# AN ANALYSIS OF ACCIDENTS ON TURNED DOWN GUARDRAIL ENDS IN THE STATE OF TEXAS (CALENDAR YEAR 1989)

(Report Number 9901-H)

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## INTRODUCTION

In a memorandum dated June 28, 1990 from the Director of the Office of Highway Safety of the Federal Highway Administration to the Regional Federal Highway Administrators, the following language appears:

> Turned-down terminals should not be used on new installations of guardrails for freeway, expressway, or other high speed, high volume facilities.
>
> Safety improvement projects, hazard elimination projects, or 3R/4R projects on high speed, high volume facilities should require replacement of turned-down end terminals with approved terminals.
>
> Use of turned-down terminals on projects involving high speed, but moderate traffic carrying facilities should be considered on a case-by-case basis or an approved State developed policy.
>
> Development of adequate recovery area behind the terminal and sufficient distance from protected piers, abutments or other fixed hazards is necessary to prevent tragic "vault into object" accidents from occurring.
>
> Use of turned-down terminals on low speed or any low volume facility may be allowed based on reasonable risk management considerations.

In response to this memorandum, the Texas State Department of Highways and Public Transportation (SDHPT) asked the Texas Transportation Institute (TTI) to conduct a study to determine:

- The annual number of accidents on the state maintained highway system involving turned-down guardrail ends
- The severity of these accidents, i.e., how many people are killed and injured in these accidents?
- The number of vehicles that are overturning on turned-down ends each year
- The highway types and traffic volumes associated with these accidents
- The antecedent conditions associated with these accidents, e.g., speed, alcohol, skidding, etc.

### Discussion

In an idealized study to assess the effects of turned-down guardrail ends on vehicle overturns and accidental deaths and injuries, comparisons would be drawn between accidents involving turned-down guardrail ends and accidents involving another type of end treatment (e.g., a breakaway cable terminal). In the state of Texas, however, the turned-down end is, effectively, the only treatment in use. Therefore, such a comparison is not possible.

In lieu of a comparison between competing end-treatments, this study estimates the number of vehicles that are overturning on turned-down guardrail ends – and the number of people who are killed or injured in such accidents each year. Although such estimates may reflect the inherent safety of turned-down guardrail ends, they are, perhaps, even more reflective of the number of turned-down guardrail end treatments deployed throughout the Texas highway system, and the volume of traffic carried by the system.

If the analyses in this study were to demonstrate that accidents on turned-down guardrail ends are a serious problem, if vehicle overturns, and the deaths and injuries associated with these accidents were relatively common, then the added cost of switching from the turned-down end to some other end treatment might be justified.

On the other hand, if the number of turned-down guardrail end accidents were small, and/or if the consequences of these accidents were fairly benign, then a policy requiring that inexpensive turned-down guardrail ends be replaced with more expensive end-treatments might be counterproductive.

### Objectives of this Study

The stated objectives of this study were, as a minimum, to determine if, and to what degree, turned-down guardrail ends are associated with (1) vehicle overturn and (2) accidental death and injury in Texas.

## PROCEDURE

In 1989 some 190,512 traffic accidents were recorded on the Texas, state-maintained highway system. Of these 190,512 accidents, 4,047 (2.1%) were reported to have involved collisions with guardrails. 5,102 vehicles (and drivers) and 7,423 persons (i.e., drivers, vehicle occupants, pedestrians, etc.) were said to have been involved in these 4,047 reported guardrail accidents.

The accident data used for the analyses in this paper are derived from this base set of 4,047 reported guardrail accidents by means of the procedure outlined below:

1. The 4,047 reported guardrail accidents were subsetted to include only those accidents that resulted in a fatality. One hundred accidents met this definition. Photocopies of the accident reports for these 100 accidents were provided by the Texas Department of Public Safety (DPS).

2. Of the remaining 3,947, non-fatal guardrail accidents on record, a 25 percent sample was developed by selecting every fourth accident in the data file in the order that the accident records were created by DPS (i.e., by accident case number). Photocopies of the 987 non-fatal accidents in the 25 percent sample were provided by DPS.

3. The author then reviewed the photocopied reports for each of the 100 fatal accidents and for each of the 987 non-fatal accidents. Each report was coded on two supplemental variables:

A. Where was the guardrail struck?

On a turned-down end
Not on a turned-down end
Unable to determine
Object struck was not a guardrail

B. Did the striking vehicle overturn?

Yes
No
Undetermined

4. The supplemental codes generated by the author were then merged by accident case number with the standard accident-oriented variables (e.g., time of day, day of week, etc.), vehicle-oriented variables (e.g., driver age, vehicle type) and road inventory variables (e.g., annualized average daily traffic, AADT) contained in the Texas traffic accident data base maintained by TTI (from data provided by DPS and SDHPT).

**Reported Guardrail Accidents**

The guardrail accidents cited in this report are reported guardrail accidents – accidents known to law enforcement personnel and reported to DPS. It is no doubt true that some, perhaps many, guardrail accidents on the Texas state-maintained highway system go unreported each year. Most of these non-reported accidents are assumed to be minor accidents – accidents that involve property damage only (PDO) or only minor injuries. Nevertheless, the problem of non-reported accidents can have serious consequences for some analyses based upon accident data (e.g., Griffin, 1990).

Imagine, for example, that on high-volume, urban interstates it is not uncommon for drivers to strike a guardrail somewhere throughout its length of need with only minor damage to the vehicle and the rail, and no driver/occupant injuries. Such an accident might very well go unreported. (Scenario 1)

Imagine, on the other hand, that when a vehicle strikes the end of a guardrail it has a fair chance of (a) overturning on the rail, (b) straddling the rail, or (c) traveling behind the rail to strike a fixed object, overturning on the side slope or getting stuck in the mud. Under these circumstances, accidents on the end of a guardrail may have a greater likelihood of coming to the attention of law enforcement personnel and thus of becoming "reported accidents." (Scenario 2)

If scenarios 1 and 2 are both true, if accidents on guardrail ends are relatively more likely to be reported than accidents occurring throughout the length of need, then the relative frequency of "end of rail" impacts to "not end of rail" impacts will be exaggerated.

**Definition of Guardrail Accident**

Simply stated, a guardrail accident, as defined for purposes of this study, meets two criteria:

1. In the DPS files, the "fixed object" cited in the accident is reported to be a "guardrail," and

2. The author, on the basis of his reading of the accident report, did not have sufficient evidence to reject the assertion by DPS that the accident was a guardrail accident.

It should be noted that the definition of a guardrail accident as used in this study does not imply that the impact with the guardrail was the "first harmful event" or the "most harmful event" in the accident. In some accidents, including fatal accidents, the impact with the guardrail may be of relatively little consequence.

> **Example Narrative:** Unit 1 (a motorcycle) westbound on Lyndon B. Johnson Freeway in the second lane south of north curb at a very high rate of speed collided front to the left rear of Unit 2 (a passenger car) which was also westbound in the second lane south of the north curb. This impact forced Unit 2 into a clockwise rotation and into a northerly direction. Unit 2 continued colliding front to the guard railing .... (Note: The motorcyclist was killed. The driver of the passenger car which struck the guard rail was uninjured.)

**Author's Coding**

Was the object struck a guardrail? When an officer's narrative or diagram indicated that the object struck was a concrete guardrail, a cement divider, a wall, etc., the author ruled that the accident in question was not a guardrail accident.[1]

> **Example Narrative:** No. 1 E/B on Katy Frwy in the left Ln. No. 2 was stalled in the left Ln. Also E/B pedestrian was standing behind No. 2. No. 1 FD struck pedestrian, penning pedestrian between No 1 FD and No 2 BD. No. 2 FLQ then struck the concrete rail.

Nevertheless, in the absence of contradictory evidence, some non-guardrail accidents were, no doubt, falsely retained as guardrail accidents.

What was the point of impact on the rail? To determine whether a particular guardrail impact was on the turned-down end (or at some other location on the rail), the officer's narrative, and more often the officer's diagram, proved useful.

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[1]On the Texas Peace Officer's Accident Report Form (ST-3) there is a fill-in-the-blank question entitled "Damage to Property Other Than Vehicles." Answers to this question were sometimes helpful in determining whether or not the object struck in the accident was really a guardrail.

**Example Narrative:** #1 Northbound on US 277. #1 ran off road on rightside. #1 then struck turndown section of guardrail at approach to a bridge.

It should be quickly stated that the preceding example is atypical. Most accident reports were not nearly this explicit in describing where the guardrail was struck. In the absence of such explicit information, and in spite of the best efforts by the author, some accidents may have been falsely coded as turned-down end accidents, and vice versa.

Did the striking vehicle overturn? Individual accidents were coded as overturn accidents when the vehicle striking the rail (or its trailer or semi-trailer) rolled over on its side or top. Vehicle overturn was determined from the narratives, scene diagrams and vehicle damage ratings (TAD's) reported by the officers.

**Example Narrative:** Unit #1 was traveling east on FM-774 and failed to negotiate a curve drifting off the south side of the road onto the grass. Unit #1 began skidding sideways and struck guard fence driving upon the guard fence, causing the left side of Unit #1 to leave the ground. Unit #1 continued along the guard fence in a sideways direction and overturned the vehicle onto the right top side and back onto its wheels.

In the process of coding 1,087 accident report forms with regard to vehicle overturn, some errors may have occurred. Generally speaking, however, it was easier to determine whether or not a vehicle turned over than it was to determine whether or not the object struck was a guardrail – and whether or not the point of impact was on a turned-down end.

## RESULTS

### Estimated Deaths and Injuries in Accidents on Turned-Down Guardrail Ends

Of the 987 non-fatal accidents reviewed by the author, 756 were determined to have involved collisions on the turned-down end of a guardrail (N=152) or at some other location on the rail (N=604). Some 115 accidents appeared to be guardrail accidents, but it was not clear where the rail was struck. Another 116 accidents were found to be non-guardrail accidents. (Table 1)

For the 100 fatal accidents reviewed, 87 were found to be guardrail accidents: 32 collisions were on the end of the rail, 46 were not on the end of the rail, and for 9 the point of impact was undetermined. The remaining 13 accidents were found to be non-guardrail accidents. (Table 1)

Table 2 displays the deaths and injuries sustained by the 269 persons involved in turned-down end collisions. For comparison purposes, the deaths and injuries sustained by the 1,269 persons involved in collisions that were not on turned-down ends are also displayed.

Table 1: Classification of Accident Reports Provided by DPS

| Where was the guardrail struck? | Non-Fatal Accidents | Fatal Accidents |
|---|---|---|
| On the turned-down end | 152 | 32 |
| Not on the turned-down end | 604 | 46 |
| Unable to determine | 115 | 9 |
| Object struck was not a guardrail | 116 | 13 |
| | 987 | 100 |

Table 2(a): Severity of the Injuries Sustained by 269 Persons Involved in Guardrail Accidents on Turned-Down Ends

| Accident Severity | Number of Persons Injured by Severity of Injury | | | | | |
|---|---|---|---|---|---|---|
| | None | C | B | A | Fatal | Total |
| No Injury | 136 | - | - | - | - | 136 |
| C-Level | 4 | 17 | - | - | - | 21 |
| B-Level | 2 | 0 | 29 | - | - | 31 |
| A-Level | 2 | 0 | 7 | 16 | - | 25 |
| Fatal | 6 | 1 | 5 | 5 | 39 | 56 |
| | 150 | 18 | 41 | 21 | 39 | 269 |

Table 2(b): Severity of the Injuries Sustained by 1,238 Persons Involved in Guardrail Accidents that were Not on Turned-Down Ends

| Accident Severity | Number of Persons Injured by Severity of Injury | | | | | |
|---|---|---|---|---|---|---|
| | None | C | B | A | Fatal | Total |
| No Injury | 492 | - | - | - | - | 492 |
| C-Level | 114 | 153 | - | - | - | 267 |
| B-Level | 61 | 32 | 139 | - | - | 232 |
| A-Level | 37 | 14 | 16 | 66 | - | 133 |
| Fatal | 23 | 19 | 17 | 6 | 49 | 114 |
| | 727 | 218 | 172 | 72 | 49 | 1,238 |

Based upon the data in Tables 1 and 2, and expanding the accidents and injuries sustained in non-fatal accidents by a factor of four to account for the 25 percent sample used in the study, estimates of the numbers of guardrail accidents, deaths and injuries on the Texas, state-maintained highway system (1989) are offered in Table 3.[2]

[2]In deriving the estimates shown in Table 3, the 115 non-fatal (and 9 fatal guardrail accidents) for which point of impact was unknown were divided among "accidents on turned-down ends" and "accidents not on turned-down ends." This division of accidents was made in proportion to the relative numbers of known

Table 3: Estimated Numbers of Guardrail Accidents, Deaths and Injuries on the Texas, State-Maintained Highway System by Point of Impact (1989)

| | Accidents on Turned Down Ends | Accidents Not on Turned Down Ends |
|---|---|---|
| Guardrail Accidents | | |
| Non-Fatal Accidents | 700 | 2,784 |
| Fatal Accidents | 36 | 51 |
| | 736 | 2,835 |
| Persons Injured (by Severity) | | |
| Possible (C-Level) Injuries | 81 | 984 |
| Non-incapacitating (B-Level) Injuries | 172 | 741 |
| Incapacitating (A-Level) Injuries | 85 | 338 |
| Fatalities | 43 | 54 |
| | 381 | 2,117 |

If the estimates in Table 3 are taken at face value, it is apparent that fatalities (on a per accident basis) are relatively more common on turned-down ends. For every 100 guardrail accidents that are not on the turned-down end, there are 1.90 fatalities; for every 100 guardrail accidents on a turned-down end, there are 5.84 fatalities, approximately three times as many.

For every 100 guardrail accidents on a turned-down end there are 11.55 incapacitating (A-Level) injuries; for guardrail accidents that are not on the turned-down end, incapacitating injuries average 11.92 per 100 accidents.

Non-incapacitating (B-Level) injuries in guardrail accidents on turned-down

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"accidents on turned-down ends" and "accidents not on turned-down ends," as outlined below:

| Point of Impact | Non-Fatal Accidents | Reapportioned | Fatal Accidents | Reapportioned |
|---|---|---|---|---|
| On Turned Down Ends | 152 | 175 | 32 | 36 |
| Not on Turned Down Ends | 604 | 696 | 46 | 51 |
| Undetermined | 115 | - | 9 | - |
| | 871 | 871 | 87 | 87 |

Note that the ratio of 152 to 604 is equivalent to the ratio of 175 to 696 (and the ratio of 32 to 46 is equivalent to the ratio of 36 to 51), except for rounding. Since the reapportioned estimates of 175 and 696 are both based on a 25 percent sample of guardrail accidents, both figures were multiplied by four (4) before being entered in Table 3. The reapportioned estimates of 36 and 51 were not expanded by four since these estimates were derived from a census of all fatal guardrail accidents in 1989.

