# Traffic Barrier Performance Related to Vehicle Size and Type

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ABSTRACT

Field investigations were completed at 3,302 traffic barrier accident sites in New York State to determine the effects of various parameters on barrier performance. Information gathered includes vehicle size and type, barrier type and rail height, and highway parameters. Performance was assessed in terms of occupant injuries, vehicle containment, and secondary collisions. New York's traffic barriers resulted in lower occupant injury rates than do roadside accidents in general, with modern barrier types resulting in fewer injuries than older barriers. Satisfactory vehicle containment was achieved in about 75 percent of the reported barrier accidents. Secondary collisions resulted in about 25 percent of all barrier accidents, primarily when the vehicle was not contained by the barrier. Secondary collisions with fixed objects were most common, followed by rollovers, but other vehicles or pedestrians were rarely involved. Injury rates were much higher when satisfactory containment was not achieved or secondary collisions resulted. Traffic barriers performed best for passenger automobiles and had somewhat reduced performance for vans and light trucks. Heavy trucks experienced about the same severe injury rates as passenger automobiles, but they also frequently penetrated traffic barriers and were involved in secondary collisions. Injury rates in motorcycle accidents were extremely high. Traffic barriers performed best in collisions with midsized passenger automobiles, followed by the smallest and then the largest passenger automobiles. The lower protection provided large automobiles appears to be related to more frequent barrier penetration and secondary collisions.

In-service evaluation is recognized as a final stage of development for new or extensively modified highway safety appurtenances (1). New York State's light-post traffic barriers were developed and perfected during the 1960s. Field performance evaluations conducted in the 1960s and early 1970s confirmed that these barriers provide excellent protection to errant vehicles (2,3). However, during the past few years, substantial changes in vehicle design have occurred and smaller, lighter vehicles are now a large portion of the vehicle fleet. In addition, many highways along which these barriers were installed have been overlaid resulting in changes in effective barrier height. Finally, other barrier types are in service--both early designs that may be reaching the end of their useful life and new designs used selectively for special situations. Thus information was needed to relate the severity of barrier accidents to vehicle size and type, barrier type and mounting height, and roadway features.

## PURPOSE AND SCOPE

This investigation is based on traffic accidents on state highways in New York State. Information was compiled on personal injuries, vehicle damage and characteristics, barrier and highway characteristics, and various impact and vehicle trajectory parameters. These data were then analyzed to determine how barrier performance was affected by vehicle size and weight, barrier type and mounting height, and roadway features. In this paper barrier performance in general and the effects of vehicle size and type are examined. Further analysis of accident records will be complete in 1986, and those results will be included in subsequent reports.

## METHODOLOGY

New York State law requires an accident report on any traffic accident resulting in personal injury, property damage exceeding $400, or damage to property other than the vehicles involved. These reports are generally filed by the motorist for minor accidents and by a police officer for more severe accidents. Although the law requires an accident report for any accident resulting in damage to a traffic barrier, most minor barrier accidents do not generate a report. Reports are more likely in cases that result in personal injury or vehicle damage sufficient to require towing.

Accident reports provide information on accident time and location, roadway and weather parameters, personal injury and vehicle damage, vehicle registration data, and a brief narrative and sketch describing the accident. These reports are coded by Department of Motor Vehicles (DMV) personnel for computer storage and analysis. For this project, DMV provided a computer tape covering the 12-month period from July 1, 1982, through June 30, 1983, listing all accidents on state-maintained highways in which the first harmful event was impact with a guardrail or median barrier. Because it is difficult or impossible to determine the effect of the barrier on personal injuries, vehicle damage, and other performance indicators for secondary barrier collisions, only accidents in which collision with a barrier was the first harmful event were included in this project.

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Each accident in this investigation was classified according to the most severe injury in the vehicle. Injury severity for each vehicle occupant involved in the accident was contained in the record, with the injury classification for each accident based on the most severe injury level. The most severe non-fatal injuries, A injuries, include severe lacerations, broken or distorted limbs, skull fractures, and other serious injuries. Abrasions, lacerations, and lumps to the head are classed as B injuries, and C injuries are limited to momentary unconsciousness, limping, nausea, hysteria, and complaint of pain with no visible injury.

No injury level was designated on nearly one-third of the records received from DMV. Because injuries are required by state law to be reported, and because most of the accident reports were filed by police agencies, it appears to be reasonable to assume that those records with no specific report of injuries actually represented accidents with no injuries. Although a few minor injuries may have gone undetected, it does not appear likely that many severe injuries would have been unreported.

Using vehicle registration data from another DMV file, vehicle identification numbers (VINs) were added to the accident file for vehicles registered in New York State. The Vindicator Program developed by NHTSA was used to decode the VIN number and add specific vehicle data--make, model, series, weight, wheelbase--to the accident file. The resulting file contained accident description--date, location, impact conditions and factors--as well as personal injury data and detailed vehicle descriptions for about two-thirds of the records. New York's 16,000-mi state highway system includes more than 4,200 mi of traffic barrier. The initial accident file provided by DMV contained 4,698 records, which agreed well with the number expected on the basis of historical records. Subsequent elimination of accidents in New York City and on the NYS Thruway plus invalid traffic barrier records reduced the actual sample to 3,302 accidents.

Although the computer file contained some of the data needed for this investigation, the hard-copy accident reports contained more vital data in the narratives and sketches. That information was necessary to pinpoint accident sites to specific runs of barrier because the coded location was based on reference markers at tenth-mile intervals. In addition, valuable data on impact conditions, vehicle damage, and postimpact vehicle trajectories could only be obtained from the narratives and sketches. In all, hard-copy reports were reviewed for nearly 4,000 of the original 4,698 accidents.

The primary measure of barrier performance is personal injury, but vehicle damage provides a secondary measure. Vehicle damage is important from a financial standpoint, and lower damage is desirable from the standpoint of reduced cost to the motorist. More important, vehicle damage is a surrogate measure of impact severity and injury potential. Vehicle damage was therefore examined in this investigation as a secondary measure of barrier performance. Damage data on individual accident records also provided information about impact conditions. By using the data listed on the accident reports plus the accident sketches and narratives, damage ratings were made for all but two records in the primary accident file. In many cases, although it was possible to determine that some damage had occurred, the exact extent was unknown. When severity ratings were made by research staff, they were made on the conservative side. That is, damage was at least as severe as the rating assigned.

Another important measure of barrier performance is its ability to contain and gradually redirect a vehicle parallel to the roadway. Undesirable responses include barrier penetration (vaulting, submarining, breakthrough), abrupt stops or snags, or deflecting the barrier to contact an object behind it. Barrier response for most of the records was classified into one of eight categories using the narrative descriptions in the hard-copy accident reports. Those categories were redirected, stopped in contact with the barrier, snagged, penetrated, ran under, broke through, went over, and deflected to a fixed object. Redirection accidents were generally quite obvious from the narrative descriptions, but the stopped and snagged categories were more difficult to classify. Definite snags were apparent in only a small number of accidents, but it is possible that some of those classified as "stopped" actually involved a degree of snagging or pocketing. Likewise, it was sometimes difficult to determine the means by which penetration occurred. Therefore, in addition to the three specific classifications of under, over, and through, a fourth general penetration category was included for cases in which a specific determination was impossible.

Another measure of barrier performance in this study is secondary collisions. Following impact with a barrier, the desirable vehicle reaction is to redirect smoothly parallel to the barrier or to stop adjacent to it. Secondary responses--collisions with other fixed objects or vehicles and rollovers--are highly undesirable because they increase the risk of injury to vehicle occupants as well as to those in other vehicles. Secondary impacts were categorized on the DMV records from information contained on the accident report. In this investigation research staff validated the second event codes using the hard-copy narratives and sketches.

The DMV computer records were printed out on special forms with each record on a separate page. These forms were designed to make it possible to add additional roadway and barrier data in coded form. Before proceeding, however, each of the hard-copy reports was reviewed to eliminate incorrectly coded records that did not involve traffic barriers or that were otherwise invalid. Data coding on the forms was accomplished through examination of department photolog files to obtain barrier and roadway parameters, and field inspections were made to determine traffic barrier height and to confirm barrier and roadway parameters.

