2. Overturning tends to be related to the side skidding and vehicle rotation that are common to curve accidents.
3. The dynamics of overturning are enhanced by the usually greater cross-slope breaks at both the edge of the pavement and the edge of the shoulder on curves.

To suggest the development of realistic prediction models or design criteria from the results of these two studies may be overoptimistic. However, the results do suggest some possible new orientations. For example, the 4:1 side slope that is commonly regarded as minimally acceptable, based on full-scale tests and simulations performed on tangent sections, may in fact be unacceptable on highway curves. In addition, the reexamination of guardrail warrants suggested by Hall and Zador may have some merit. It must be remembered, however, that their study only considers fatal overturning crashes, which constitute a small portion of all roadside accidents. Decisions on guardrail placement must, of course, consider the net effect on all roadside encroachments.

On another, more minor matter, the reader should be cautioned about basing any overt conclusions on the comparisons between Georgia and New Mexico data. The differences documented in these papers probably reflect little more than the basic differences in the two state's practices, terrains, and relative traffic exposures to various highway design configurations.

Although the fact is not new, these studies strongly reemphasize the basic safety problem of highway curves. As everyone knows, curves cannot be eliminated and flattening them is usually too expensive (and, except for extremely sharp curves, may only be marginally effective). If major improvements are to be made in safety on highway curves, therefore, these studies and the ongoing research in which I am participating seem to suggest that we look toward minimizing the consequences of run-off-the-road accidents. All indications are that, if there is to be a major emphasis in general roadside safety improvement efforts, it ought to be directed toward highway curves.

Authors' Closure

We would like to thank Glennon for his comments on these two papers. We believe that there is more importance to the results of these studies than that cited by Glennon. A study of all fatal overturning crashes in two states for a one-year period may be a limited sample, but national data clearly indicate that these types of crashes are responsible for a significant portion of highway fatalities. Furthermore, these two studies are the most recent of a series of studies of off-road crashes undertaken by the research group using common methodology. Combined, these projects have involved nearly 1000 on-site engineering surveys at crash locations plus an equal number at comparison locations.

Our data do not support Glennon's statement that roadsides are more hazardous on curves. The disproportionate share of crashes that occur at these locations seems to be more closely related to roadway alignment than to roadside design. As the paper by Wright and Zador states, undesirable geometric design features can increase the demands on the driver-vehicle system and contribute to loss of vehicle control and possible roadside encroachment. Once a driver has lost control of a vehicle, the type and severity of a crash are largely determined by the roadside environment: the dimensions and slopes of the cross section, the nature and density of roadside obstacles, and the configuration of the roadside surface.

There are several techniques the engineer can apply to reduce the frequency and severity of rollover crashes. These techniques, which include improved signing and delineation, roadway realignment, roadside barriers, and flatter side slopes, are not guaranteed to eliminate either roadside encroachments or fatal rollover crashes. We recognize, of course, that vehicles can depart from tangent roadways and overturn on very flat side slopes and that guardrail impacts can result in fatalities. We believe our data support the finding that, although it is impossible to eliminate fatal rollover crashes, the engineer can take action at a limited and identifiable number of locations to reduce the frequency of fatal roadside crashes.

Abridgment

Evaluation of Driveway-Related Accidents in Texas

RAMEY O. ROGNESS AND STEPHEN H. RICHARDS

The results of an extensive study of driveway-related accidents that occurred in Texas between 1975 and 1977 are presented. The study was conducted as part of a larger study to determine the extent and nature of driveway operational and safety problems on Texas streets and highways. The state of Texas computerized master accident file was the primary source of data for the evaluation. The findings of the study indicate that driveway-related accidents constitute a significant portion of the state's total traffic-accident experience. In fact, 16 percent of all traffic accidents in Texas during the three study years were driveway related. This percentage and the overall accident characteristics are consistent with results of previous research. The study results also indirectly suggest that better design and operation of driveways could reduce the number of driveway-related accidents and thus improve traffic safety.

An evaluation of safety and operational problems experienced at urban driveways in Texas was recently conducted (1). Improved guidelines for urban driveway location, design, and operation were developed based on the findings of this evaluation (2). As part of the research, an extensive study of driveway-related accidents that occurred in Texas between 1975 and 1977 was conducted.

The study primarily evaluated driveway-related accidents on city streets and county roads ("off-system" facilities) in Texas. A limited comparative study of driveway-related accidents on state-maintained highways was also performed. The study evaluated the driveway safety problem in terms of the number of accidents, severity, characteristics, and, to some extent, causative factors.