The estimated numbers of deaths and injuries (by severity) shown in Table 3 were derived by identical logic.

ends average 23.37 per 100 accidents; for guardrail accidents that do not involve the turned-down end, the corresponding rate is 26.14 incapacitating injuries per 100 accidents.

### Estimated Vehicle Overturns in Accidents on Turned-Down Guardrail Ends

Thirty-six percent of all vehicles impacting a turned-down guardrail end in non-fatal accidents, and 72 percent of all vehicles impacting a turned-down end in fatal accidents were found to overturn. For non-fatal and fatal guardrail accidents in which the turned-down end was not struck, the corresponding figures are 12 percent and 54 percent, respectively. (Table 4)

Table 4(a): Vehicle Overturn in Non-Fatal Guardrail Accidents on the Texas, State-Maintained Highway System by Point of Impact (1989)

| | Accidents on Turned Down Ends | Accidents Not on Turned Down Ends | Undetermined Point of Impact |
|---|---|---|---|
| Vehicle Overturned | 55 ( 36%) | 69 ( 12%) | 20 ( 17%) |
| Vehicle Did Not Overturn | 94 ( 62%) | 534 ( 88%) | 86 ( 75%) |
| Undetermined | 3 ( 2%) | 1 ( -%) | 9 ( 8%) |
| | 152 100% | 604 100% | 115 100% |

Table 4(b): Vehicle Overturn in Fatal Guardrail Accidents on the Texas, State-Maintained Highway System by Point of Impact (1989)

| | Accidents on Turned Down Ends | Accidents Not on Turned Down Ends | Undetermined Point of Impact |
|---|---|---|---|
| Vehicle Overturned | 23 ( 72%) | 25 ( 54%) | 9 (100%) |
| Vehicle Did Not Overturn | 9 ( 28%) | 21 ( 46%) | 0 ( 0%) |
| | 32 100% | 46 100% | 9 100% |

Applying the percentages from Table 4 to the estimates in Table 3, it is projected that 278 vehicles per year overturn on turned-down guardrail ends on the Texas, state-maintained highway system.

### Further Analyses of Non-Fatal Guardrail Accidents on Turned-Down Ends

To better understand where, when, and why non-fatal guardrail accidents were occurring in 1989 – and to determine who was involved in these accidents, and what kind of vehicles they were driving – further analyses were undertaken. To provide perspective, accidents on turned-down guardrail ends were compared to guardrail accidents that did not occur on turned-down ends.

Where did these accidents occur?

Non-fatal guardrail accidents on turned-down ends occur predominantly, as expected, in the larger districts – districts with higher traffic volumes and more miles or guardrail. Collectively, the Houston (12), Dallas (18), San Antonio (15) and Fort Worth (2) districts produce half of all non-fatal, guardrail accidents on turned-down ends – and two thirds of all accidents that are not on turned-down ends. (Figure 1)

Non-fatal guardrail accidents, regardless of whether or not they occur on a turned-down end, are relatively more common in towns and cities with populations in excess of 50,000. Nevertheless, over one third of all non-fatal guardrail accidents on turned-down ends are recorded in rural areas. (Figure 2)

Ten percent of all non-fatal accidents on turned-down guardrail ends occur on Farm-to-Market Roads. The balance are fairly evenly divided between Interstates and US and State Highways. (Figure 3)

As the previous two figures suggest, non-fatal accidents on turned-down guardrail ends are associated with lower traffic volumes (i.e., lower annualized average daily traffic, AADT) than guardrail accidents off the turned-down end. Approximately 25 percent of all non-fatal, guardrail accidents on turned-down ends occur on highways carrying fewer than 8,500 vehicle per day. For non-fatal, guardrail accidents off the turned-down end, the corresponding AADT is 19,000 vehicles per day.[3] (Figure 4)

When did these accidents occur?

Non-fatal accidents on turned-down guardrail ends occur disproportionately during the winter, i.e., during the months of December, January, February and March. A somewhat similar, though less prominent pattern, is seen for non-fatal, guardrail accidents that are not on the turned-down end. (Figure 5)

Thursdays, Fridays and Saturdays are the days that are most strongly associated with non-fatal, guardrail accidents on turned-down ends. Saturdays and Sundays are more common for non-fatal, guardrail accidents that are not on turned-down ends. (Figure 6)

Over 60 percent of all non-fatal guardrail accidents involving turned-down ends occur during hours of darkness. For similar accidents that do not involve turned-down ends, the corresponding figure is slightly over 40 percent. (Figure 7)

Non-fatal guardrail accidents on turned-down ends are somewhat over represented between the hours of 9:00 pm and 5:00 am, and to a lesser extent during the evening rush hours between 4:00 pm and 7:00 pm. For non-fatal guardrail accidents that do not involve turned-down ends, the evening hours (9:00 pm to 3:00 am) and the morning and afternoon rush hours (7:00 am to 9:00 am; 3:00 pm to 7:00 pm) are conspicuously over represented. (Figure 8)

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[3]Table A1 in the appendix provides the raw data on which Figure 4 was based.

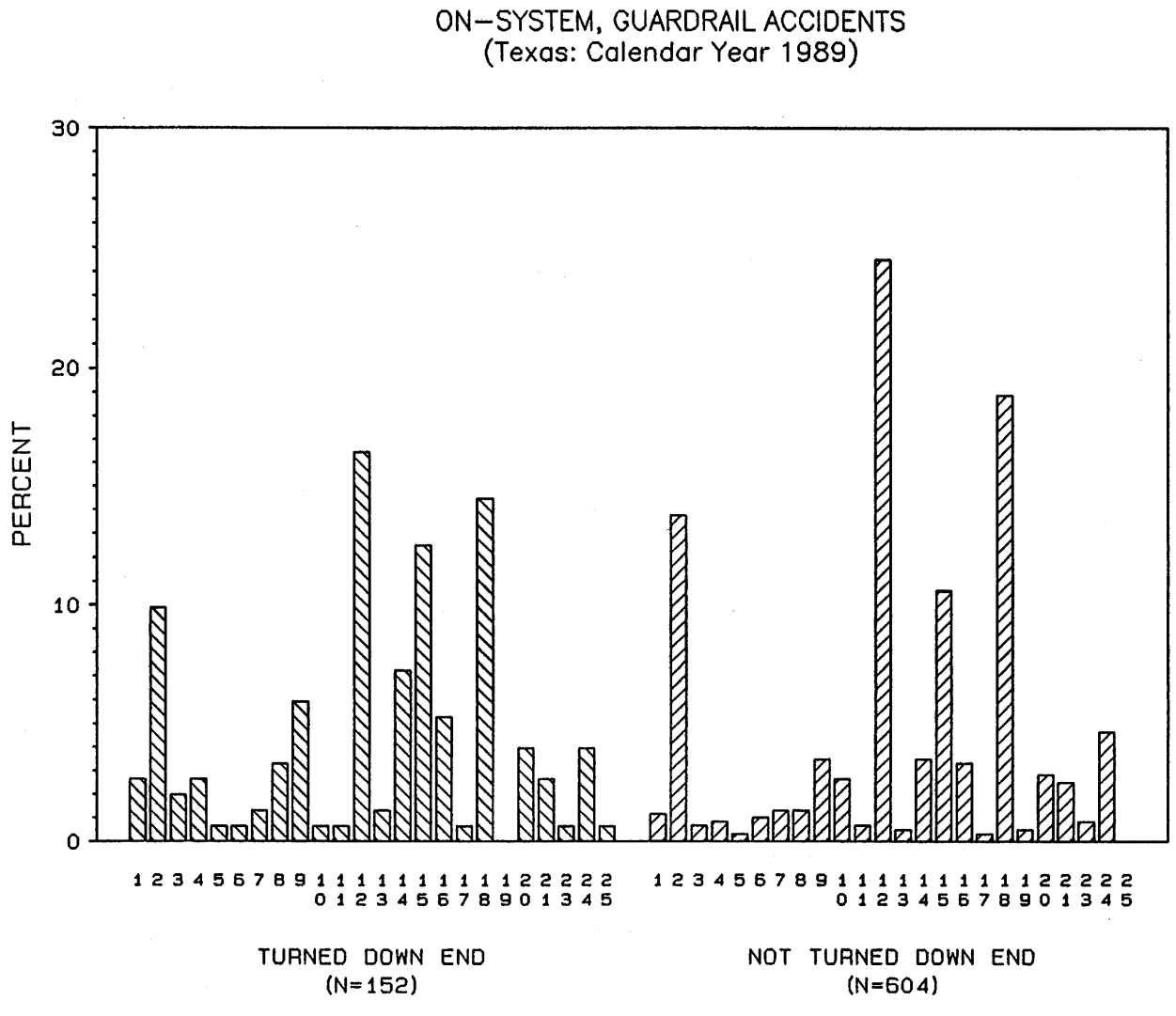


Figure 1: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY HIGHWAY DISTRICT AND POINT OF IMPACT

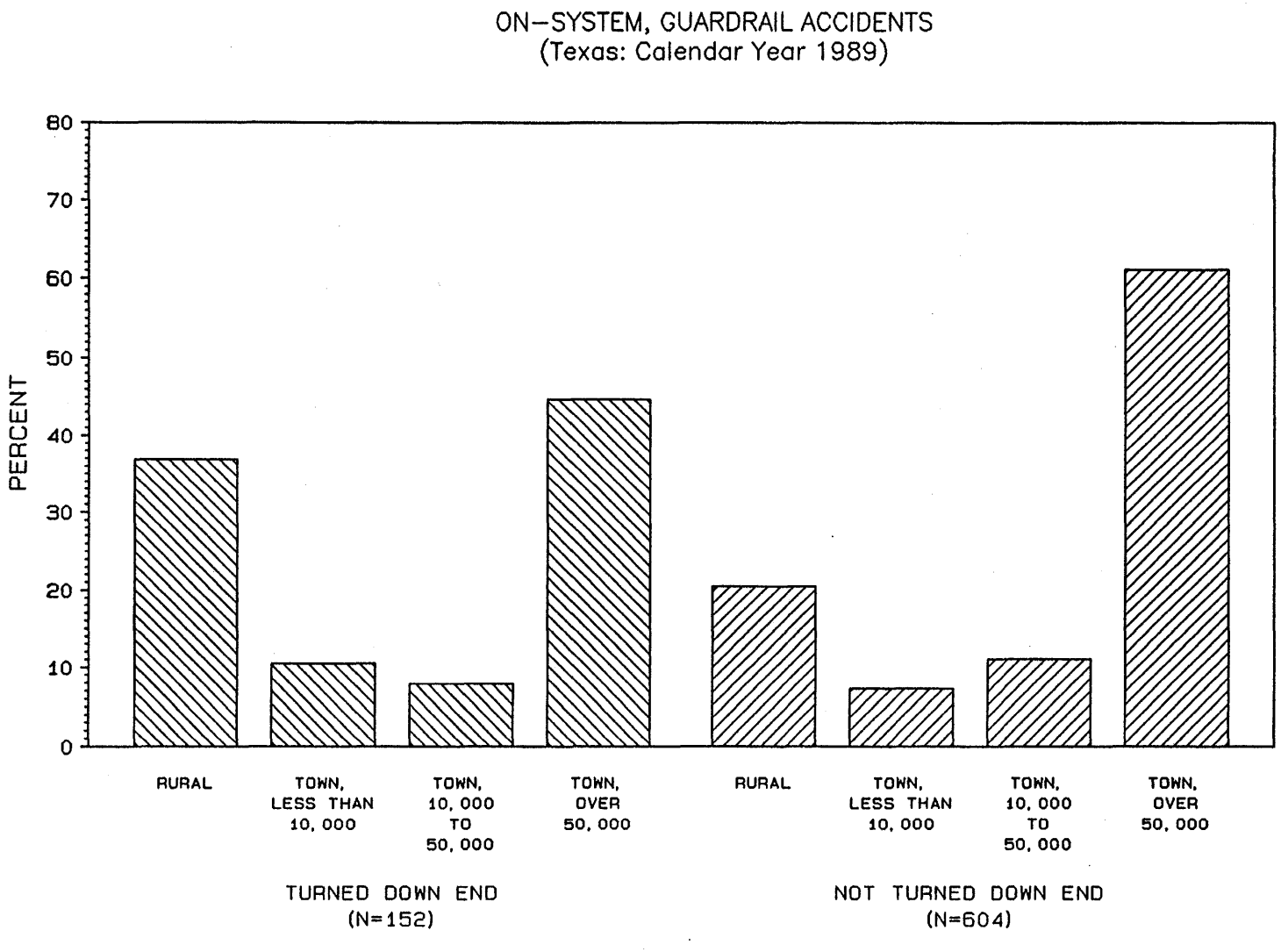


Figure 2: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY POPULATION AND POINT OF IMPACT