At every site where roadway or barrier conditions indicated that recent changes may have been made, data obtained during the field visit were compared with the photolog files and construction records. In this way highway changes were detected, and the data entered for each record were correct, with a high degree of reliability, for the time of the accident.

Following completion of the field investigation, the additional data were added to the DMV accident file. The resulting file contained 3,302 records, all on the state highway system outside New York City and all screened to ensure that they described valid barrier accidents. Not every file was complete because in some cases vehicle data were missing. In other cases the accident site could not be located precisely, and some or all of the roadway or barrier data were thus missing. However, ensuring that all the data on the file were reliable meant that the conclusions drawn from this study could be accepted with a high level of confidence.

## TRAFFIC BARRIERS ENCOUNTERED

New York State's standard traffic barriers consist of cable, W-beam, and box-beam rail on S 3 x 5.7 steel posts (light posts); W-beam on W 6 x 9 steel posts with block outs (heavy posts); and concrete safety shape barrier. Occasionally, W-beam on wood posts with block outs is used on parkways as well as limited quantities of other barrier types including thrie-beam on heavy posts and self-restoring barrier (SERB). These systems are shown as standards in the 1977 AASHTO barrier guide (4) or have recently been developed and standardized through FHWA-sponsored research. In addition to barriers now specified, various types of previously specified barriers remain in service. These include various combinations of cable and W-beam rail on wood, concrete and steel posts, as well as other types of posts, rails, and concrete walls.

Barriers encountered in this investigation were as follows:

| Barrier Type | No. of Accidents |
|---|---|
| Light-post traffic barriers | 1,887 |
| Heavy-post blocked-out W-beam | 94 |
| Concrete safety shape | 90 |
| Obsolete barriers | 810 |
| Others, unknown | 421 |
| Total | 3,302 |

## RESULTS

### General Barrier Performance

The primary purpose of traffic barrier is to prevent vehicles from contacting features along the highway that are potentially more hazardous than the barrier itself. If a system performs well, barrier accidents should be less severe than other roadside accidents. Barrier accidents examined in this study are compared with other accident types in Table 1.

**TABLE 1 Comparison of Traffic Barrier Accident Severity and Other Accident Types**

| | | | PERCENT OF TOTAL ACCIDENTS | | | | |
|---|---|---|---|---|---|---|---|
| ACCIDENT TYPE (a) | LOCATION (b) | TOTAL ACCIDENTS | FATAL | A INJURY | B INJURY | C INJURY | NO INJURY |
| ALL BAR | ST.WIDE | 3,302 | 1.33 | 9.45 | 25.83 | 22.44 | 40.94 |
| CUR BAR | ST.WIDE | 2,071 | 1.16 | 9.37 | 26.99 | 24.58 | 37.90 |
| ALL | ST.WIDE | 270,688 | .71 | | 63.49 | | 35.80 |
| ALL R S | ST.WIDE | 40,163 | 1.50 | | 74.22 | | 24.29 |

(a) ALL = ALL ACCIDENTS, ALL BAR = ALL BARRIER ACCIDENTS, CUR BAR = CURRENT BARRIER ACCIDENTS, ALL R S = ALL ROAD SIDE ACC

(b) ST.WIDE = STATE MAINTAINED HIGHWAYS UPSTATE AND LONG ISLAND

The data for all accidents and roadside accidents are taken from DMV reports (5) for calendar year 1983. However, injuries are not broken down by severity class. The DMV report lists the total number of injured persons in each severity class not the total number of accidents. Because some vehicles have more than one occupant, often with different injury severities, the injury distribution by occupant is less severe than by accident. Therefore only the total number of injury accidents was examined. Injury classification for the barrier study, on the other hand, is based on the most severe injury in each accident. Because the same injury reporting system was used for the general data in Table 1, it is subject to the same assumptions regarding unreported injuries as is the traffic barrier data base.

The data in Table 1 reveal that guide rail accident statewide are more severe in terms of fatalities and total injuries than are all New York State accidents. However, fixed object accidents are normally more severe than vehicle-to-vehicle accidents, and when barrier accidents from this study are compared with roadside accidents in general, this becomes apparent. Statewide barrier accidents were significantly less severe than all statewide roadside accidents. Considering only currently specified barriers, performance is even better.

Table 2 relates injury severity to vehicle damage, barrier function, and secondary collisions. About 60 percent of the vehicles were rated as lightly damaged, and less than 7 percent were demolished. These data show a pronounced relationship between vehicle damage and injury severity: as damage increased, so did the likelihood of injury. More than half of the fatalities occurred in vehicles that were demolished, and 80 percent of the accidents with no reported injury had vehicle damage rated light. Stated differently, the risk of serious injury or death was less than 7 percent in vehicles with damage rated light but increased to nearly 39 percent if the vehicle was demolished. These relationships are shown graphically in Figure 1.

This information may hold importance for evaluating the results of full-scale crash tests for which injury data are not available. Although vehicle damage in this study was not rated very precisely, a clear-cut relationship is apparent between vehicle damage and injury severity. It therefore appears that more precise scales of vehicle damage, such as those used in full-scale crash tests, may provide an excellent surrogate measure of injury potential.

Barrier function, including injury severity for each category, is also summarized in Table 2. Responses with acceptable containment--redirection and stopped adjacent to the barrier--have much lower severity rates than the unsatisfactory responses of snagging and noncontainment. Comparing those two groups of responses results in a highly significant difference. Accidents in which the vehicle was contained had less than 10 percent severe injuries (fatal and A) and more than 40 percent with no injuries compared with nearly 25 percent severe injuries and only 13.5 percent without injuries when containment was not achieved. Fortunately, in nearly 80 percent of the cases the vehicle was satisfactorily contained. Snagging was noted in only 0.5 percent of the accidents, and there were various types of penetration in 12.5 percent. Because light-post barrier deflects a substantial amount on impact, adequate distance must be provided behind the barrier to accommodate that deflection. Only 13 cases were noted in this analysis--less than 0.5 percent--in which deflection was sufficient to permit the vehicle to contact a fixed object behind the barrier. Underrunning the barrier, a concern with modern vehicles with low frontal geometry, was the least common and occurred in less than 1/4 of 1 percent of all cases.

Secondary collisions, also summarized in Table 2, occurred in just over one-fourth of the cases. Secondary collisions with another motor vehicle were extremely rare--only six were recorded in the primary data file--and secondary collisions with pedestrians were even more rare, with two cases recorded. Most common was collision with a fixed object, which accounted for 583 of 871 second events. Overturning was the next most common and accounted for nearly one-third of the secondary collisions. The data in Table 2 indicate clearly the increased injury severity associated with second events. Although second events were recorded in only 26 percent of the total accidents, they accounted for nearly 90 percent of the fatal accidents and half of the A injuries. Less than 14 percent of the second event accidents had no

TABLE 2 Injury Severity Related to Vehicle Damage, Barrier Function, and Secondary Collisions

