVING FIRES**, PER MILLION "EXPOSURE"# YEARS, BACK SEAT OCCUPANTS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Fire Crash Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	5	0.734	6.81		
	first 1 after	10	0.885	11.29	-66	
2	last 1 before	7	0.619	11.31		
	first 1 after	17	0.739	23.02	-103	-23% Z=0.29
4	last 2 before	7	1.448	4.84		
	first 2 after	11	1.882	5.85	-21	
2	last 2 before	12	1.152	10.42		
	first 2 after	34	1.645	20.67	-98	-64% Z=0.85
4	last 3 before	8	1.784	4.48		
	first 3 after	16	2.351	6.81	-52	
2	last 3 before	15	1.456	10.30		
	first 3 after	45	2.149	20.94	-103	-34% Z=0.56
4	last 4 before	8	2.046	3.91		
	first 4 after	24	2.903	8.27	-111	
2	last 4 before	15	1.619	9.27		
	first 4 after	65	2.519	25.81	-178	-32% Z=0.55

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05).

**Persons who were killed in a vehichle that caught fire. FARS, however, does not specify whether the person's fatal injury was due to the fire or to other causes.

#"<u>Exposure years</u>" equal the number of vehicle years (from Table 4-1) multiplied by the proportion of occupants who are sitting in the back seat (in Washington State - see Tables 3-1 and B-11).

TABLE C-11

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, OCCUPANTS OF COMPACT AND INTERMEDIATE SIZED CARS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	785	3.411	230.1		
	first 1 after	786	3.818	205.9	11	
2	last 1 before	1913	5.978	320.0		
	first 1 after	2778	8.236	337.3	-5	-18% Z=2.80*
4	last 2 before	1483	7.297	203.2		
	first 2 after	1651	7.976	207.0	-2	
2	last 2 before	3345	10.814	309.3		
	first 2 after	6404	18.511	346.0	-11	-10% Z=2.25*
4	last 3 before	1690	8.859	190.8		
	first 3 after	2126	9.601	221.4	-16	
2	last 3 before	3888	13.483	288.4		
	first 3 after	9466	25.059	377.7	-31	-13% Z=3.21*
4	last 4 before	1872	10.425	179.5		
	first 4 after	2767	11.714	236.2	-32	
2	last 4 before	4067	14.431	281.8		
	first 4 after	12119	29.960	404.5	-44	-9% Z=2.49*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE C-12

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, OCCUPANTS OF FULL SIZED AND LUXURY CARS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	1678	9.221	182.0		
	first 1 after	1800	10.870	165.6	9	
2	last 1 before	950	4.880	194.7		
	first 1 after	1049	5.706	183.8	6	-4% Z=0.73
4	last 2 before	2749	17.596	156.2		
	first 2 after	4087	24.633	165.9	-6	
2	last 2 before	1617	9.500	170.2		
	first 2 after	2275	12.751	178.4	-5	+1% Z=0.32
4	last 3 before	3154	21.921	143.9		
	first 3 after	5310	30.727	172.8	-20	
2	last 3 before	1935	11.984	161.4		
	first 3 after	3084	16.520	186.7	-16	+4% Z=0.94
4	last 4 before	3412	25.469	134.0		
	first 4 after	6781	37.565	180.5	-35	
2	last 4 before	2132	14.111	151.1		
	first 4 after	3840	19.901	193.0	-28	+5% Z=1.54

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE C-13

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, OCCUPANTS OF GENERAL MOTORS CARS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	1200	5.639	212.8		
	first 1 after	1135	5.800	195.7	8	
2	last 1 before	1285	4.796	267.9		
	first 1 after	1464	5.259	278.4	-4	-13% Z=2.15*
4	last 2 before	1770	11.199	158.0		
	first 2 after	2555	13.282	192.4	-22	
2	last 2 before	1902	8.895	213.8		
	first 2 after	3342	12.399	269.6	-26	-4% Z=0.82
4	last 3 before	2051	13.906	147.5		
	first 3 after	3275	17.131	191.2	-30	
2	last 3 before	2225	10.856	204.9		
	first 3 after	4662	16.507	282.4	-38	-6% Z=1.60
4	last 4 before	2245	16.445	136.5		
	first 4 after	4131	20.679	199.8	-46	
2	last 4 before	2406	12.298	195.6		
	first 4 after	6087	20.204	301.3	-54	-5% Z=1.43