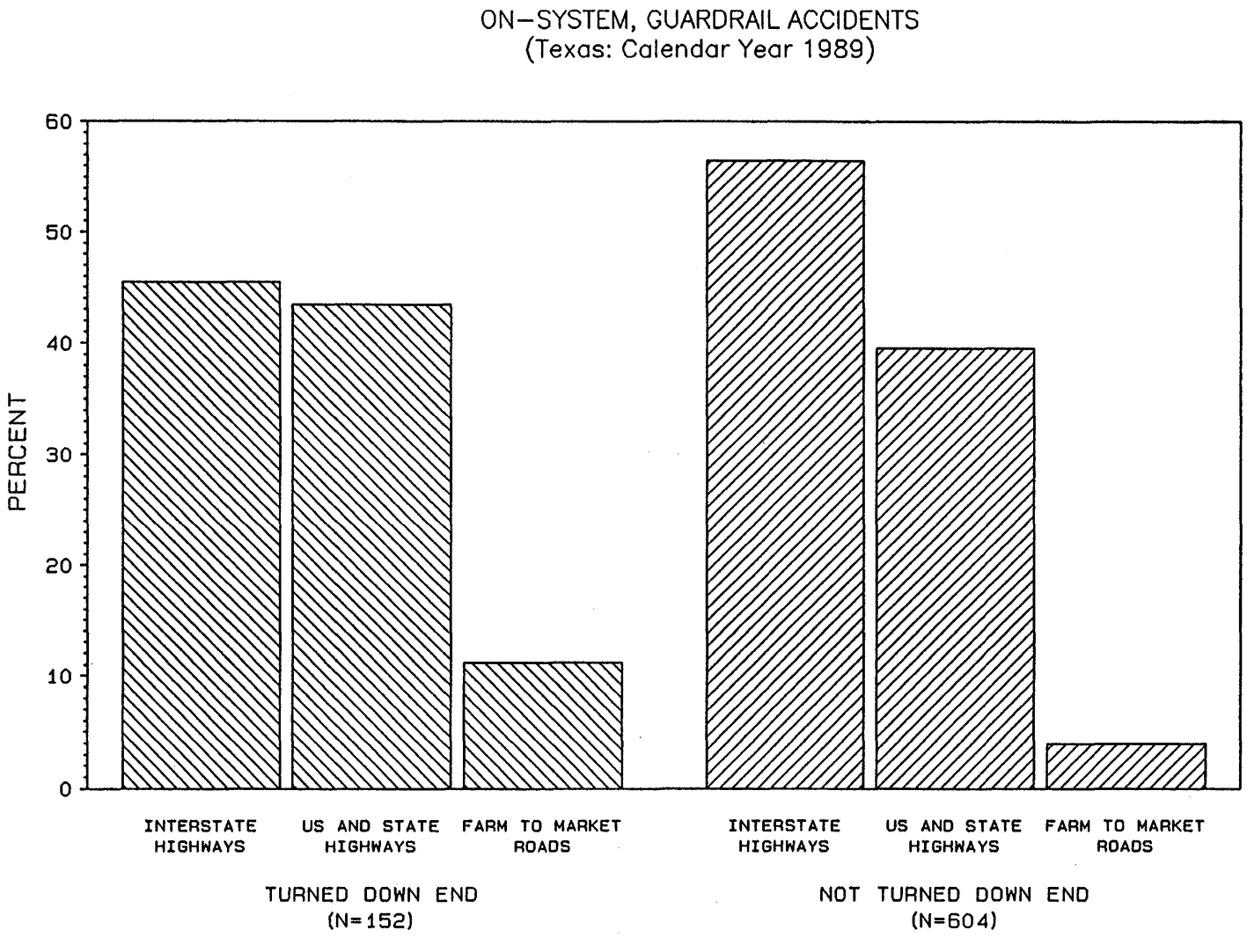


Figure 3: NON-FATAL, GUARDRAIL ACCIDENTS (N=756) BY HIGHWAY TYPE AND POINT OF IMPACT

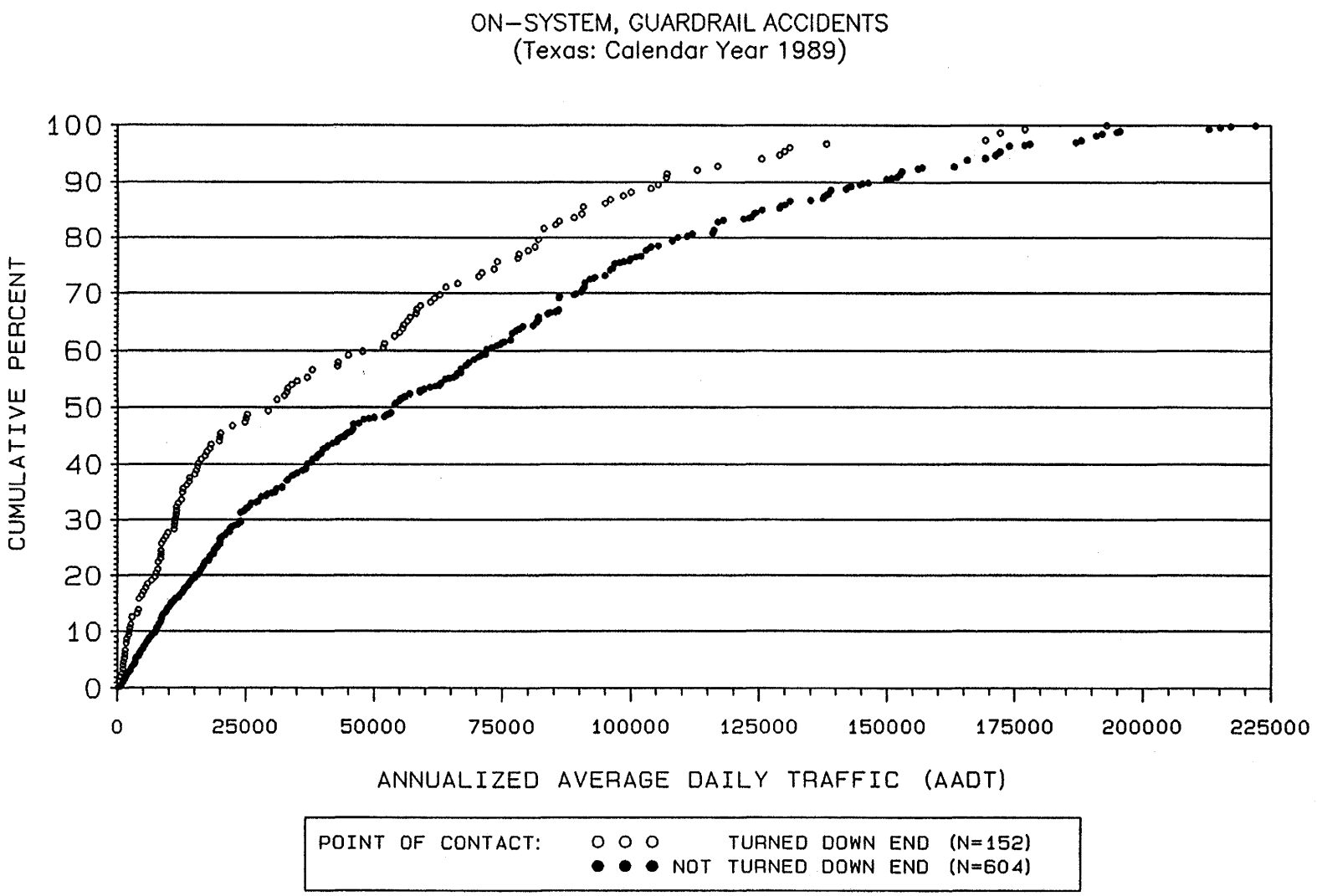


Figure 4: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY AADT AND POINT OF IMPACT

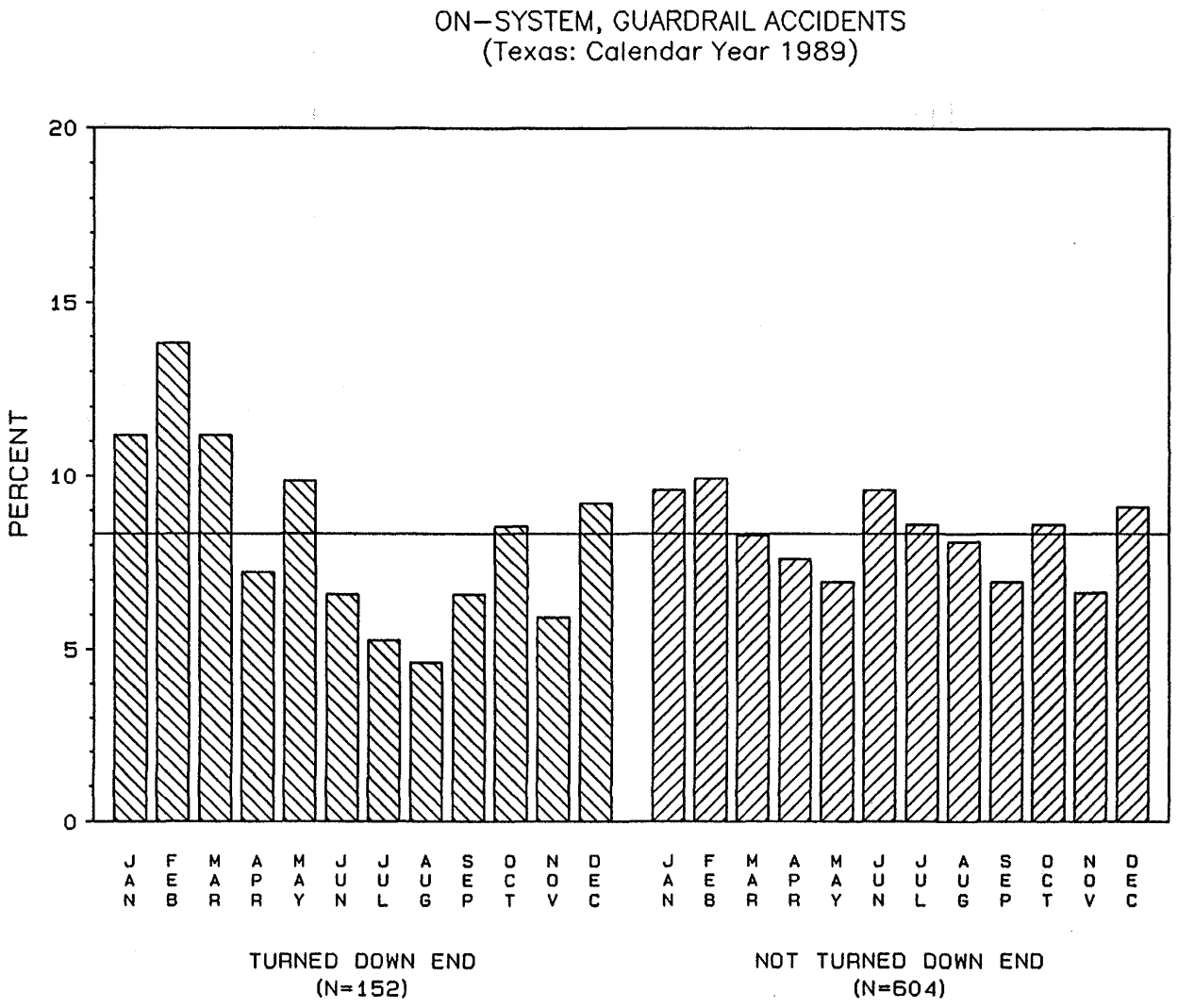


Figure 5: NON-FATAL, GUARDRAIL ACCIDENTS (N=756) BY MONTH AND POINT OF IMPACT

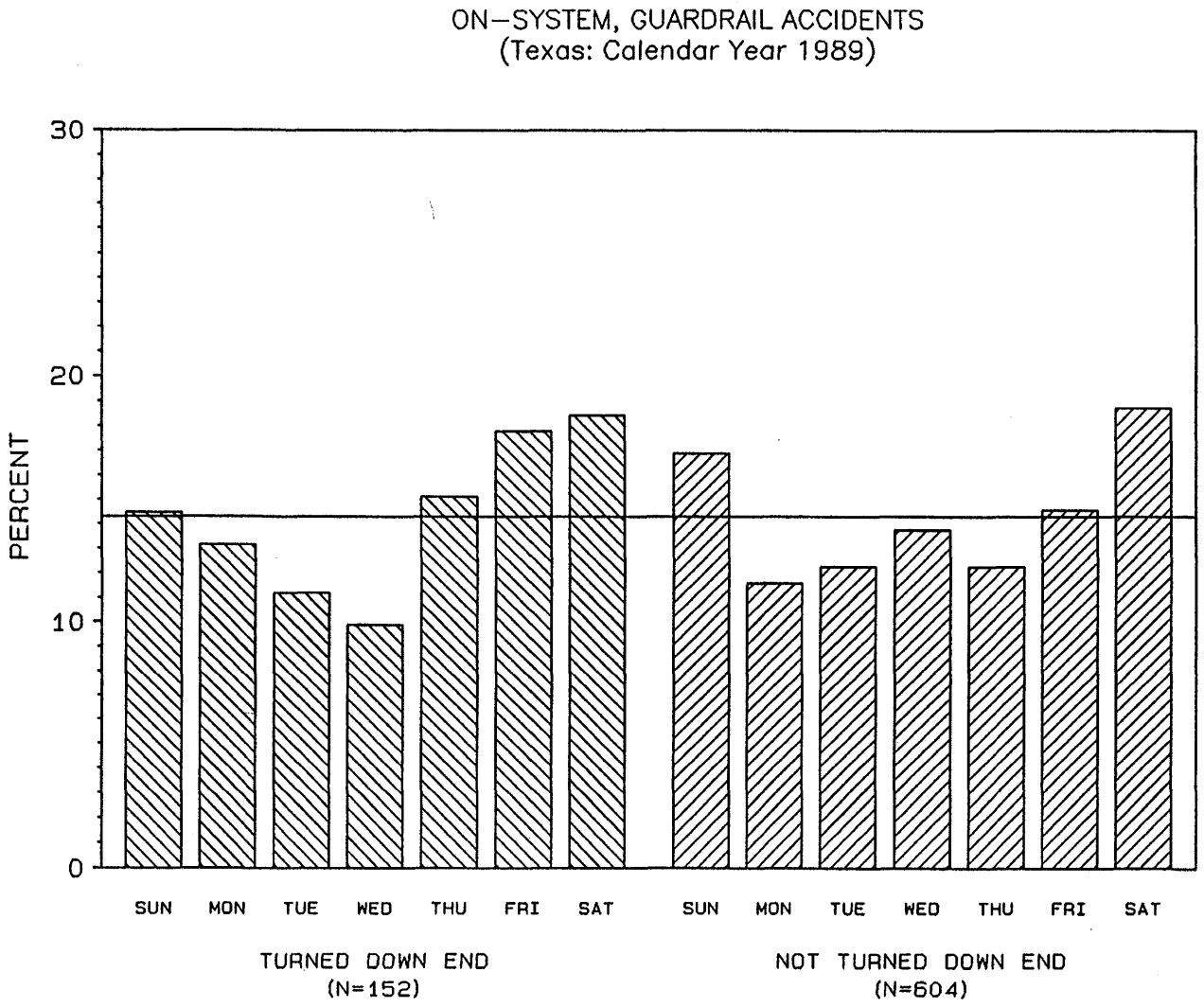


Figure 6: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY DAY OF WEEK AND POINT OF IMPACT