| | INJURY SEVERITY | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FATAL | | A INJURY | | B INJURY | | C INJURY | | NONE REPORTED | | TOTAL | |
| VEHICLE DAMAGE (NOTE 1) | | | | | | | | | | | | |
| DEMOLISHED | 23 | 52.27% | 61 | 19.55% | 77 | 9.03% | 47 | 6.34% | 10 | .74% | 218 | 6.60% |
| SEVERE | 8 | 18.18% | 46 | 14.74% | 123 | 14.42% | 101 | 13.63% | 53 | 3.92% | 331 | 10.02% |
| MODERATE | 6 | 13.64% | 82 | 26.28% | 265 | 31.07% | 216 | 29.15% | 206 | 15.24% | 775 | 23.47% |
| LIGHT | 7 | 15.91% | 122 | 39.10% | 386 | 45.25% | 377 | 50.88% | 1081 | 79.96% | 1973 | 59.75% |
| NONE | 0 | .00% | 1 | .32% | 0 | .00% | 0 | .00% | 2 | .15% | 3 | .09% |
| UNKNOWN | 0 | .00% | 0 | .00% | 2 | .23% | 0 | .00% | 0 | .00% | 2 | .06% |
| TOTAL | 44 | 100.00% | 312 | 100.00% | 853 | 100.00% | 741 | 100.00% | 1352 | 100.00% | 3302 | 100.00% |
| VEHICLE DAMAGE (NOTE 2) | | | | | | | | | | | | |
| DEMOLISHED | 23 | 10.55% | 61 | 27.98% | 77 | 35.32% | 47 | 21.56% | 10 | 4.59% | 218 | 100.00% |
| SEVERE | 8 | 2.42% | 46 | 13.90% | 123 | 37.16% | 101 | 30.51% | 53 | 16.01% | 331 | 100.00% |
| MODERATE | 6 | .77% | 82 | 10.58% | 265 | 34.19% | 216 | 27.87% | 206 | 26.58% | 775 | 100.00% |
| LIGHT | 7 | .35% | 122 | 6.18% | 386 | 19.56% | 377 | 19.11% | 1081 | 54.79% | 1973 | 100.00% |
| NONE | 0 | .00% | 1 | 33.33% | 0 | .00% | 0 | .00% | 2 | 66.67% | 3 | 100.00% |
| UNKNOWN | 0 | .00% | 0 | .00% | 2 | 100.00% | 0 | .00% | 0 | .00% | 2 | 100.00% |
| TOTAL | 44 | 1.33% | 312 | 9.45% | 853 | 25.83% | 741 | 22.44% | 1352 | 40.94% | 3302 | 100.00% |
| BARRIER FUNCTION (NOTE 3) | | | | | | | | | | | | |
| REDIRECT | 19 | 43.18% | 190 | 60.90% | 576 | 67.53% | 533 | 71.93% | 925 | 68.42% | 2243 | 67.93% |
| STOP | 1 | 2.27% | 38 | 12.18% | 95 | 11.14% | 59 | 7.96% | 129 | 9.54% | 322 | 9.75% |
| SNAG | 1 | 2.27% | 2 | .64% | 5 | .59% | 3 | .40% | 6 | .44% | 17 | .51% |
| PENETRATED | 5 | 11.36% | 20 | 6.41% | 48 | 5.63% | 22 | 2.97% | 13 | .96% | 108 | 3.27% |
| RAN UNDER | 0 | .00% | 3 | .96% | 1 | .12% | 4 | .54% | 0 | .00% | 8 | .24% |
| BROKETHR | 5 | 11.36% | 11 | 3.53% | 34 | 3.99% | 19 | 2.56% | 17 | 1.26% | 86 | 2.60% |
| WENT OVER | 12 | 27.27% | 43 | 13.78% | 63 | 7.39% | 70 | 9.45% | 22 | 1.63% | 210 | 6.36% |
| DEFLECT TOFIX | 0 | .00% | 1 | .32% | 10 | 1.17% | 2 | .27% | 0 | .00% | 13 | .39% |
| UNKNOWN | 1 | 2.27% | 4 | 1.28% | 21 | 2.46% | 29 | 3.91% | 240 | 17.75% | 295 | 8.93% |
| TOTAL | 44 | 100.00% | 312 | 100.00% | 853 | 100.00% | 741 | 100.00% | 1352 | 100.00% | 3302 | 100.00% |
| BARRIER FUNCTION (NOTE 4) | | | | | | | | | | | | |
| REDIRECT | 19 | .85% | 190 | 8.47% | 576 | 25.68% | 533 | 23.76% | 925 | 41.24% | 2243 | 100.00% |
| STOP | 1 | .31% | 38 | 11.80% | 95 | 29.50% | 59 | 18.32% | 129 | 40.06% | 322 | 100.00% |
| SNAG | 1 | 5.88% | 2 | 11.76% | 5 | 29.41% | 3 | 17.65% | 6 | 35.29% | 17 | 100.00% |
| PENETRATED | 5 | 4.63% | 20 | 18.52% | 48 | 44.44% | 22 | 20.37% | 13 | 12.04% | 108 | 100.00% |
| RAN UNDER | 0 | .00% | 3 | 37.50% | 1 | 12.50% | 4 | 50.00% | 0 | .00% | 8 | 100.00% |
| BROKETHR | 5 | 5.81% | 11 | 12.79% | 34 | 39.53% | 19 | 22.09% | 17 | 19.77% | 86 | 100.00% |
| WENT OVER | 12 | 5.71% | 43 | 20.48% | 63 | 30.00% | 70 | 33.33% | 22 | 10.48% | 210 | 100.00% |
| DEFLECT TOFIX | 0 | .00% | 1 | 7.69% | 10 | 76.92% | 2 | 15.38% | 0 | .00% | 13 | 100.00% |
| UNKNOWN | 1 | .34% | 4 | 1.36% | 21 | 7.12% | 29 | 9.83% | 240 | 81.36% | 295 | 100.00% |
| TOTAL | 44 | 1.33% | 312 | 9.45% | 853 | 25.83% | 741 | 22.44% | 1352 | 40.94% | 3302 | 100.00% |
| SECOND EVENT | | | | | | | | | | | | |
| MOTOR VEHICLE | 0 | .00% | 0 | .00% | 1 | 16.67% | 2 | 33.33% | 3 | 50.00% | 6 | 100.00% |
| PEDESTRIAN | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 2 | 100.00% | 2 | 100.00% |
| OTHER NOT FIXED OBJ | 0 | .00% | 0 | .00% | 0 | .00% | 1 | 50.00% | 1 | 50.00% | 2 | 100.00% |
| LIGHT/UTILITY POLE | 4 | 7.14% | 9 | 16.07% | 25 | 44.64% | 15 | 26.79% | 3 | 5.36% | 56 | 100.00% |
| GUIDERAIL | 1 | 1.00% | 11 | 11.00% | 36 | 36.00% | 25 | 25.00% | 27 | 27.00% | 100 | 100.00% |
| SIGN POST | 1 | 3.85% | 1 | 3.85% | 11 | 42.31% | 6 | 23.08% | 7 | 26.92% | 26 | 100.00% |
| TREE | 7 | 6.48% | 21 | 19.44% | 41 | 37.96% | 23 | 21.30% | 16 | 14.81% | 108 | 100.00% |
| BUILDING/WALL | 0 | .00% | 0 | .00% | 3 | 75.00% | 1 | 25.00% | 0 | .00% | 4 | 100.00% |
| CURBING | 1 | 14.29% | 3 | 42.86% | 0 | .00% | 3 | 42.86% | 0 | .00% | 7 | 100.00% |
| FENCE | 1 | 5.88% | 5 | 29.41% | 7 | 41.18% | 3 | 17.65% | 1 | 5.88% | 17 | 100.00% |
| BRIDGE STRUCTURE | 3 | 7.69% | 5 | 12.82% | 15 | 38.46% | 10 | 25.64% | 6 | 15.38% | 39 | 100.00% |
| CULVERT/HEAD WALL | 1 | 7.69% | 7 | 53.85% | 3 | 23.08% | 2 | 15.38% | 0 | .00% | 13 | 100.00% |
| MEDIAN/BARRIER | 0 | .00% | 3 | 20.00% | 6 | 40.00% | 2 | 13.33% | 4 | 26.67% | 15 | 100.00% |
| SNOW EMBANKMENT | 0 | .00% | 0 | .00% | 4 | 50.00% | 0 | .00% | 4 | 50.00% | 8 | 100.00% |
| EARTH ELEM/RC/DITCH | 2 | 1.09% | 27 | 14.75% | 62 | 33.88% | 68 | 37.16% | 24 | 13.11% | 183 | 100.00% |
| FIRE HYDRANT | 0 | .00% | 1 | 50.00% | 0 | .00% | 1 | 50.00% | 0 | .00% | 2 | 100.00% |
| OTHER FIXED OBJECT | 0 | .00% | 3 | 60.00% | 0 | .00% | 0 | .00% | 2 | 40.00% | 5 | 100.00% |
| OVERTURNED | 15 | 5.81% | 55 | 21.32% | 107 | 41.47% | 69 | 26.74% | 12 | 4.65% | 258 | 100.00% |
| FIRE/EXPLOSION | 0 | .00% | 0 | .00% | 3 | 50.00% | 0 | .00% | 3 | 50.00% | 6 | 100.00% |
| SUBMERSION | 2 | 50.00% | 0 | .00% | 1 | 25.00% | 0 | .00% | 1 | 25.00% | 4 | 100.00% |
| RAN OFF ROADWY ONLY | 0 | .00% | 0 | .00% | 2 | 66.67% | 1 | 33.33% | 0 | .00% | 3 | 100.00% |
| OTHER NON COLLISION | 1 | 14.29% | 0 | .00% | 2 | 28.57% | 2 | 28.57% | 2 | 28.57% | 7 | 100.00% |
| FIXED OBJECT SUB TOT | 21 | 3.60% | 96 | 16.47% | 213 | 36.54% | 159 | 27.27% | 94 | 16.12% | 583 | 100.00% |
| ALL SECOND EV SUB T | 39 | 4.48% | 151 | 17.34% | 329 | 37.77% | 234 | 26.87% | 118 | 13.55% | 871 | 100.00% |
| NO SECOND EVENT | 5 | .21% | 161 | 6.62% | 524 | 21.55% | 507 | 20.86% | 1234 | 50.76% | 2431 | 100.00% |
| TOTAL | 44 | 1.33% | 312 | 9.45% | 853 | 25.83% | 741 | 22.44% | 1352 | 40.94% | 3302 | 100.00% |