STUDY RESULTS

The accident study revealed that driveway-related

Table 1. Severity of driveway-related accidents on off-system roadways.

Accident Severity	Driveway-Related Accidents		All Accidents	
	Number	Percent	Number	Percent
Fatal	35	0.1	960	0.3
Injury	4 635	10.6	53 420	19.4
Property damage only	38 930	89.3	221 765	80.3
Total	43 600		276 145	

Note: Data are based on 1975-1977 Texas accident records.

accidents are relatively common in Texas and constitute a significant portion of the state's total accident problem. It suggested that driveway accidents in Texas are influenced by driveway design features, vehicle operating characteristics, and uncontrolled traffic movements at driveways.

Accident Frequency

During the three-year period from 1975 to 1977, there were 130 868 driveway-related accidents reported on city streets and county roads in Texas, or approximately 43 600 accidents/year. This number represents more than 16 percent of all off-system accidents (one out of six off-system accidents was driveway-related.)

Approximately 95 percent of these off-system driveway-related accidents reportedly occurred in urban areas. The remaining 5 percent occurred on rural county roads. In comparison, 92 percent of all off-system accidents reportedly occurred on city streets, and 8 percent occurred on county roads during the study period. Thus, the off-system driveway safety problem is concentrated, in terms of accident numbers, in urban areas.

Accident Severity

The severity of driveway-related accidents that occurred on city streets and county roads in Texas is summarized in Table 1. The data in the table indicate that about 35 fatal, 4635 injury, and 38 930 property-damage-only (PDO) accidents occurred each year during the three-year study period. These accidents resulted in an average of 36 deaths and more than 6300 injuries/year.

Table 1 also presents data that indicate that the severity of driveway-related accidents, on the average, was less than that for all off-system accidents. There were 8 fatalities per 10 000 driveway-related accidents during the study years. In contrast, 34 of every 10 000 off-system accidents resulted in a fatality.

In addition, injury rates associated with off-system driveway-related accidents were lower than injury rates for total off-system accidents. Approximately 11 percent of off-system driveway-related accidents resulted in at least one injured person, whereas 20 percent of the total accidents resulted in an injury. By using a test of proportions, these data indicate a statistically significant difference in driveway-related accident severity compared with total accident severity.

Vehicle Involvement

Vehicle involvement in driveway-related accidents is summarized below:

Type of Vehicle Involvement	Driveway-Related Accidents (%)	All Accidents (%)
Two moving vehicles	77.8	68.7
Vehicle and parked car	18.5	14.5
Vehicle and fixed object	2.3	12.0
Vehicle and pedestrian	0.3	1.4
Other	1.1	3.4

More than 96 percent of the accidents involved more than one vehicle. Almost 78 percent of these multiple-vehicle accidents involved two or more moving vehicles, and 18 percent involved a vehicle colliding with a parked car. In comparison, only 84 percent of all accidents on the off-system facilities involved more than one vehicle. This difference (96 versus 84 percent) is statistically significant but not surprising, since one might expect that one-car accidents would be less common at driveways.

A summary of the types of vehicles involved in driveway-related accidents is given below:

Type of Vehicle Involved	Driveway-Related Accidents (%)	All Accidents (%)
Passenger car	78	77
Truck	18	19
Motorcycle	3	1
Other	1	3

The data indicate that vehicle involvement in driveway-related accidents was similar to vehicle involvement in all types of accidents with a few important exceptions.

The study revealed that motorcycle involvment in driveway accidents was significantly different than in accidents as a whole. Only 3 percent of the accidents at driveways involved a motorcycle, yet these accidents accounted for one-third of the fatalities that resulted from driveway-related accidents in Texas between 1975 and 1977. In addition, the characteristics of motorcycle accidents at driveways were found to be somewhat different from those of most other types of driveway-related accidents. A disproportionately large percentage of driveway-related motorcycle accidents involved a motorcycle going out of control after the driver hit the curbing at a driveway.

The study also revealed that truck accidents at driveways are different from other types of driveway accidents. A disproportionately high percentage of driveway-related truck accidents involved a rear-end collision. A disproportionately low percentage of truck accidents, on the other hand, were accidents of the one-car, loss-of-control type. Truck involvement in angle-backing accidents was relatively high.