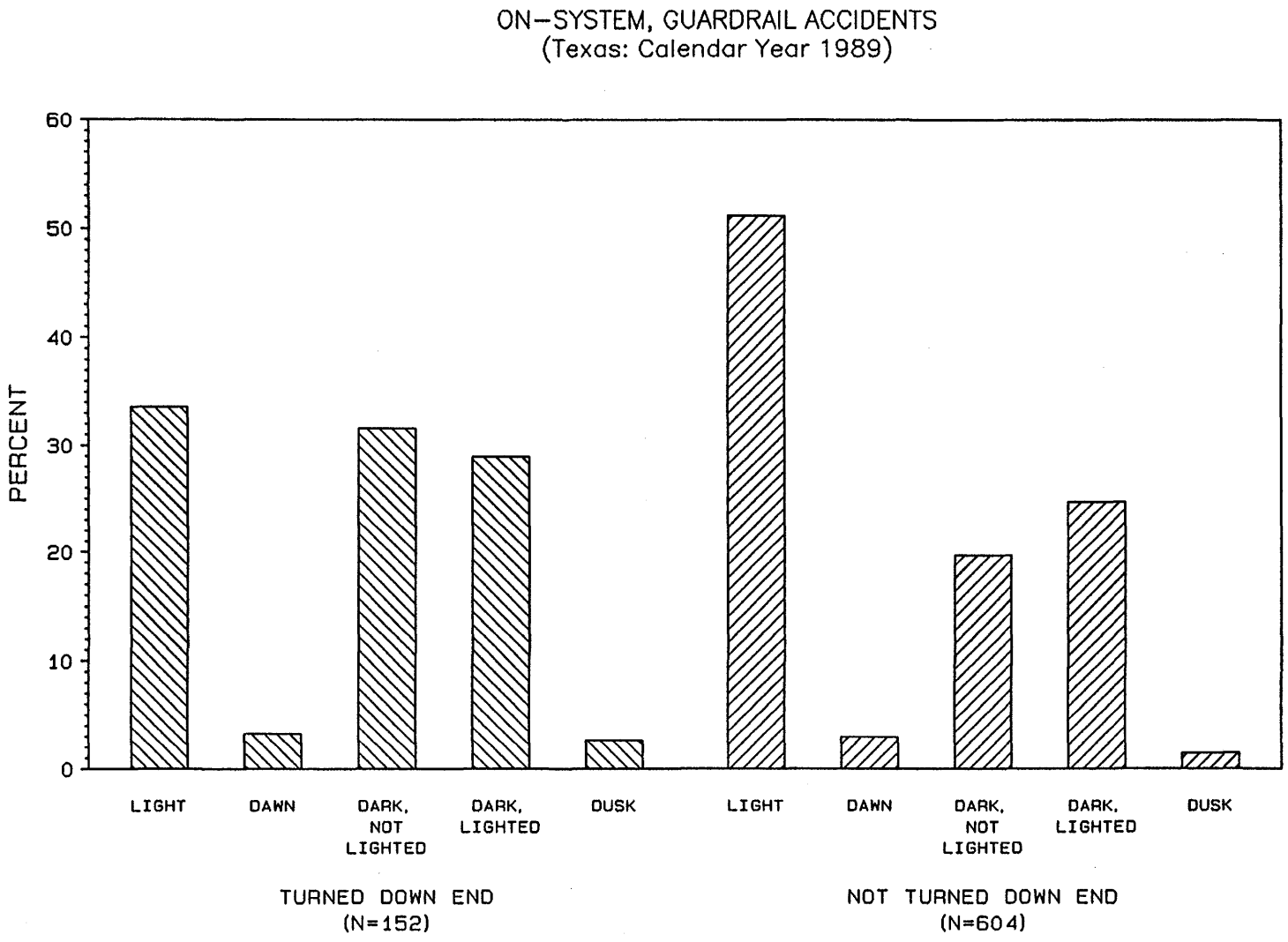


Figure 7: NON-FATAL, GUARDRAIL ACCIDENTS (N=756) BY LIGHT CONDITION AND POINT OF IMPACT

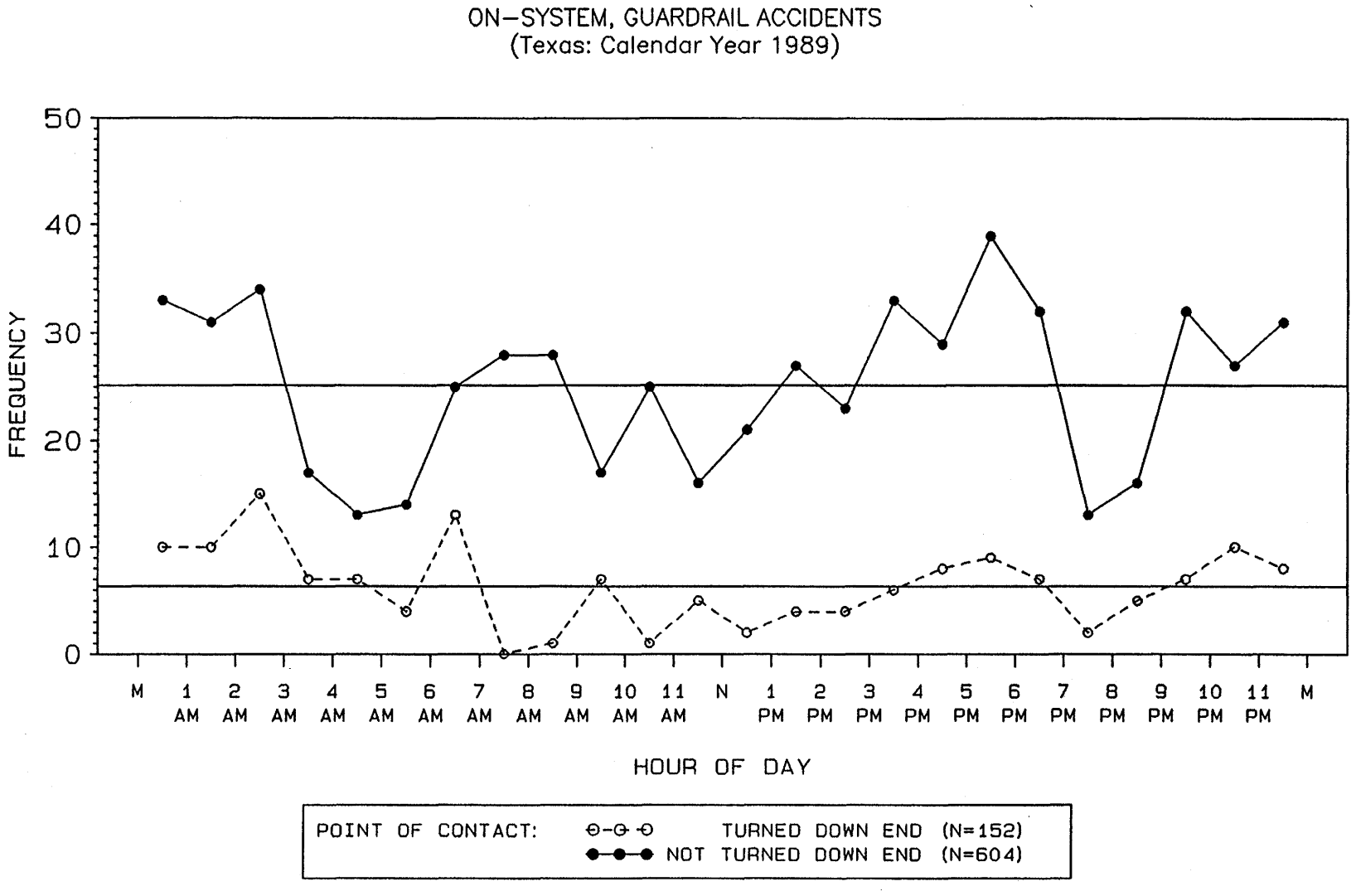


Figure 8: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY HOUR OF DAY AND POINT OF IMPACT

Why did these accidents occur?

The two tables offered in this section serve to document (1) the different configurations (i.e., the manner of collision) in which guardrail accidents occur and (2) the factors that may have contributed to the accidents.

From the data in Table 5 it is clear that the "manner of collision" associated with non-fatal, guardrail accidents on turned-down ends is predominantly (98 percent of the time) a single vehicle accident, i.e., a single motorvehicle (MV) going straight, turning right or turning left. For non-fatal, guardrail accidents that do not involve turned-down ends, single vehicle accidents are still the norm, but non-fatal, multivehicle accidents are somewhat more common.[4]

In Table 6 several antecedent conditions (accident factors) that may have produced an accident, or increased the severity of an accident, are listed. Ten percent of the non-fatal, guardrail accidents on turned-down ends are associated with driver inattention. Twelve percent of the non-fatal, guardrail accidents that are not on turned-down ends are associated with a driver swerving to avoid an animal, an object, a slowing or stopped motorvehicle, etc.

Surface condition is also seen to play a role in producing non-fatal, guardrail accidents. Approximately 25 percent of all non-fatal, guardrail accidents on turned-down ends are associated with wet, icy, snowy or muddy pavements. For non-fatal, guardrail accidents off turned-down ends, the corresponding figure is approximately 30 percent. (Figure 9)

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[4]"Manner of collision" as defined by DPS is referenced to the "first harmful event" in an accident. Thus, if a vehicle veers off the highway, strikes a guardrail and then proceeds to collide with six additional motorvehicles, that accident is coded as a "single MV going straight." If one vehicle sideswipes another while both vehicles are traveling in the same direction, and if the second vehicle then yaws out of control and strikes a guardrail, that accident is coded: same dir, straight, sideswipe.

Note that 116 (19 percent) of the non-fatal, guardrail accidents that did not involve a turned-down end occurred after a previous collision with another motorvehicle. For the accidents involving turned-down guardrail ends, only 2 (1 percent) occurred after a previous motorvehicle collision.

Table 5: Manner of Collision by Point of Impact for Non-Fatal Guardrail Accidents

| | POINT OF IMPACT | | | |
|---|---|---|---|---|
| | TURN DOWN | | NOT TURN DOWN | |
| MANNER OF COLLISION | FREQ | PERCENT | FREQ | PERCENT |
| SINGLE MV GOING STRAIGHT | 127 | 83.55 | 458 | 75.83 |
| SINGLE MV TURNING RIGHT | 17 | 11.18 | 21 | 3.48 |
| SINGLE MV TURNING LEFT | 6 | 3.95 | 8 | 1.32 |
| SINGLE MV BACKING | . | . | 1 | 0.17 |
| ANGLE COLL, BOTH STRAIGHT | . | . | 7 | 1.16 |
| ANGLE COLL, 1 STR, 2 R-TURN | . | . | 5 | 0.83 |
| ANGLE COLL, 1 STR, 2 L-TURN | 1 | 0.66 | 2 | 0.33 |
| SAME DIR, STRAIGHT, REAREND | 1 | 0.66 | 36 | 5.96 |
| SAME DIR, STRAIGHT, SIDESWIPE | . | . | 47 | 7.78 |
| SAME DIR, 1 STRAIGHT, 2 STOP | . | . | 8 | 1.32 |
| SAME DIR, 1 STRAIGHT, 2 R-TURN | . | . | 1 | 0.17 |
| SAME DIR, 1 STRAIGHT, 2 L-TURN | . | . | 2 | 0.33 |
| SAME DIR, BOTH R-TURN | . | . | 1 | 0.17 |
| SAME DIR, 1 R-TURN, 2 L-TURN | . | . | 1 | 0.17 |
| OPP DIR, BOTH STRAIGHT. | . | . | 4 | 0.66 |
| OPP DIR, 1 STRAIGHT, 2 L-TURN | . | . | 1 | 0.17 |
| OPP DIR, 1 BACK, 2 STOP | . | . | 1 | 0.17 |
| TOTAL | 152 | 100.00 | 604 | 100.00 |

Table 6: Accident Factors by Point of Impact for Non-Fatal Guardrail Accidents

| ACCIDENT FACTOR | POINT OF CONTACT | | | |
|---|---|---|---|---|
| | END OF RAIL | | NOT END OF RAIL | |
| | FREQ | PERCENT | FREQ | PERCENT |
| NO CODE APPLICABLE | 105 | 69.08 | 354 | 58.61 |
| LOST CONTROL OR SKIDDED | 7 | 4.61 | 42 | 6.95 |
| PASSENGER INTERFERENCE | . | . | 3 | 0.50 |
| ATTENTION DIVERTED | 15 | 9.87 | 21 | 3.48 |
| GUSTY WINDS | . | . | 2 | 0.33 |
| VEHICLE PASSING ON LEFT | 1 | 0.66 | 1 | 0.17 |
| VEHICLE CHANGING LANES | . | . | 32 | 5.30 |
| VEHICLE ENTERING DRIVEWAY | . | . | 1 | 0.17 |
| VISION, SUNLIGHT OR GLARE | 1 | 0.66 | 1 | 0.17 |
| VISION, OTHER OBSTRUCTION | 1 | 0.66 | 2 | 0.33 |
| SWERVE, NOT SPECIFIED | 2 | 1.32 | 10 | 1.66 |
| SWERVE, AVOIDING ANIMAL | 2 | 1.32 | 6 | 0.99 |
| SWERVE, AVOIDING OBJECT | . | . | 5 | 0.83 |
| SWERVE, SLOW OR STOP MV | . | . | 11 | 1.82 |
| SWERVE, MV ENTERING ROAD | 1 | 0.66 | 3 | 0.50 |
| SWERVE, MV IN WRONG LANE | . | . | 2 | 0.33 |
| SWERVE, PREVIOUS ACCIDENT | . | . | 1 | 0.17 |
| SWERVE, MV CHANGING LANES | 2 | 1.32 | 36 | 5.96 |
| SLOW, REASON NOT SPECIFIED | . | . | 6 | 0.99 |
| SLOW, TRAFFIC CONTROL | . | . | 2 | 0.33 |
| SLOW, SLOW OR STOPPED MV | . | . | 18 | 2.98 |
| SLOW, MV ENTERING ROAD | . | . | 1 | 0.17 |
| SLOW, TO TURN RIGHT | . | . | 2 | 0.33 |
| SLOW, TO TURN LEFT | . | . | 3 | 0.50 |
| SCHOOL BUS | . | . | 1 | 0.17 |
| HIGHWAY CONSTRUCTION-UNRELATED | 12 | 7.89 | 32 | 5.30 |
| HIGHWAY CONSTRUCTION-RELATED | 3 | 1.97 | 6 | 0.99 |
| TOTAL | 152 | 100.00 | 604 | 100.00 |