NOTES: FATAL + A INJURIES = SEVERE INJURIES
1 - PERCENT OF EACH INJURY SEVERITY OCCURRING IN EACH DAMAGE CATEGORY
2 - PERCENT OF EACH DAMAGE CATEGORY OCCURRING IN EACH SEVERITY CATEGORY
3 - PERCENT OF EACH INJURY SEVERITY OCCURRING IN EACH BARRIER FUNCTION CATEGORY
4 - PERCENT OF EACH BARRIER FUNCTION CATEGORY OCCURRING IN EACH SEVERITY CATEGORY

reported injuries compared with more than half of the accidents without second events. Especially harmful second event types were collisions with utility poles with 23 percent severe injuries, collisions with trees with 26 percent severe injuries, and overturns with 27 percent severe injuries.

Injury severity was shown in the previous paragraphs to be higher when a second event occurred and in those cases in which the vehicle was not properly contained by the barrier. It is logical to expect that if a vehicle is satisfactorily contained, second events will be less likely. This relationship is examined in Table 3, which provides a comparison of the occurrence of second events for the various categories of barrier function. When the vehicle was redirected or stopped adjacent to the barrier, second events were relatively rare--less than 20 percent of all accidents. However, when the vehicle was not properly contained, the vehicle overturned in 28

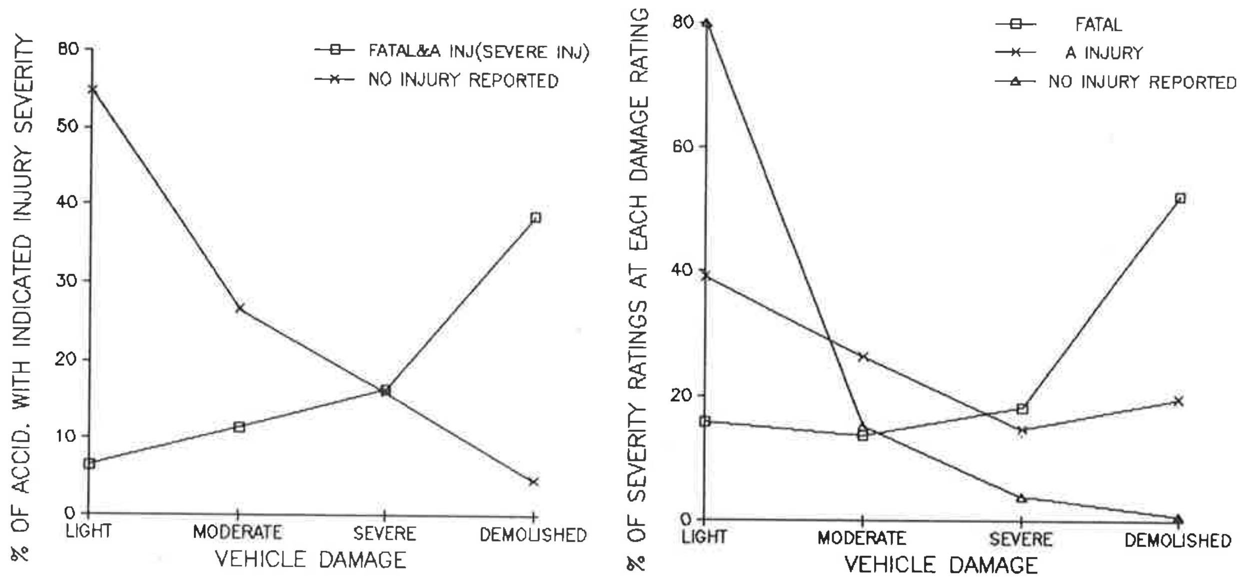


**FIGURE 1** Injury severity related to vehicle damage.

percent of the cases and struck a fixed object in 52 percent of the cases. This clearly points out the desirability of smooth containment and redirection in vehicle-barrier collisions.

## Effects of Vehicle Type on Barrier Performance

By using information from the accident report, vehicle type was classified for all but 7 of the 3,302 accidents in the primary file. Table 4 gives injury severity, barrier function, and secondary collision data for each vehicle type. Passenger automobiles had by far the lowest overall injury rates. Vans and light trucks had B and C injury rates nearly identical to those of passenger automobiles, but the rate of fatal and A injuries was significantly higher. Based on a small number of fatal and A injury accidents, the rate for tractor-trailers is not much

**TABLE 3** Secondary Collisions Related to Barrier Function

SECOND EVENT[1]

| BARRIER FUNCT | OVERTURNED | | FIXED OBJECT | | OTHER | | NONE | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| REDIRECT | 125 | 48.45% | 328 | 56.16% | 15 | 50.00% | 1775 | 73.05% | 2243 | 67.93% |
| STOP | 11 | 4.26% | 18 | 3.08% | 2 | 6.67% | 291 | 11.98% | 322 | 9.75% |
| CONTAINED S T | 136 | 52.71% | 346 | 59.25% | 17 | 56.67% | 2066 | 85.02% | 2565 | 77.68% |
| SNAG | 2 | .78% | 3 | .51% | 0 | .00% | 12 | .49% | 17 | .51% |
| PENETRATED | 28 | 10.85% | 63 | 10.79% | 4 | 13.33% | 13 | .53% | 108 | 3.27% |
| RAN UNDER | 0 | .00% | 1 | .17% | 0 | .00% | 7 | .29% | 8 | .24% |
| BROKETHR | 18 | 6.98% | 51 | 8.73% | 2 | 6.67% | 15 | .62% | 86 | 2.60% |
| WENT OVER | 72 | 27.91% | 94 | 16.10% | 7 | 23.33% | 37 | 1.52% | 210 | 6.36% |
| PENETRATED ST | 118 | 45.74% | 209 | 35.79% | 13 | 43.33% | 72 | 2.96% | 412 | 12.48% |
| DEFLECT TOFIX | 0 | .00% | 12 | 2.05% | 0 | .00% | 1 | .04% | 13 | .39% |
| UNKNOWN | 2 | .78% | 14 | 2.40% | 0 | .00% | 279 | 11.48% | 295 | 8.93% |
| TOTAL | 258 | 100.00% | 584 | 100.00% | 30 | 100.00% | 2430 | 100.00% | 3302 | 100.00% |