Trucks were also involved in a disproportionately high percentage of accidents in which a parked car was hit. The maneuvering requirements of trucks at driveways probably explain this finding. Approximately 39 percent of fatal driveway-related accidents involved a truck. It is notable that 72 percent of all fatal accidents at off-system driveways in Texas during the three-year study period involved a truck or a motorcycle.

City Size

An evaluation was conducted to determine whether the characteristics of driveway-related accidents varied with the size of the town or city in which the accidents occurred. This evaluation revealed that in smaller cities and towns the percentage of total driveway-related accidents that involved a backing

vehicle was higher. For example, more than 25 percent of the driveway-related accidents in towns with a population of less than 2500 were angle-backing accidents. In cities with a population of more than 250 000, however, only 12 percent of driveway-related accidents were angle-backing accidents.

Several other differences were found in the characteristics of driveway-related accidents in large cities versus those in small towns. For the most part, however, the differences were a by-product of the greater occurrence of backing accidents in smaller towns and cities.

The increased percentage of driveway-related backing accidents in smaller cities and towns was not totally explained in this study. However, two factors that may explain this trend were suggested by an extensive statewide inventory of driveways and a review of driveway regulatory practices in Texas (1). First, many cities with populations of less than 20 000 do not regulate driveway design or operation. It is possible that the unregulated (and, consequently, inadequate) driveways and parking facilities in these towns contribute to the higher rate of driveway-related backing accidents. Second, in many smaller cities and towns, a higher percentage of the driveways serve single-family dwelling units and other low-traffic-volume generators. More backing maneuvers may occur at these driveways compared with other types of driveways.

Driveway Accidents on State-Maintained Highways

A limited study of driveway-related accidents that occurred during 1977 on state-maintained highways in Texas was conducted to determine whether there were similarities in accident characteristics between on-system and off-system facilities. This evaluation revealed that 22 754 driveway-related accidents were reported as occurring on on-system facilities in Texas in 1977. This number represents approximately 10 percent of all on-system accidents. In comparison, more than 16 percent of all off-system accidents in Texas were driveway-related. Thus, driveways appear to be a less critical safety problem on on-system facilities, at least in terms of accident numbers. This might be anticipated since there are fewer driveways along the rural highways and urban freeways that make up much of the on-system highway network in Texas.

The evaluation also revealed, however, that on-system driveway-related accidents were generally more severe than off-system driveway-related accidents. This finding may be explained by the generally higher speeds on state highways.

Motorcycles were involved in a disproportionately high percentage of on-system driveway-related accidents. Truck involvement, however, was not significantly different from truck involvement in all types of off-system driveway-related accidents.

SUMMARY AND DISCUSSION OF RESULTS

The finding that 16 percent of all accidents on city streets and county roads in Texas are driveway-related is consistent with the findings of previous studies by Box (3,4) and McGuirk (5). These respective researchers found that 12 and 14 percent of all traffic accidents occur at driveways.

By combining the off-system and on-system accident data, it was revealed that more than 93 percent of all driveway-related accidents in Texas occur in urban areas. Approximately two-thirds of all driveway-related accidents studied involved a vehicle exiting a driveway. Less than one-third involved a vehicle that was attempting to enter a driveway. Backing accidents at driveways were very common and were more common in smaller towns than in large cities.

Motorcycle and truck accidents appear to pose the greatest safety problem. Almost 72 percent of all fatal accidents involved a truck or a motorcycle. These vehicles must therefore be considered in the design and operation of driveways.

The problem of motorcycle accidents at driveways may be related to poor visibility. Vehicle drivers simply may not always see motorcycles at driveways. In addition, a high percentage of driveway-related motorcycle accidents involve a motorcycle going out of control after striking a raised curbing at a driveway. Improved driveway geometry and delineation (painting) of driveway curbs and islands could prevent some of these accidents. The problem of truck accidents at driveways, on the other hand, is apparently related to the maneuvering requirements of trucks and their large size.

The study findings suggest that improved design and operation of driveways could reduce the number of driveway-related accidents. The conflicting movements at multiple adjacent driveways could be reduced by limiting the number of driveways and by designing driveways so that potential conflict areas can be easily recognized by street traffic. Many accidents may be prevented by installing left-turn bays and/or right-turn deceleration lanes at major driveways. In addition, adequate throat width and curb radii should be provided at driveways to allow smoother turning movements. Other accidents may be prevented by designing and operating parking areas so that drivers are not forced to back through driveways.

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