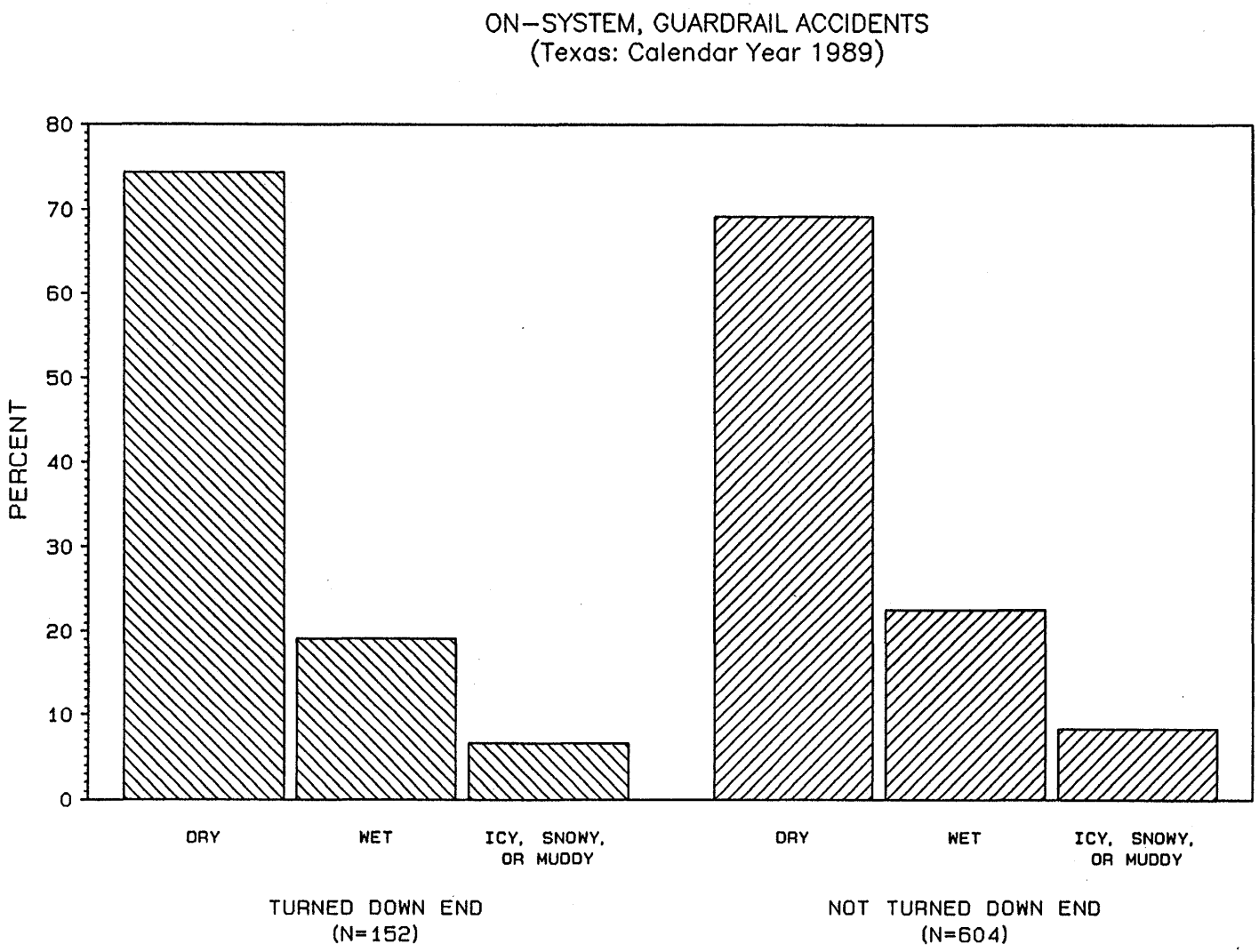


Figure 9: NON–FATAL, GUARDRAIL ACCIDENTS (N=756) BY ROAD CONDITION AND POINT OF IMPACT

Who was Involved in These Accidents and What Kinds of Vehicles were They Driving?[5]

The association between driver age and point of impact on a guardrail (on the turned-down end versus not on the turned down end) is weak. For example, 38 percent of all drivers striking turned-down guardrail ends are less than 25 years of age. The corresponding number for drivers striking guardrails at some point other than the turned down end is 32 percent.[6] (Figure 10)

One in five drivers striking a turned-down guardrail end was found to be fatigued or asleep. For drivers striking guardrails at points off the turned-down end, one in 12 was found to be fatigued or asleep. (Figure 11)

Speeding was involved in over 40 percent of all guardrail accidents recorded, regardless of whether the point of impact was on the turned-down end, or off the turned-down end. Speeding "over the posted limit" was cited only one fourth to one third as often as traveling at a speed that was unsafe for the prevailing conditions (e.g., rain, ice, etc.). (Figure 12)

Driving while intoxicated was cited for one in four drivers striking a turned down guardrail end; for drivers striking a guardrail off the turned-down end, the ratio was one to five. (Figure 13)

Slightly more than 60 percent of all vehicles involved in single-vehicle guardrail accidents are passenger cars. This statement is true for impacts on turned-down ends and off turned-down ends. However, for those passenger cars that strike a turned-down end, 39 percent overturn. For those passenger cars that strike the guardrail away from the turned-down end, only eight percent overturn.[7] (Figure 14)

**Further Analyses of Fatal Guardrail Accidents on Turned-Down Ends**

The 78 fatal guardrail accidents reviewed in this section consist of 32 accidents on turned-down ends and 46 that are not on turned-down ends. Because of the relatively small sample sizes available for analysis, percentage breakouts by variables with multiple levels (say, five or more levels) are too noisy to yield meaningful information. The relative percentages of 32 fatal guardrail ac-

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[5]The 608 drivers and vehicles discussed in this section were involved in single vehicle accidents, i.e., accidents for which driver/vehicle information was available on only one vehicle. By restricting the analyses in this section to single vehicle accidents, the drivers/vehicles discussed were necessarily (and directly) involved in a collision with a guardrail.

For a summary of all 938 drivers/vehicles involved in non-fatal guardrail accidents, including those drivers/vehicles involved in multivehicle accidents, see Table A2 in the appendix.

[6]Ages were not available for 30 drivers.

[7]For four single vehicle, non-fatal guardrail accidents, vehicle overturn was undetermined.