SECOND EVENT[2]

| BARRIER FUNCT | OVERTURNED | | FIXED OBJECT | | OTHER | | NONE | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|
| REDIRECT | 125 | 5.57% | 328 | 14.62% | 15 | .67% | 1775 | 79.14% | 2243 | 100.00% |
| STOP | 11 | 3.42% | 18 | 5.59% | 2 | .62% | 291 | 90.37% | 322 | 100.00% |
| CONTAINED S T | 136 | 5.30% | 346 | 13.49% | 17 | .66% | 2066 | 80.55% | 2565 | 100.00% |
| SNAG | 2 | 11.76% | 3 | 17.65% | 0 | .00% | 12 | 70.59% | 17 | 100.00% |
| PENETRATED | 28 | 25.93% | 63 | 58.33% | 4 | 3.70% | 13 | 12.04% | 108 | 100.00% |
| RAN UNDER | 0 | .00% | 1 | 12.50% | 0 | .00% | 7 | 87.50% | 8 | 100.00% |
| BROKETHR | 18 | 20.93% | 51 | 59.30% | 2 | 2.33% | 15 | 17.44% | 86 | 100.00% |
| WENT OVER | 72 | 34.29% | 94 | 44.76% | 7 | 3.33% | 37 | 17.62% | 210 | 100.00% |
| PENETRATED ST | 118 | 28.64% | 209 | 50.73% | 13 | 3.16% | 72 | 17.48% | 412 | 100.00% |
| DEFLECT TOFIX | 0 | .00% | 12 | 92.31% | 0 | .00% | 1 | 7.69% | 13 | 100.00% |
| UNKNOWN | 2 | .68% | 14 | 4.75% | 0 | .00% | 279 | 94.58% | 295 | 100.00% |
| TOTAL | 258 | 7.81% | 584 | 17.69% | 30 | .91% | 2430 | 73.59% | 3302 | 100.00% |

1 - PERCENT OF SECOND EVENT CATEGORY OCCURRING IN EACH BARRIER FUNCTION CATEGO
2 - PERCENT OF BARRIER FUNCTION CATEGORY OCCURRING IN EACH SECOND EVENT CATEGO

TABLE 4 Vehicle Type Related to Injury Severity, Barrier Function, and Secondary Events

| INJURY LEVEL | PASSENGER CAR | | MOTORCYCLE | | VAN/LT TRUCK | | HEAVY TRUCK | | SEMI | | BUS | | UNKNOWN | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FATAL | 27 | .96% | 7 | 8.43% | 7 | 2.17% | 1 | 6.67% | 2 | 3.64% | 0 | .00% | 0 | .00% | 44 | 1.33% |
| A INJURY | 229 | 8.13% | 33 | 39.76% | 42 | 13.04% | 0 | .00% | 4 | 7.27% | 1 | 50.00% | 3 | 42.86% | 312 | 9.45% |
| B INJURY | 708 | 25.12% | 31 | 37.35% | 84 | 26.09% | 6 | 40.00% | 24 | 43.64% | 0 | .00% | 0 | .00% | 853 | 25.83% |
| C INJURY | 631 | 22.39% | 12 | 14.46% | 74 | 22.98% | 7 | 46.67% | 16 | 29.09% | 1 | 50.00% | 0 | .00% | 741 | 22.44% |
| NONE | 1223 | 43.40% | 0 | .00% | 115 | 35.71% | 1 | 6.67% | 9 | 16.36% | 0 | .00% | 4 | 57.14% | 1352 | 40.94% |
| TOTAL | 2818 | 100.00% | 83 | 100.00% | 322 | 100.00% | 15 | 100.00% | 55 | 100.00% | 2 | 100.00% | 7 | 100.00% | 3302 | 100.00% |
| BARRIER FUNCTION | | | | | | | | | | | | | | | | |
| REDIRECTED | 1959 | 69.52% | 50 | 60.24% | 201 | 62.42% | 5 | 33.33% | 21 | 38.18% | 2 | 100.00% | 0 | .00% | 2238 | 67.78% |
| STOP | 264 | 9.37% | 22 | 26.51% | 32 | 9.94% | 1 | 6.67% | 3 | 5.45% | 0 | .00% | 0 | .00% | 322 | 9.75% |
| CONTAINED SUB TOTAL | 2223 | 78.89% | 72 | 86.75% | 233 | 72.36% | 6 | 40.00% | 24 | 43.64% | 2 | 100.00% | 0 | .00% | 2560 | 77.53% |
| SNAGGED | 14 | .50% | 0 | .00% | 3 | .93% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 17 | .51% |
| PENETRATED | 76 | 2.70% | 1 | 1.20% | 20 | 6.21% | 3 | 20.00% | 8 | 14.55% | 0 | .00% | 0 | .00% | 108 | 3.27% |
| RAN UNDER | 4 | .14% | 4 | 4.82% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 8 | .24% |
| BROKE THROUGH | 66 | 2.34% | 1 | 1.20% | 7 | 2.17% | 4 | 26.67% | 8 | 14.55% | 0 | .00% | 0 | .00% | 86 | 2.60% |
| WENT OVER | 159 | 5.64% | 4 | 4.82% | 33 | 10.25% | 2 | 13.33% | 12 | 21.82% | 0 | .00% | 0 | .00% | 210 | 6.36% |
| PENETRATED SUB TOTAL | 305 | 10.82% | 10 | 12.05% | 60 | 18.63% | 9 | 60.00% | 28 | 50.91% | 0 | .00% | 0 | .00% | 412 | 12.48% |
| DEFLECTED TO FIX OBJ | 9 | .32% | 0 | .00% | 3 | .93% | 0 | .00% | 1 | 1.82% | 0 | .00% | 0 | .00% | 13 | .39% |
| UNKNOWN | 267 | 9.47% | 1 | 1.20% | 23 | 7.14% | 0 | .00% | 2 | 3.64% | 0 | .00% | 7 | 100.00% | 300 | 9.09% |
| TOTAL | 2818 | 100.00% | 83 | 100.00% | 322 | 100.00% | 15 | 100.00% | 55 | 100.00% | 2 | 100.00% | 7 | 100.00% | 3302 | 100.00% |
| SECOND EVENT | | | | | | | | | | | | | | | | |
| FIXED OBJECT | 465 | 16.50% | 8 | 9.64% | 86 | 26.71% | 7 | 46.67% | 14 | 25.45% | 1 | 50.00% | 0 | .00% | 581 | 17.60% |
| OVERTURNED | 172 | 6.10% | 13 | 15.66% | 52 | 16.15% | 6 | 40.00% | 15 | 27.27% | 0 | .00% | 0 | .00% | 258 | 7.81% |
| OTHER SECOND EVENT | 24 | .85% | 1 | 1.20% | 5 | 1.55% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 30 | .91% |
| SECOND EVENT SUB T | 661 | 23.46% | 22 | 26.51% | 143 | 44.41% | 13 | 86.67% | 29 | 52.73% | 1 | 50.00% | 0 | .00% | 869 | 26.32% |
| NO SECOND EVENT | 2157 | 76.54% | 61 | 73.49% | 179 | 55.59% | 2 | 13.33% | 26 | 47.27% | 1 | 50.00% | 0 | .00% | 2426 | 73.47% |
| UNKNOWN | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 0 | .00% | 7 | 100.00% | 7 | .21% |
| TOTAL | 2818 | 100.00% | 83 | 100.00% | 322 | 100.00% | 15 | 100.00% | 55 | 100.00% | 2 | 100.00% | 7 | 100.00% | 3302 | 100.00% |

higher than for passenger automobiles, but the rate of B and C injuries appears to be substantially higher. Motorcycle accidents had by far the highest severity rate, with all the reported accidents resulting in personal injury and nearly half resulting in a fatality or an A injury. Only 15 accidents involving heavy trucks were recorded, but it appears that the total injury rate was substantially higher than for passenger automobiles. Only one accident each was reported involving an intercity bus and a school bus; these resulted in an A injury and a C injury, respectively.

Considering barrier function, satisfactory containment--redirected or stopped--resulted in 79 percent of the passenger automobile impacts and 72 percent of the light truck impacts, but in just over 40 percent of the impacts involving heavy trucks and tractor-trailers. Considering only midsection collisions (no collisions on barrier terminals), 88 percent of the passenger automobiles and 83 percent of the vans and light trucks were contained. Containment of heavy trucks and tractor-trailers changed only slightly from the total sample because of the low occurrence of terminal accidents for those vehicle types.

Passenger automobiles and motorcycles experienced secondary impacts in only about one-quarter of all collisions compared with 45 percent of the van and light truck accidents and 60 percent of the heavy truck and tractor-trailer collisions combined. Overturning was relatively rare for passenger automobiles: only 6 percent of all collisions resulted in this type of second event. However, overturning occurred in 16 percent of the van and light truck collisions and in 30 percent of the heavy truck and tractor-trailer accidents. Nearly all the remaining second events were impacts on fixed objects for each of the vehicle types.