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

TABLE C-14

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, OCCUPANTS OF FORD MOTOR CO. CARS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	464	2.185	212.3		
	first 1 after	531	2.480	214.1	-1	
2	last 1 before	432	2.068	208.9		
	first 1 after	632	2.702	233.9	-12	-11% Z=1.17
4	last 2 before	931	4.081	228.2		
	first 2 after	1229	5.394	227.8	none	
2	last 2 before	936	4.092	228.7		
	first 2 after	1395	5.895	236.7	-3	-4% Z=0.57
4	last 3 before	1186	5.899	201.0		
	first 3 after	1903	7.321	259.9	-29	
2	last 3 before	1153	5.586	206.4		
	first 3 after	2950	10.523	280.3	-36	-5% Z=0.97
4	last 4 before	1363	7.420	183.7		
	first 4 after	2822	10.270	274.8	-50	
2	last 4 before	1335	7.305	182.7		
	first 4 after	4046	13.601	297.5	-63	-9% Z=1.85

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE C-15

FARS 1975-85: FATALITY RATES PER MILLION VEHICLE YEARS, OCCUPANTS OF CHRYSLER CORP. CARS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Deaths	Millions of Car Years	Deaths per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	500	2.703	185.0		
	first 1 after	607	3.795	160.0	14	
2	last 1 before	429	1.745	245.9		
	first 1 after	671	2.870	233.8	5	-10% Z=1.10
4	last 2 before	1037	4.421	187.8		
	first 2 after	1269	7.934	159.9	15	
2	last 2 before	844	3.352	251.8		
	first 2 after	1541	6.415	240.2	5	-12% Z=1.90

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

TABLE C-16

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, OCCUPANTS OF COMPACT AND INTERMEDIATE SIZED CARS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	198	3.411	58.0		
	first 1 after	138	3.818	36.1	38	
2	last 1 before	727	5.978	121.6		
	first 1 after	1063	8.236	129.1	-6	-70% Z=4.44*
4	last 2 before	358	7.297	49.1		
	first 2 after	316	7.976	39.6	19	
2	last 2 before	1230	10.814	113.7		
	first 2 after	2394	18.511	129.3	-14	-41% Z=4.05*
4	last 3 before	419	8.859	47.3		
	first 3 after	418	9.601	43.5	8	
2	last 3 before	1454	13.483	107.8		
	first 3 after	3510	25.059	140.1	-30	-41% Z=4.55*
4	last 4 before	484	10.425	46.4		
	first 4 after	539	11.714	46.0	1	
2	last 4 before	1516	14.431	105.1		
	first 4 after	4368	29.960	145.8	-39	-40% Z=4.87*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

TABLE C-17

FARS 1975-85: EJECTEES** PER MILLION VEHICLE YEARS,
OCCUPANTS OF FULL SIZED AND LUXURY CARS

2 DOOR VS. 4 DOOR CARS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL* Z Test
4	last 1 before	399	9.221	43.3		
	first 1 after	378	10.870	34.8	20	
2	last 1 before	277	4.880	56.8		
	first 1 after	297	5.706	52.1	8	-14% Z=1.20
4	last 2 before	661	17.596	37.6		
	first 2 after	874	24.633	35.5	6	
2	last 2 before	497	9.500	52.3		
	first 2 after	632	12.751	49.6	5	none Z=0.03
4	last 3 before	772	21.921	35.2		
	first 3 after	1177	30.727	38.3	-9	
2	last 3 before	630	11.984	52.6		
	first 3 after	851	16.520	51.5	2	+10% Z=1.46
4	last 4 before	857	25.469	33.6		
	first 4 after	1509	37.565	40.2	-19	
2	last 4 before	718	14.111	50.9		
	first 4 after	1077	19.901	54.1	-6	+11% Z=1.78

*Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group. None of the observed net effects were statistically significant (two-sided alpha = .05 - i.e., Z greater than 1.96).

**Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

TABLE C-18

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS,
OCCUPANTS OF GENERAL MOTORS CARS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS,
BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models
that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	275	5.639	48.8		
	first 1 after	212	5.800	36.6	25	
2	last 1 before	418	4.796	87.2		
	first 1 after	447	5.259	85.0	2	-30% Z=2.31*
4	last 2 before	398	11.199	35.5		
	first 2 after	480	13.282	36.1	-2	
2	last 2 before	620	8.895	69.7		
	first 2 after	994	12.399	80.2	-15	-13% Z=1.45
4	last 3 before	465	13.906	33.4		
	first 3 after	601	17.131	35.1	-5	
2	last 3 before	755	10.856	69.5		
	first 3 after	1392	16.507	84.3	-21	-16% Z=1.89
4	last 4 before	525	16.445	31.9		
	first 4 after	775	20.679	37.5	-17	
2	last 4 before	827	12.298	67.2		
	first 4 after	1816	20.204	89.9	-34	-14% Z=1.84

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

TABLE C-19

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, OCCUPANTS OF FORD MOTOR CO. CARS

2 DOOR VS. 4 DOOR SEDANS AND HARDTOPS OF THE SAME MAKES AND MODELS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS
(Excludes station wagons, convertibles, and any make/models that were produced only with 2 doors or only with 4 doors)

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	106	2.185	48.5		
	first 1 after	99	2.480	39.9	17	
2	last 1 before	147	2.068	71.1		
	first 1 after	248	2.702	91.8	-29	-57% Z=2.59*
4	last 2 before	221	4.081	54.2		
	first 2 after	275	5.394	51.0	6	
2	last 2 before	335	4.092	81.9		
	first 2 after	516	5.895	87.5	-7	-14% Z=1.11
4	last 3 before	293	5.899	49.7		
	first 3 after	477	7.321	65.2	-31	
2	last 3 before	419	5.586	75.0		
	first 3 after	1039	10.523	98.7	-32	none Z=0.04
4	last 4 before	361	7.420	48.6		
	first 4 after	678	10.270	66.0	-36	
2	last 4 before	492	7.305	67.3		
	first 4 after	1384	13.601	101.8	-51	-11% Z=1.28

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

TABLE C-20

FARS 1975-85: EJECTEES# PER MILLION VEHICLE YEARS, OCCUPANTS OF CHRYSLER CORP. CARS

2 DOOR VS. 4 DOOR CARS, BEFORE VS. AFTER INSTALLATION OF SBL IN 2 DOOR CARS

N of Doors	MY Before/ After SBL Install. in 2 Door Cars	n of Ejectees	Millions of Car Years	Ejectees per Million Yrs.	Gross Red. (%)	NET RED. FOR SBL** Z Test
4	last 1 before	150	2.703	55.5		
	first 1 after	140	3.795	36.9	34	
2	last 1 before	151	1.745	86.5		
	first 1 after	233	2.870	81.2	6	-41% Z=2.19*
4	last 2 before	274	4.421	49.6		
	first 2 after	274	7.934	34.5	30	
2	last 2 before	297	3.352	88.6		
	first 2 after	561	6.415	87.4	1	-42% Z=3.14*

*Statistically significant effect (two-sided alpha = .05 - i.e., Z greater than 1.96)

**Note: positive numbers indicate that the SBL group (2 door cars) had greater improvements than the control group (4 door cars); negative numbers indicate that SBL did worse than the control group.

#Persons who were ejected in a crash that was fatal to somebody, but who, themselves, were not necessarily killed.

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