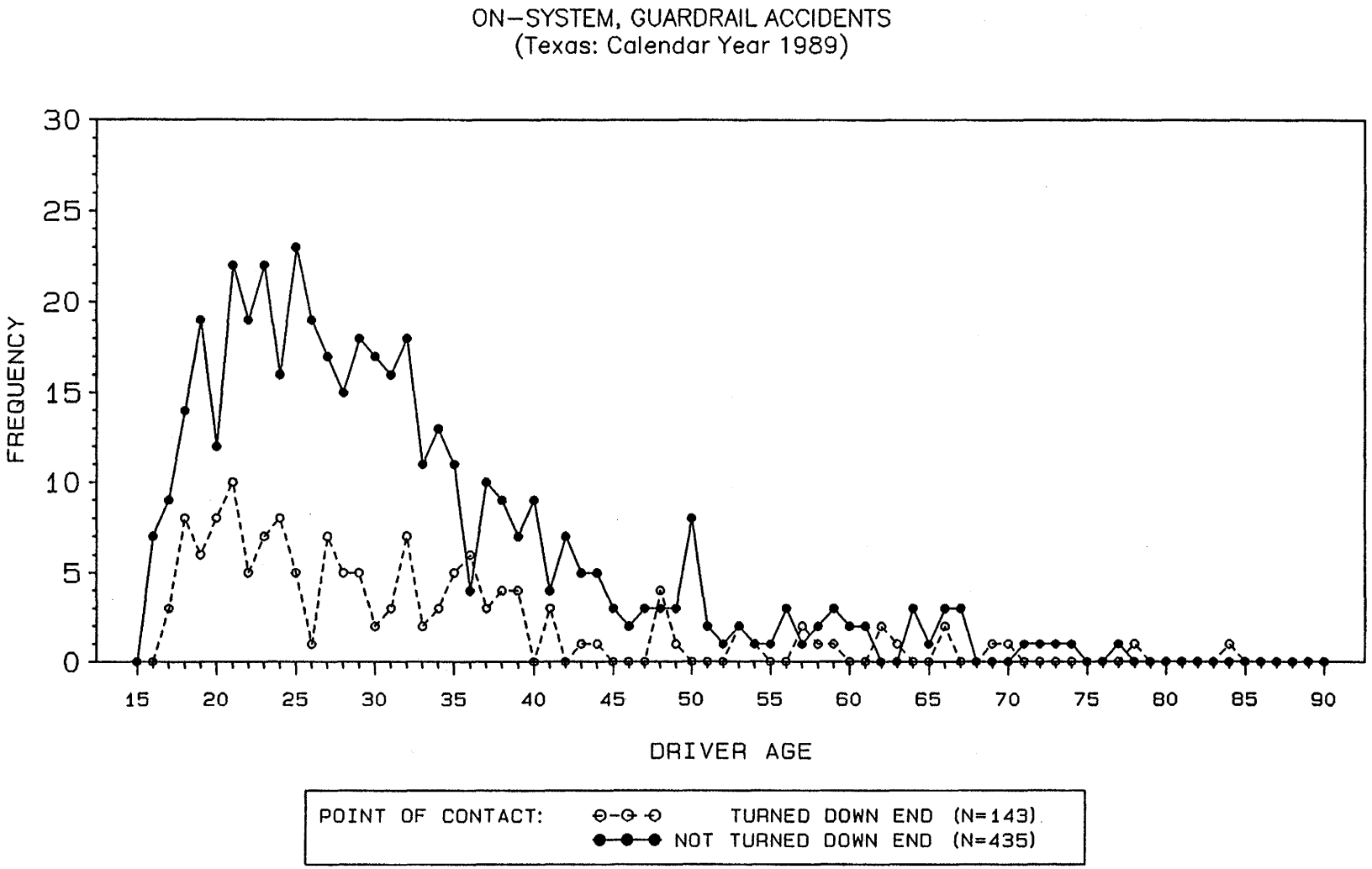


Figure 10: SINGLE VEHICLE, NON–FATAL, GUARDRAIL ACCIDENTS (N=578)
BY DRIVER AGE AND POINT OF IMPACT

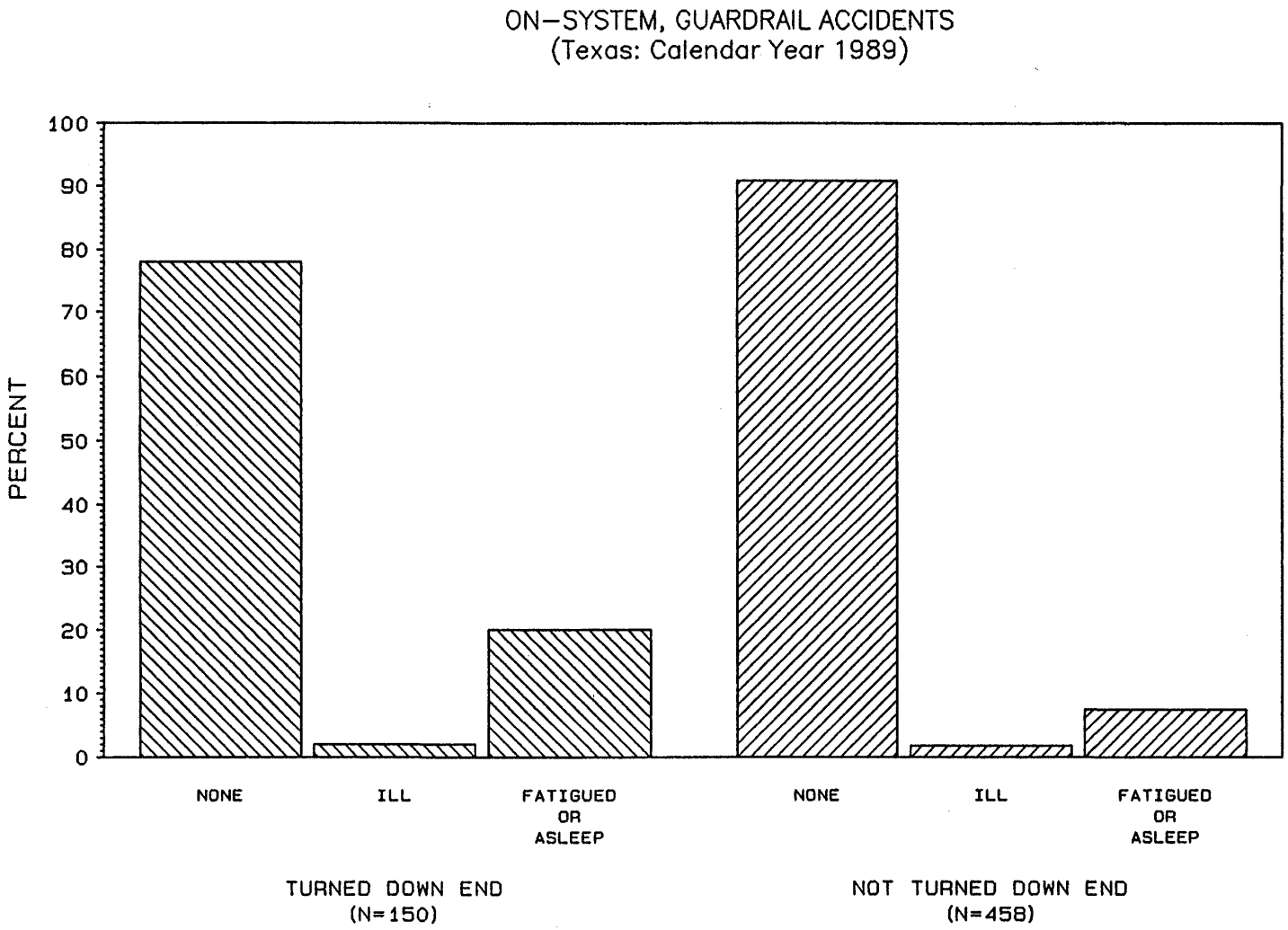


Figure 11: SINGLE VEHICLE, NON–FATAL, GUARDRAIL ACCIDENTS (N=608)
BY DRIVER DEFECT AND POINT OF IMPACT

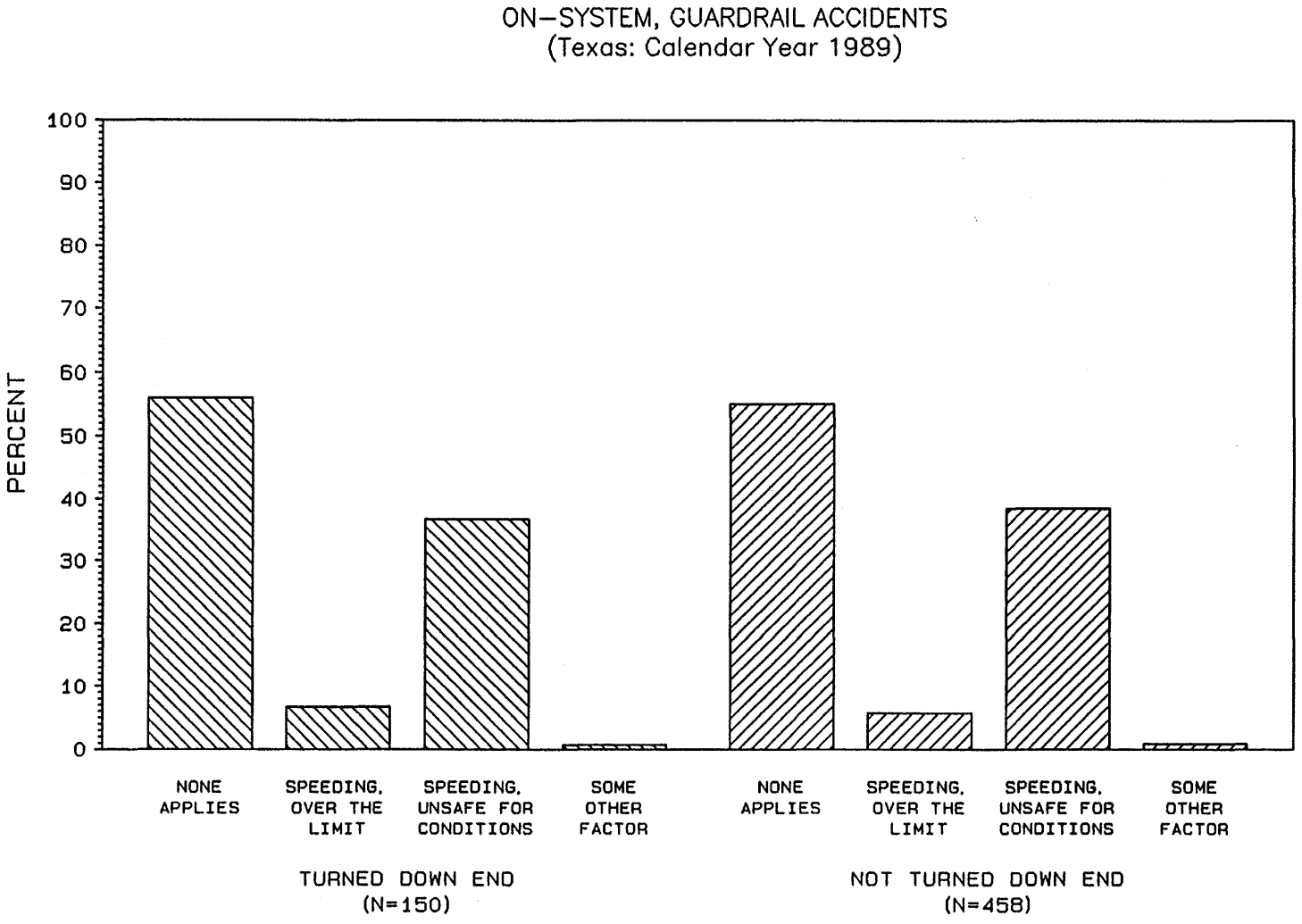


Figure 12: SINGLE VEHICLE, NON–FATAL, GUARDRAIL ACCIDENTS (N=608)
BY CONTRIBUTING FACTOR (1) AND POINT OF IMPACT

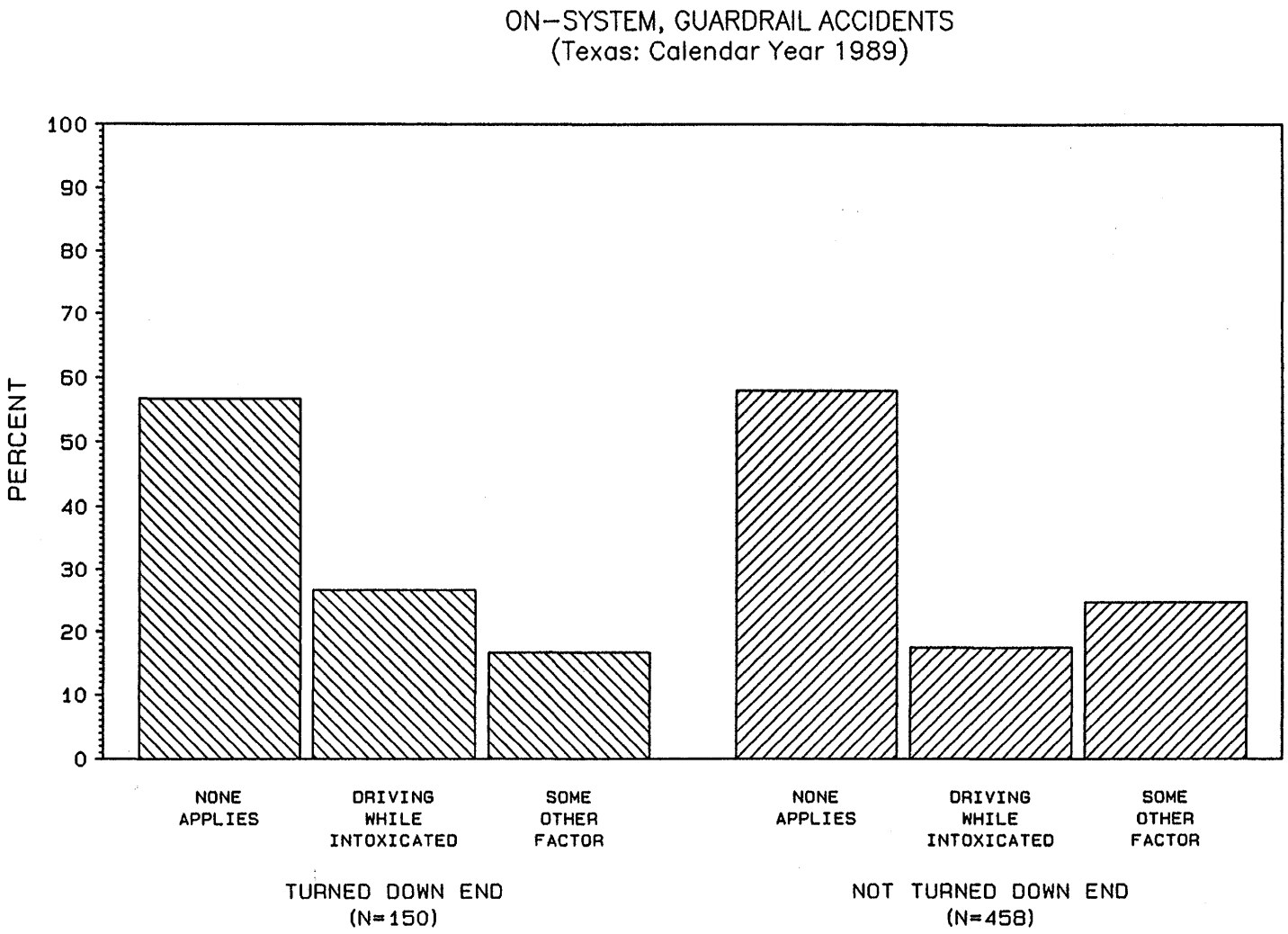


Figure 13: SINGLE VEHICLE, NON-FATAL, GUARDRAIL ACCIDENTS (N=608)
BY CONTRIBUTING FACTOR (2) AND POINT OF IMPACT

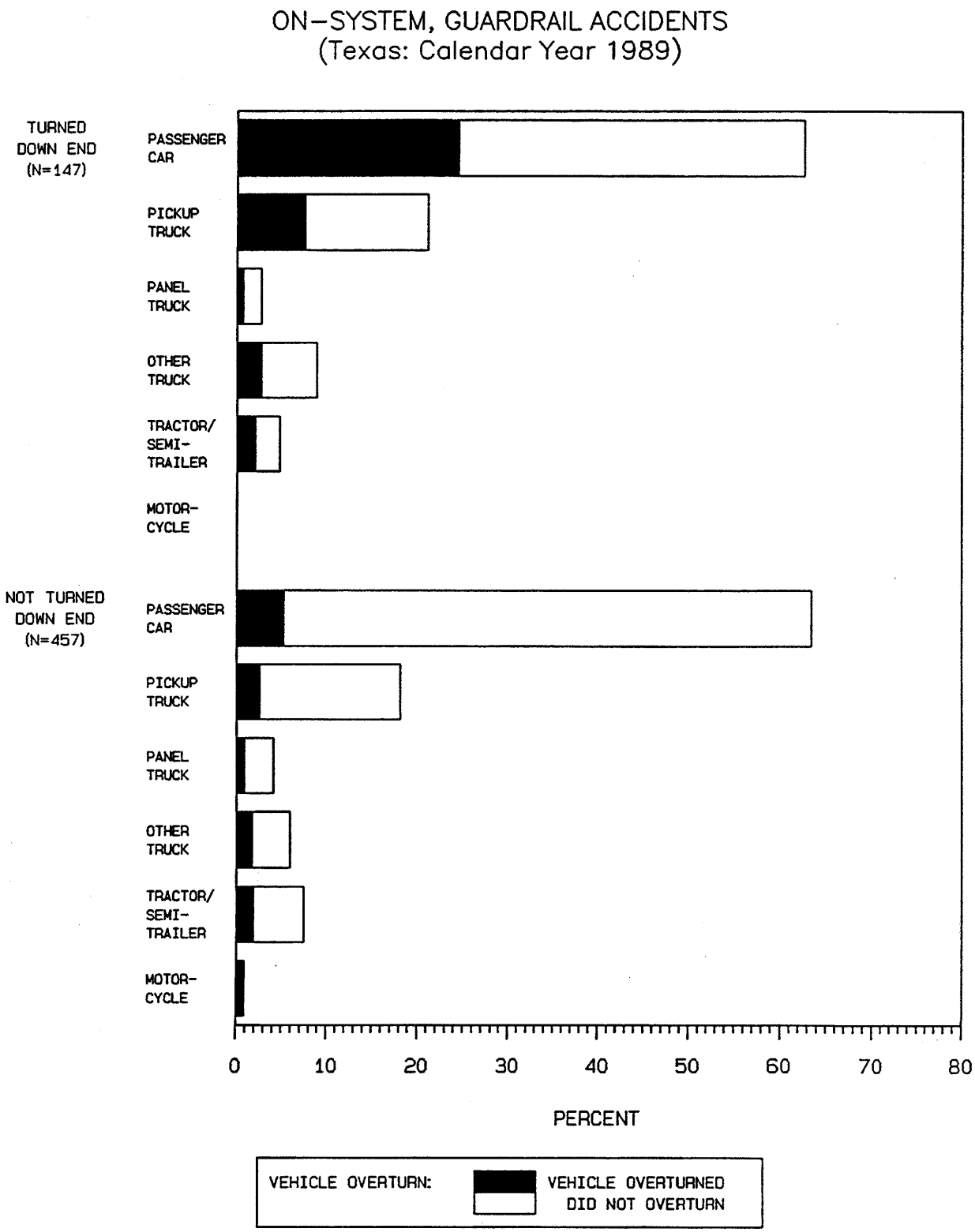


Figure 14: SINGLE VEHICLE, NON-FATAL, GUARDRAIL ACCIDENTS (N=604) BY VEHICLE TYPE, OVERTURN AND POINT OF IMPACT

cidents distributed among 12 different monthly categories or among seven different daily categories, for example, are difficult to interpret, and potentially misleading. Such figures will not be presented.

The figures that are presented in this section (based upon fatal accidents) are more interesting, and more striking when compared to similar figures in the previous section (based upon non-fatal accidents).

Where did these accidents occur?

Twenty-two (69 percent) of 32 fatal guardrail accidents on turned-down ends occurred in rural areas. For non-fatal accidents, the corresponding figure is 37 percent. (Figure 15)

Fourteen fatal accidents on turned-down guardrail ends occurred on Interstates and another 14 occurred on a US or State Highway. The balance (4) occurred on Farm-to-Market Roads. (Figure 16)

Fatal guardrail accidents (on turned-down ends and off turned down ends) are associated with lower traffic volumes than non-fatal accidents. This phenomenon is demonstrated by the more rapid rise of the cumulative percentage curves shown in Figure 17 than in Figure 4.[8]

When did these accidents occur?

Fifteen (47 percent) of 32 fatal accidents on turned-down ends occurred during hours of darkness on unlighted highways. Another five occurred during hours of darkness on lighted highways. (Figure 18)

Why did these accidents occur?

Table 7 indicates that in 94 percent of the fatal guardrail accidents on turned-down ends, the first harmful event is a collision with a guardrail by a single motorvehicle going straight. For fatal guardrail accidents that do not involve turned-down ends, the impact with the rail follows a prior collision with another motorvehicle in 28 percent of the cases. It is quite conceivable that some of the fatalities in these accidents were produced by the collision (between vehicles) that preceded the impact with the guardrail.

In only two (6 percent) of the 32 fatal, guardrail accidents is an accident factor offered by the investigating officer. The corresponding figure for accidents that are not on the turned-down end is 30 percent. (Table 8)

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[8]The data upon which Figure 17 is based are provided in Table A3 in the appendix.