## Effects of Passenger Automobile Size and Weight on Barrier Performance

In addition to classifying vehicle type from information on the accident form, VINs obtained from registration files provided detailed vehicle information. Passenger automobiles were further sorted by wheelbase, using categories suggested by NHTSA (6), and by weight, using categories from earlier reports by New York State (7) and General Motors (8).

Size classes used in the analysis are as follows:

| Vehicle Class | Description | Wheelbase (in.) | Weight (lb) |
|---|---|---|---|
| 1 | Small subcompact | <96 | <2,000 |
| 2 | Subcompact | 96-101 | 2,000-2,499 |
| 3 | Compact | 102-111 | 2,500-3,249 |
| 4 | Intermediate | 112-120 | 3,250-3,999 |
| 5 | Full size | >120 | ≥4,000 |

Passenger automobile injury severity is given in Table 5 by wheelbase and by weight. Because of the small numbers of fatal accidents, severity was regrouped into three categories: fatal and A, termed severe injuries; B and C, termed nonsevere injuries; and none. A chi-square analysis was performed to determine whether severity differed by vehicle size. In terms of weight, the differences among the five classes are highly significant: the lowest severe and total injury rates were for subcompacts, and small subcompacts and compacts had only slightly higher rates. Intermediate and full-sized cars had substantially higher rates. By wheelbase, the results were quite similar except that small subcompacts had the lowest severe injury rate followed by compacts and subcompacts. Larger automobiles again had substantially higher rates, although the differences among classes were not highly significant.

TABLE 5 Injury Severity Related to Passenger Automobile Wheelbase and Weight

WHEELBASE, INCHES

| INJURY LEVEL | < 96 TOTAL | | 96-101 TOTAL | | 102-111 TOTAL | | 112-120 TOTAL | | > 120 TOTAL | | UNKNOWN TOTAL | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FATAL | 1 | .20% | 5 | .93% | 8 | 1.04% | 7 | 1.50% | 0 | .00% | 6 | 1.48% | 27 | .96% |
| A INJURY | 37 | 7.25% | 39 | 7.25% | 50 | 6.52% | 42 | 8.99% | 15 | 11.45% | 46 | 11.36% | 229 | 8.13% |
| B INJURY | 127 | 24.90% | 133 | 24.72% | 176 | 22.95% | 104 | 22.27% | 36 | 27.48% | 132 | 32.59% | 708 | 25.12% |
| C INJURY | 108 | 21.18% | 101 | 18.77% | 194 | 25.29% | 102 | 21.84% | 29 | 22.14% | 97 | 23.95% | 631 | 22.39% |
| NONE | 237 | 46.47% | 260 | 48.33% | 339 | 44.20% | 212 | 45.40% | 51 | 38.93% | 124 | 30.62% | 1223 | 43.40% |
| FATAL &A INJURY | 38 | 7.45% | 44 | 8.18% | 58 | 7.56% | 49 | 10.49% | 15 | 11.45% | 52 | 12.84% | 256 | 9.08% |
| B & C INJURY | 235 | 46.08% | 234 | 43.49% | 370 | 48.24% | 206 | 44.11% | 65 | 49.62% | 229 | 56.54% | 1339 | 47.52% |
| TOTAL | 510 | 100.00% | 538 | 100.00% | 767 | 100.00% | 467 | 100.00% | 131 | 100.00% | 405 | 100.00% | 2818 | 100.00% |

WEIGHT, lb.

| INJURY LEVEL | < 2000 TOTAL | | 2000-2499 TOTAL | | 2500-3249 TOTAL | | 3250-3999 TOTAL | | > 4000 TOTAL | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FATAL | 1 | .40% | 2 | .34% | 7 | .87% | 10 | 1.52% | 4 | 1.65% | 27 | .96% |
| A INJURY | 19 | 7.69% | 44 | 7.53% | 60 | 7.48% | 50 | 7.60% | 24 | 9.88% | 229 | 8.13% |
| B INJURY | 57 | 23.08% | 148 | 25.34% | 196 | 24.44% | 151 | 22.95% | 60 | 24.69% | 708 | 25.12% |
| C INJURY | 54 | 21.86% | 109 | 18.66% | 181 | 22.57% | 163 | 24.77% | 53 | 21.81% | 631 | 22.39% |
| NONE | 116 | 46.96% | 281 | 48.12% | 358 | 44.64% | 284 | 43.16% | 102 | 41.98% | 1223 | 43.40% |
| FATAL & A INJ | 20 | 8.10% | 46 | 7.88% | 67 | 8.35% | 60 | 9.12% | 28 | 11.52% | 256 | 9.08% |
| B & C INJURY | 111 | 44.94% | 257 | 44.01% | 377 | 47.01% | 314 | 47.72% | 113 | 46.50% | 1339 | 47.52% |
| TOTAL | 247 | 100.00% | 584 | 100.00% | 802 | 100.00% | 658 | 100.00% | 243 | 100.00% | 2818 | 100.00% |

Table 6 gives possible causes of the differences in injury rates among vehicle sizes. It was shown previously that accidents that resulted in a secondary collision or lack of barrier containment had higher severity rates. Therefore these two parameters were examined in terms of vehicle size and weight. Larger automobiles were involved in more second events and satisfactorily contained less often than smaller cars. When classified by vehicle weight, the differences among vehicles are highly significant for second event and significant for containment. By wheelbase, the differences are still apparent but not statistically significant. The types of second events also show a clear-cut difference among vehicle classes. Overturning was most frequent for small--either by wheelbase or weight--automobiles and least frequent for large automobiles. The opposite was true of fixed object collisions: small automobiles experienced the fewest and large automobiles the most. These differences are shown graphically in Figures 2 and 3. The overturn rate for the smallest automobiles was about double that of the largest automobiles, and the fixed object involvement was about half. However, because fixed object involvement was at least double the overturn rate overall, the net result was that large vehicles had a higher secondary collision rate than small vehicles. This higher involvement in secondary collisions and lower containment rate appear to explain the higher injury rates for larger automobiles.

## DISCUSSION AND FINDINGS

Accidents involving roadside and fixed objects tend to be more severe than other accident types. However, data from this investigation show that collisions with traffic barriers are less severe than roadside accidents in general, and, if only modern barrier types are considered, the reported injury rate is about 20 percent less than for all roadside accidents. Traffic barriers currently installed in New York State resulted in fatal injuries in about 1 percent of the reported accidents and other serious injuries in an additional 9 percent. Older types of barriers had about twice as many fatalities and 50 percent more serious injuries than modern barriers. Vehicle damage as determined from information provided on accident reports correlated closely with personal injuries. These data indicate that vehicle damage from full-scale crash tests may provide a good surrogate measure of personal injury potential.

Two aspects of barrier accidents were closely examined in an attempt to explain differences in performance. Barrier function, as defined by the postimpact trajectory of the vehicle, described how the barrier either met or failed to meet its primary purpose of preventing contact with the roadside hazard. Secondary collisions provided a second measure of how well the barrier performed this function. These results clearly showed that injuries were lowest when the barrier performed as intended (i.e., the vehicle was properly contained by the barrier and no secondary collision resulted). Overall, the vehicle was contained by the barrier in more than 75 percent of the accidents, and secondary collisions--primarily fixed objects or rollovers--occurred in only about 25 percent of the impacts. Secondary collisions with other vehicles or pedestrians were extremely rare; they occurred in less than 1/4 percent of all accidents. It was also shown that secondary collisions were much more likely when proper containment was not achieved. Less than 20 percent of the containment accidents resulted in secondary collisions compared with about 80 percent of the noncontainment accidents.

Traffic barriers are designed specifically to contain and protect passenger automobiles. As expected, results of this investigation confirm that barriers performed best for passenger automobiles in terms of injury severity as well as vehicle containment and secondary collisions. Very little protection

**TABLE 6 Secondary Collisions and Barrier Function Related to Passenger Automobile Size**

WHEELBASE, INCHES

| SECOND EVENTS | < 96 | | 96-101 | | 102-111 | | 112-120 | | > 120 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OVERTURNED | 38 | 7.45% | 31 | 5.76% | 36 | 4.69% | 26 | 5.57% | 4 | 3.05% | 172 | 6.10% |
| FIXED OBJECT | 66 | 12.94% | 94 | 17.47% | 119 | 15.51% | 86 | 18.42% | 26 | 19.85% | 465 | 16.50% |
| OTHER SECOND EVENT | 4 | .78% | 1 | .19% | 5 | .65% | 4 | .86% | 4 | 3.05% | 24 | .85% |
| SECOND EVENT SUB T | 108 | 21.18% | 126 | 23.42% | 160 | 20.86% | 116 | 24.84% | 34 | 25.95% | 661 | 23.46% |
| NO SECOND EVENT | 402 | 78.82% | 412 | 76.58% | 607 | 79.14% | 351 | 75.16% | 97 | 74.05% | 2157 | 76.54% |
| TOTAL | 510 | 100.00% | 538 | 100.00% | 767 | 100.00% | 467 | 100.00% | 131 | 100.00% | 2818 | 100.00% |

WEIGHT, lb.

| SECOND EVENTS | < 2000 | | 2000-2499 | | 2500-3249 | | 3250-3999 | | > 4000 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OVERTURNED | 18 | 7.29% | 37 | 6.34% | 42 | 5.24% | 43 | 6.53% | 10 | 4.12% | 172 | 6.10% |
| FIXED OBJECT | 29 | 11.74% | 85 | 14.55% | 131 | 16.33% | 114 | 17.33% | 49 | 20.16% | 465 | 16.50% |
| OTHER SECOND EVENT | 2 | .81% | 3 | .51% | 3 | .37% | 9 | 1.37% | 5 | 2.06% | 24 | .85% |
| SECOND EVENT SUB T | 49 | 19.84% | 125 | 21.40% | 176 | 21.95% | 166 | 25.23% | 64 | 26.34% | 661 | 23.46% |
| NO SECOND EVENT | 198 | 80.16% | 459 | 78.60% | 626 | 78.05% | 492 | 74.77% | 179 | 73.66% | 2157 | 76.54% |
| TOTAL | 247 | 100.00% | 584 | 100.00% | 802 | 100.00% | 658 | 100.00% | 243 | 100.00% | 2818 | 100.00% |

WHEELBASE, INCHES

| BARRIER FUNCTION | < 96 | | 96-101 | | 102-111 | | 112-120 | | > 120 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REDIRECT | 362 | 70.98% | 387 | 71.80% | 535 | 69.75% | 303 | 64.88% | 95 | 72.52% | 1959 | 69.52% |
| STOP | 42 | 8.24% | 47 | 8.72% | 71 | 9.26% | 48 | 10.28% | 7 | 5.34% | 264 | 9.37% |
| CONTAINED SUB T | 404 | 79.22% | 434 | 80.52% | 606 | 79.01% | 351 | 75.16% | 102 | 77.86% | 2223 | 78.89% |
| SNAG | 5 | .98% | 0 | .00% | 2 | .26% | 5 | 1.07% | 0 | .00% | 14 | .50% |
| PENETRATED | 10 | 1.96% | 17 | 3.15% | 15 | 1.96% | 16 | 3.43% | 6 | 4.58% | 76 | 2.70% |
| RAN UNDER | 1 | .20% | 2 | .37% | 1 | .13% | 0 | .00% | 0 | .00% | 4 | .14% |
| BROKE THROUGH | 9 | 1.76% | 12 | 2.23% | 19 | 2.48% | 16 | 3.43% | 4 | 3.05% | 66 | 2.34% |
| WENT OVER | 27 | 5.29% | 27 | 5.01% | 35 | 4.56% | 23 | 4.93% | 12 | 9.16% | 159 | 5.64% |
| PENETRATED SUB T | 47 | 9.22% | 58 | 10.76% | 70 | 9.13% | 55 | 11.78% | 22 | 16.79% | 305 | 10.82% |
| DEFLECTED TO F O | 1 | .20% | 2 | .37% | 2 | .26% | 3 | .64% | 0 | .00% | 9 | .32% |
| UNKNOWN | 53 | 10.39% | 45 | 8.35% | 87 | 11.34% | 53 | 11.35% | 7 | 5.34% | 267 | 9.47% |
| TOTAL | 510 | 100.00% | 539 | 100.00% | 767 | 100.00% | 467 | 100.00% | 131 | 100.00% | 2818 | 100.00% |

WEIGHT, lb.

| BARRIER FUNCTION | < 2000 | | 2000-2499 | | 2500-3249 | | 3250-3999 | | > 4000 | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REDIRECT | 174 | 70.45% | 427 | 73.12% | 568 | 70.82% | 435 | 66.11% | 164 | 67.49% | 1959 | 69.52% |
| STOP | 23 | 9.31% | 42 | 7.19% | 81 | 10.10% | 62 | 9.42% | 19 | 7.82% | 264 | 9.37% |
| CONTAINED SUB T | 197 | 79.76% | 469 | 80.31% | 649 | 80.92% | 497 | 75.53% | 183 | 75.31% | 2223 | 78.89% |
| SNAG | 2 | .81% | 3 | .51% | 2 | .25% | 5 | .76% | 0 | .00% | 14 | .50% |
| PENETRATED | 6 | 2.43% | 12 | 2.05% | 21 | 2.62% | 16 | 2.43% | 10 | 4.12% | 76 | 2.70% |
| RAN UNDER | 1 | .40% | 0 | .00% | 2 | .25% | 1 | .15% | 0 | .00% | 4 | .14% |
| BROKE THROUGH | 2 | .81% | 15 | 2.57% | 16 | 2.00% | 21 | 3.19% | 8 | 3.29% | 66 | 2.34% |
| WENT OVER | 15 | 6.07% | 27 | 4.62% | 36 | 4.49% | 39 | 5.93% | 23 | 9.47% | 159 | 5.64% |
| PENETRATED SUB T | 24 | 9.72% | 54 | 9.25% | 75 | 9.35% | 77 | 11.70% | 41 | 16.87% | 305 | 10.82% |
| DEFLECTED TO F O | 0 | .00% | 2 | .34% | 1 | .12% | 5 | .76% | 0 | .00% | 9 | .32% |
| UNKNOWN | 24 | 9.72% | 56 | 9.59% | 75 | 9.35% | 74 | 11.25% | 19 | 7.82% | 267 | 9.47% |
| TOTAL | 247 | 100.00% | 584 | 100.00% | 802 | 100.00% | 658 | 100.00% | 243 | 100.00% | 2818 | 100.00% |