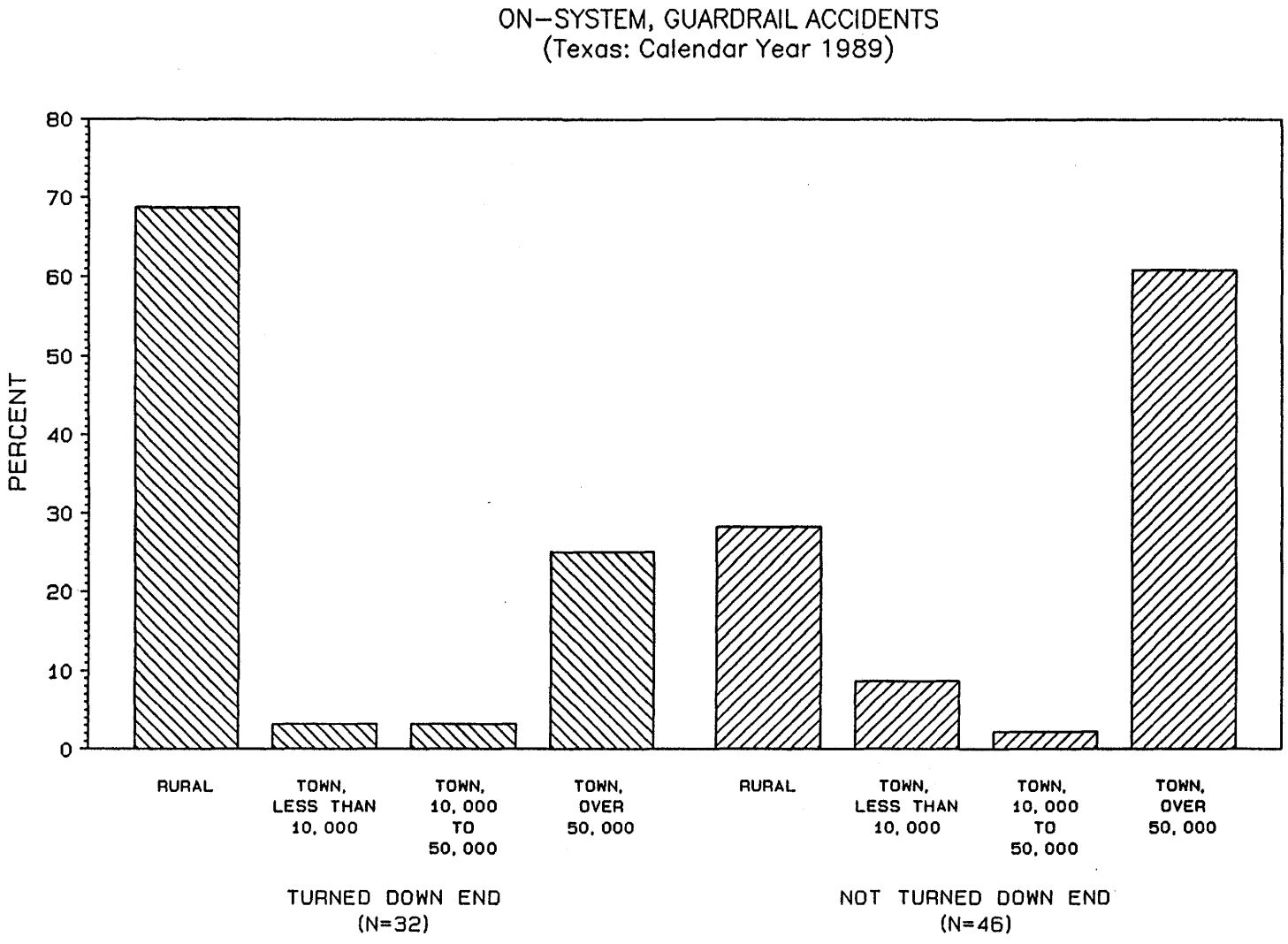


Figure 15: FATAL, GUARDRAIL ACCIDENTS (N=78) BY POPULATION AND POINT OF IMPACT

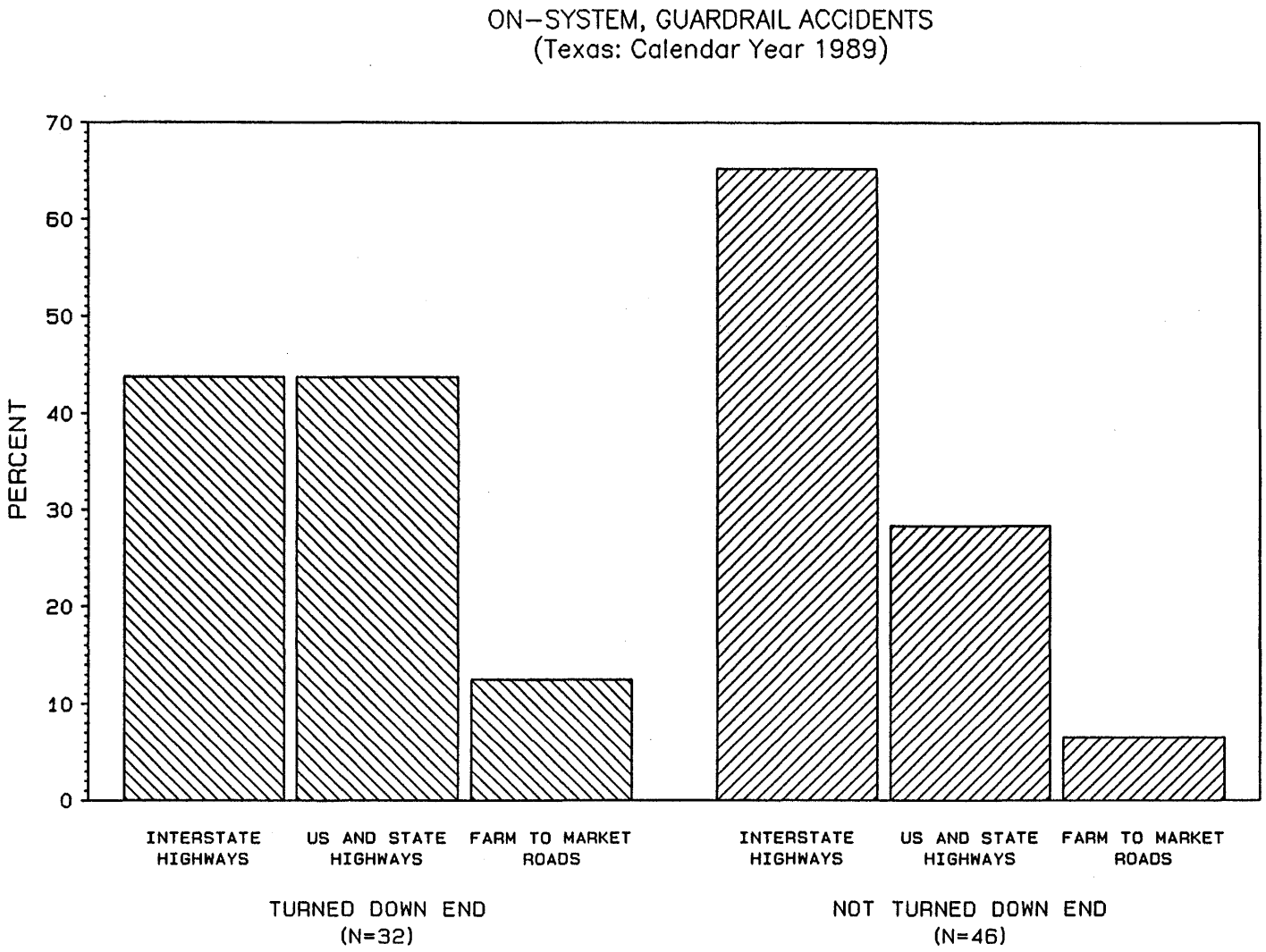


Figure 16: FATAL, GUARDRAIL ACCIDENTS (N=78) BY HIGHWAY TYPE AND POINT OF IMPACT

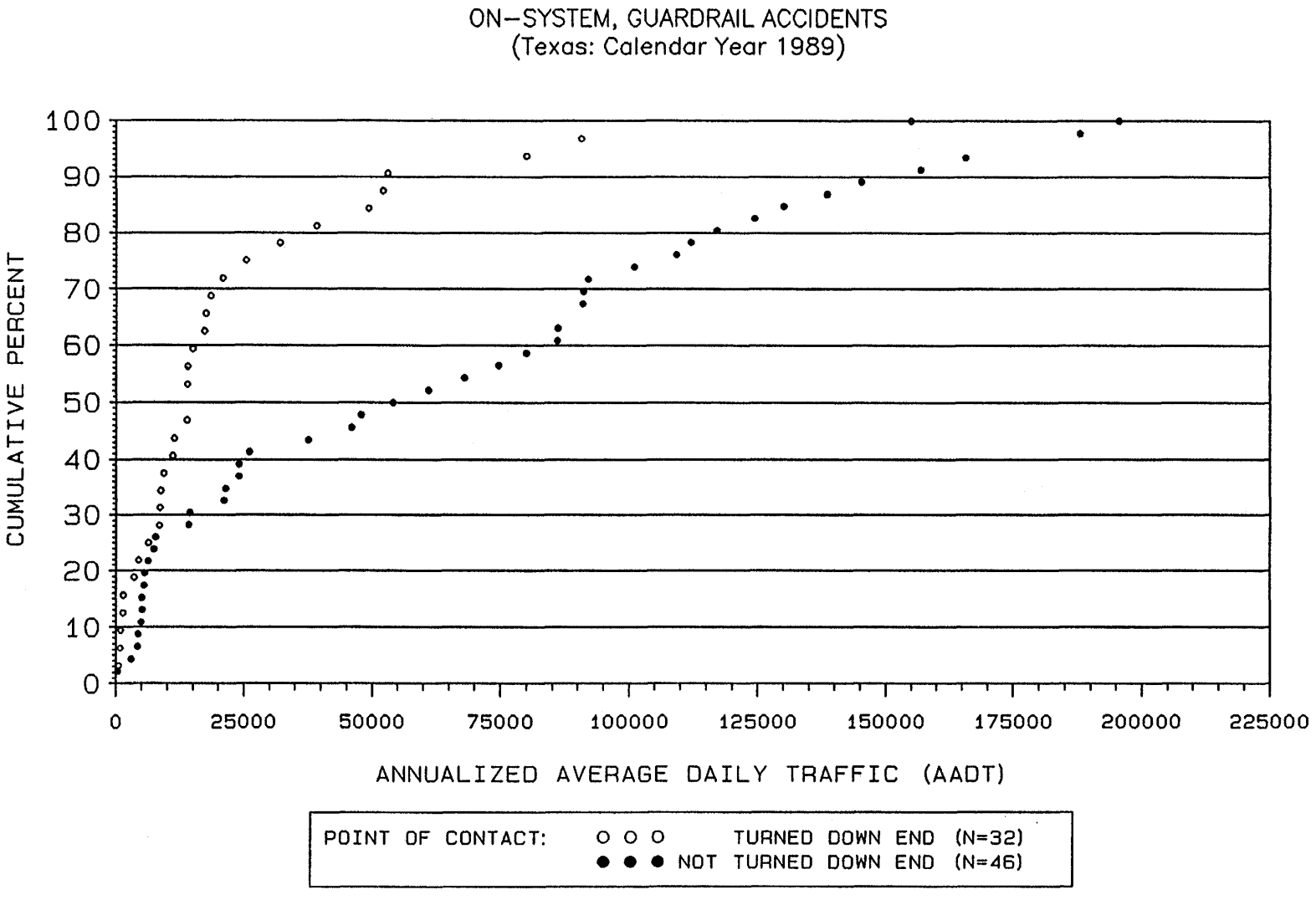


Figure 17: FATAL, GUARDRAIL ACCIDENTS (N=78) BY AADT AND POINT OF IMPACT

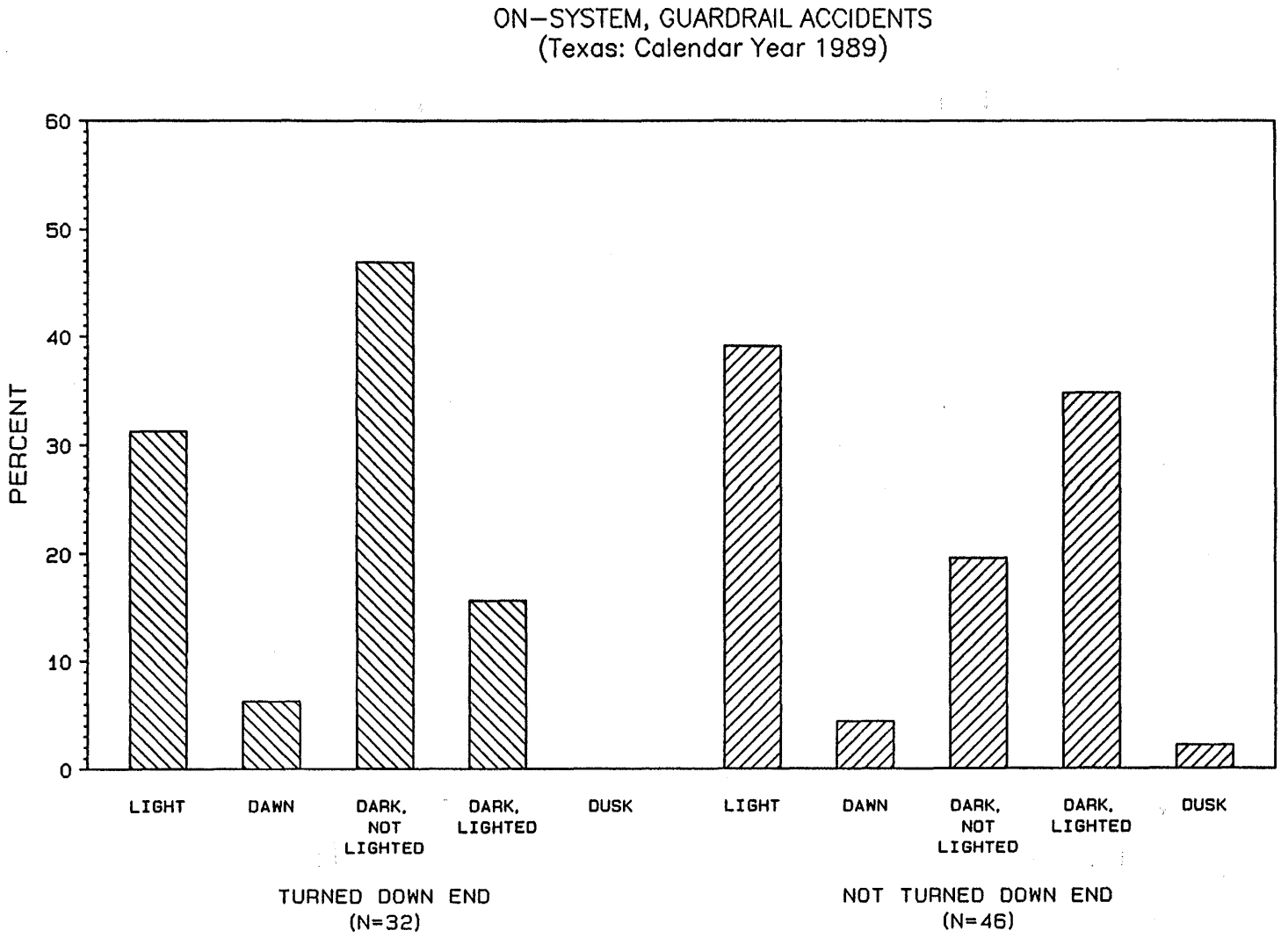


Figure 18: FATAL, GUARDRAIL ACCIDENTS (N=78) BY LIGHT CONDITION AND POINT OF IMPACT

Table 7: Manner of Collision by Point of Impact for Fatal Guardrail Accidents

| MANNER OF COLLISION | POINT OF IMPACT | | | |
|---|---|---|---|---|
| | TURN DOWN | | NOT TURN DOWN | |
| | FREQ | PERCENT | FREQ | PERCENT |
| SINGLE MV GOING STRAIGHT | 30 | 93.75 | 32 | 69.57 |
| SINGLE MV TURNING RIGHT | . | . | 1 | 2.17 |
| SINGLE MV TURNING LEFT | 1 | 3.12 | . | . |
| ANGLE COLL, 1 STR, 2 R-TURN | . | . | 1 | 2.17 |
| SAME DIR, STRAIGHT, REAREND | . | . | 5 | 10.87 |
| SAME DIR, STRAIGHT, SIDESWIPE | 1 | 3.12 | 3 | 6.52 |
| SAME DIR, 1 STRAIGHT, 2 STOP | . | . | 2 | 4.35 |
| OPP DIR, BOTH STRAIGHT. | . | . | 2 | 4.35 |
| TOTAL | 32 | 100.00 | 46 | 100.00 |

Table 8: Accident Factors by Point of Impact for Fatal Guardrail Accidents

| ACCIDENT FACTOR | POINT OF IMPACT | | | |
|---|---|---|---|---|
| | TURN DOWN | | NOT TURN DOWN | |
| | FREQ | PERCENT | FREQ | PERCENT |
| NO CODE APPLICABLE | 30 | 93.75 | 39 | 84.78 |
| VEHICLE PASSING ON RIGHT | . | . | 1 | 2.17 |
| VEHICLE CHANGING LANES | 1 | 3.12 | 2 | 4.35 |
| VEHICLE IMPROPERLY PARKED | . | . | 2 | 4.35 |
| SLOW, REASON NOT SPECIFIED | . | . | 1 | 2.17 |
| HIGHWAY CONSTRUCTION-UNRELATED | 1 | 3.12 | 1 | 2.17 |
| TOTAL | 32 | 100.00 | 46 | 100.00 |