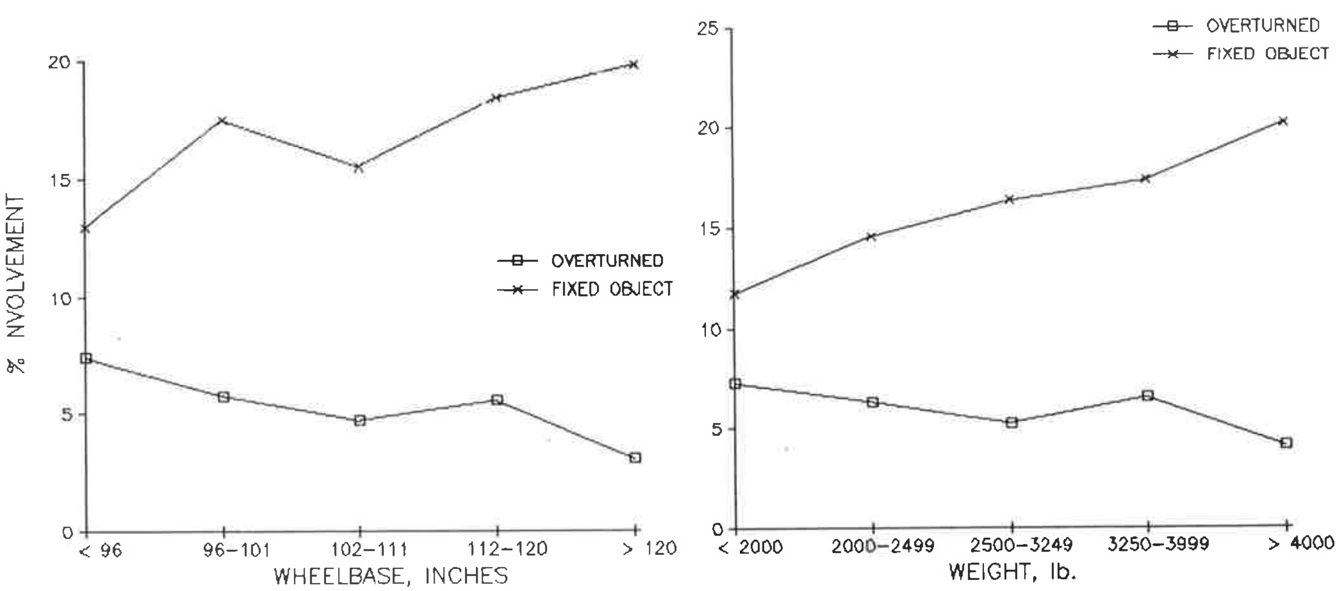


**FIGURE 2 Effects of automobile size on secondary event involvement.**

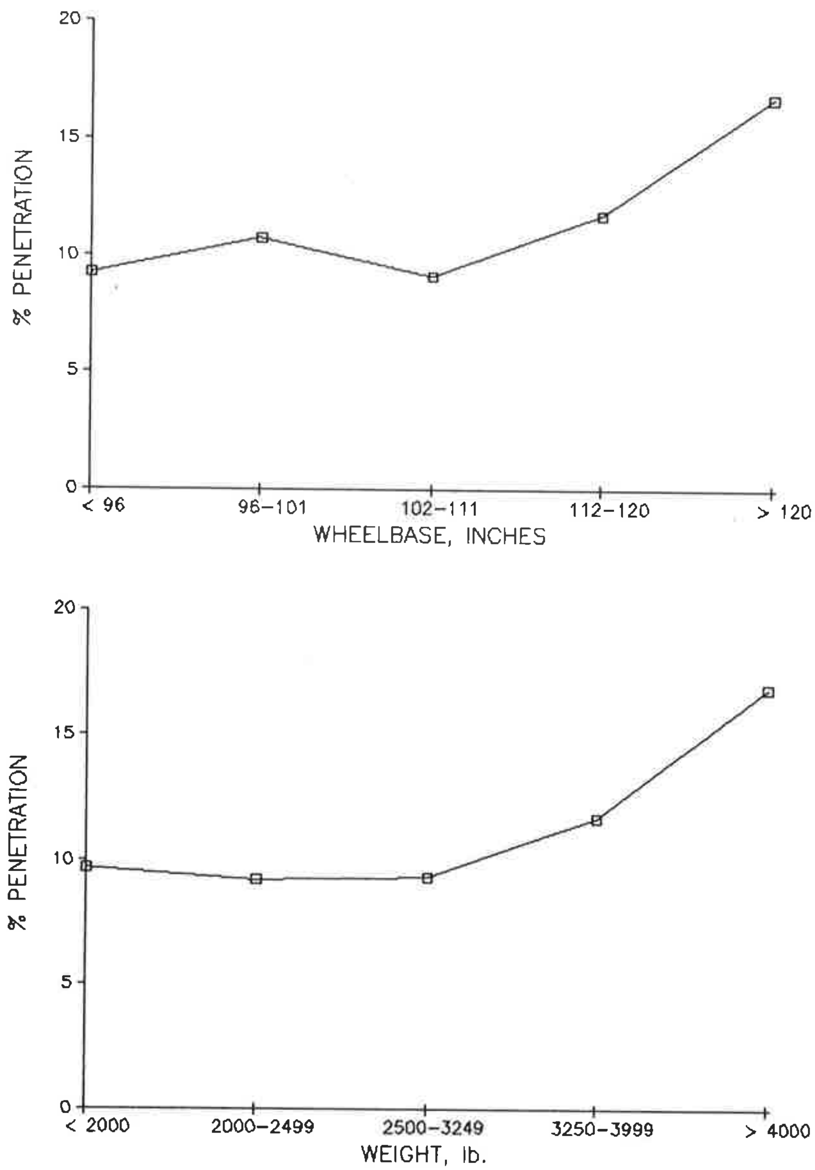


**FIGURE 3** Effects of automobile size on barrier penetration.

was afforded motorcyclists, however, and nearly half the reported collisions resulted in severe injuries. Performance with vans and light trucks was likewise not as good as with passenger automobiles. Injury rates were higher, containment was achieved less often, and secondary collisions were more frequent. After passenger automobiles, vans and light trucks were the most common vehicle types involved; they accounted for nearly 10 percent of the accidents. Further examination of these results indicates that the better results experienced with passenger automobiles compared with vans and light trucks may relate primarily to vehicle weight, with center of gravity related to a lesser degree. Vans and light trucks are generally heavier than passenger automobiles and have a higher center of gravity. When results for these vehicles are compared with those for the heaviest passenger automobiles, the difference in performance is much less than when they are compared with results for all passenger automobiles. Injury rates are still higher than those for the heaviest passenger automobiles, but the differences are considerably less. Containment was nearly as good as for the heavy passenger automobiles, and the rate of secondary collisions with fixed objects was much closer. However, secondary rollovers are still quite high for vans and light trucks compared with the heaviest passenger automobiles, which indicates that the higher centers of gravity of these vehicles, compared with passenger automobiles, may be an important consideration in collisions with traffic barriers.

As expected, traffic barriers did not contain large trucks nearly as well as passenger automobiles and light trucks; fewer than half of these vehicles were contained compared with more than 80 percent of the passenger automobiles and three-fourths of the light trucks. Secondary collisions were reported in 60 percent of the heavy truck accidents. However, in spite of the low containment rate and frequent secondary collisions, the severe injury rate was similar to that for passenger automobiles, although the nonsevere injury rate was much higher. It appears that the large mass and relatively strong passenger compartments of these heavy vehicles may help to alleviate severe injuries, even though the collision event itself is more violent than for smaller vehicles.

Traffic barrier performance with small passenger automobiles has been an area of great concern because of the low mass, reduced vehicle stability, and lesser crush resistance of these vehicles compared with larger passenger automobiles. However, results of this investigation show that even the smallest passenger automobiles--those with wheelbases less than 96 in. and curb weights less than 2,000 lb--were provided good protection by traffic barriers. The highest severe injury rates were experienced by the largest, heaviest vehicles. It appears that this trend is related to barrier strength more than vehicle properties. Heavier automobiles were contained less often than lighter ones and experienced nearly twice as many secondary collisions with fixed objects. Although smaller automobiles experienced the most rollovers, this vehicle reaction was relatively scarce for all passenger vehicles and therefore did not affect injury rates to a large degree.

On the basis of the results of 3,302 traffic barrier accidents investigated in this study, the following findings can be stated:

1. Traffic barriers accidents resulted in lower injury rates than roadside accidents in general.
2. Current traffic barriers perform much better than older barriers.
3. Severity of occupant injuries was closely related to vehicle damage.
4. Satisfactory vehicle containment resulted in more than 75 percent of the cases.
5. About 25 percent of the cases involved a secondary collision.
6. Fixed object collisions were the most common second event, occurring in less than 18 percent of all accidents, followed by rollovers with less than 8 percent. Secondary collisions with other vehicles or pedestrians were extremely rare.
7. Injury rates were much higher for accidents involving lack of containment or secondary collisions.
8. Barriers performed best for passenger automobiles and exhibited reduced performance for vans and light trucks.
9. Injury rates were extremely high for motorcycle accidents.
10. In terms of vehicles containment and secondary collisions, barriers did not perform well with heavy trucks, although severe injury rates were about the same as for passenger automobiles.
11. Traffic barriers performed best with smaller passenger automobiles and showed some reduction in performance for larger automobiles.
12. The lower protection provided the largest passenger automobiles related to reduced vehicle containment and more frequent secondary events.
13. Small automobiles experienced more rollovers following traffic barrier collisions, but this event was still relatively rare and occurred in only about 7 percent of the collisions for the smallest vehicles.
14. Large passenger automobiles experienced more secondary collisions with fixed objects than smaller ones; 20 percent of all accidents with the largest cars involved such collisions.

## ACKNOWLEDGMENT

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