None of the fatal guardrail accidents observed in this study occurred on icy, snowy or muddy surface. Indeed, 30 of 32 fatal guardrail accidents on turned-down ends were on dry pavement. (Figure 19)

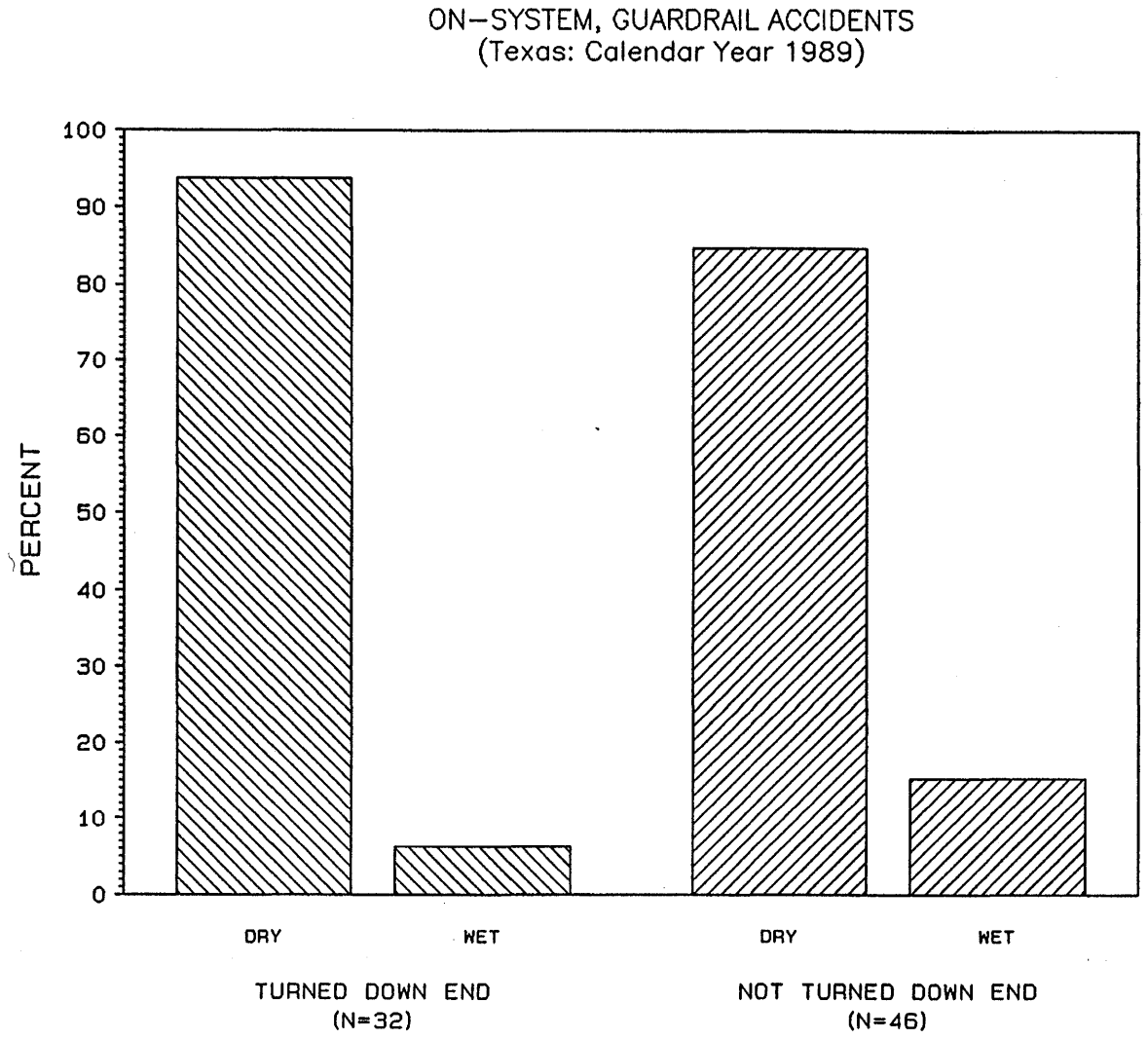


Figure 19: FATAL, GUARDRAIL ACCIDENTS (N=78) BY ROAD CONDITION AND POINT OF IMPACT

Who was Involved in These Accidents and What Kinds of Vehicles were They Driving?[9]

Fifteen (48 percent) of 31 drivers involved in fatal, single vehicle collision with turned-down guardrail ends were reported to have been fatigued or asleep. The corresponding figure for non-fatal, single vehicle collisions with turned-down guardrail ends was approximately 20 percent. (Figure 20)

Speeding (unsafe for conditions or in excess of the posted limit) was cited as a contributing factor to the accidents of 16 of 31 drivers involved in fatal, single vehicle collisions with turned-down guardrail ends. (Figure 21)

Nineteen (61 percent) of 31 drivers involved in fatal, single vehicle collisions with turned-down guardrail ends were reported to have been driving while intoxicated. (Figure 22)

Eighteen (58 percent) of all vehicles involved in fatal, single vehicle guardrail accidents on turned-down ends are passenger cars. Of the 18 accident-involved passenger cars, 14 (78 percent) overturned. (Figure 23)

**Fatalities Recorded in Guardrail Accidents**

In the final table contained in this report (Table 9), the details on 39 fatalities recorded in 32 accidents on turned-down guardrail ends (and 49 fatalities recorded in 46 accidents on guardrails at a point of impact away from turned-down ends) are depicted.

Three points are worth noting in Table 9.

(1) There is a high ejection rate for individuals killed in guardrail accidents: 16 fatally-injured driver/occupants were ejected in collisions with turned-down guardrail ends; 18 fatally-injured driver/occupants were ejected in guardrail collisions that did not involve turned-down ends.

(2) Seven of the 49 fatalities on guardrails (away from turned-down ends) were motorcycle operators, one was a pedestrian, and one was sitting in a parked car. For these nine fatalities the design of the guardrail was, apparently, of little consequence.

(3) Because 28 percent of all fatal guardrail accidents (away from turned-down ends) are preceded by a collision with another vehicle (Table 6), it seems reasonable to expect some of the other 40 fatalities involved in these accidents were incurred before the guardrail was contacted and are, therefore, unrelated to the design of the rail.

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[9]The 62 drivers and vehicles discussed in this section were involved in single vehicle accidents, i.e., accidents for which driver/vehicle information was available on only one vehicle.

For a summary of all 101 drivers/vehicles involved in fatal guardrail accidents, including those drivers/vehicles involved in multivehicle accidents, see Table A4 in the appendix.

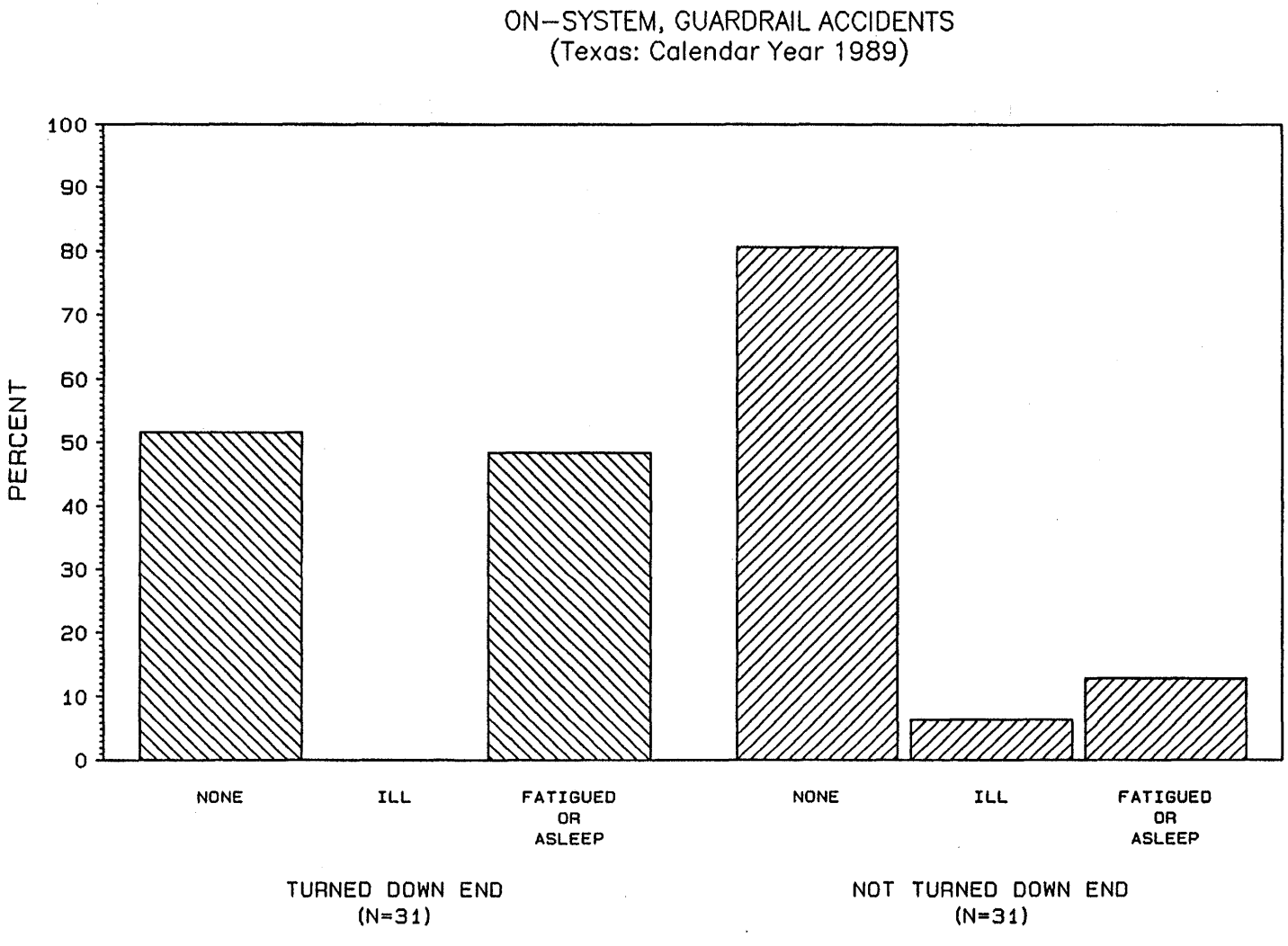


Figure 20: SINGLE VEHICLE, FATAL, GUARDRAIL ACCIDENTS (N=62)
BY DRIVER DEFECTS AND POINT OF IMPACT

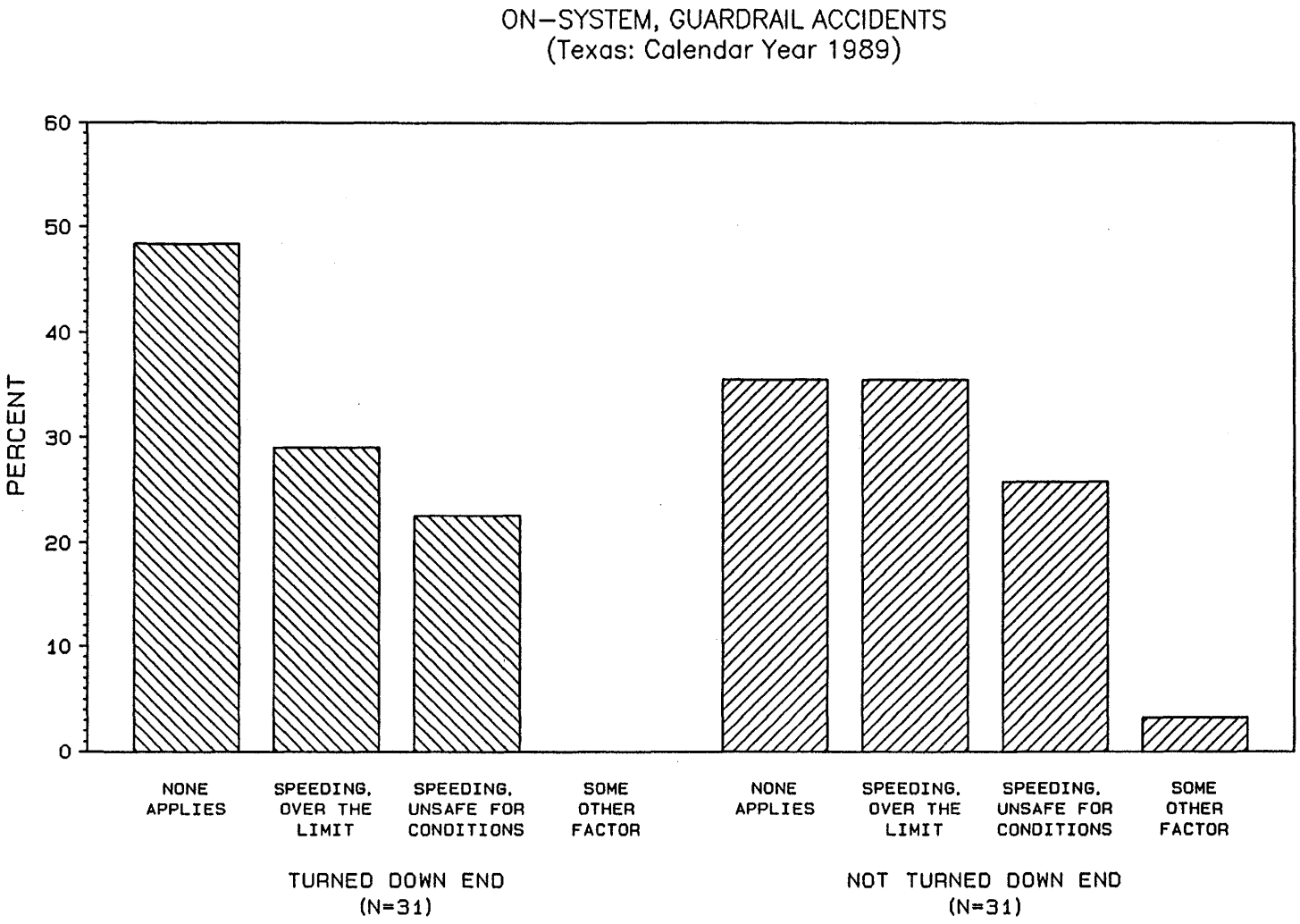


Figure 21: SINGLE VEHICLE, FATAL, GUARDRAIL ACCIDENTS (N=62)
BY CONTRIBUTING FACTOR (1) AND POINT OF IMPACT

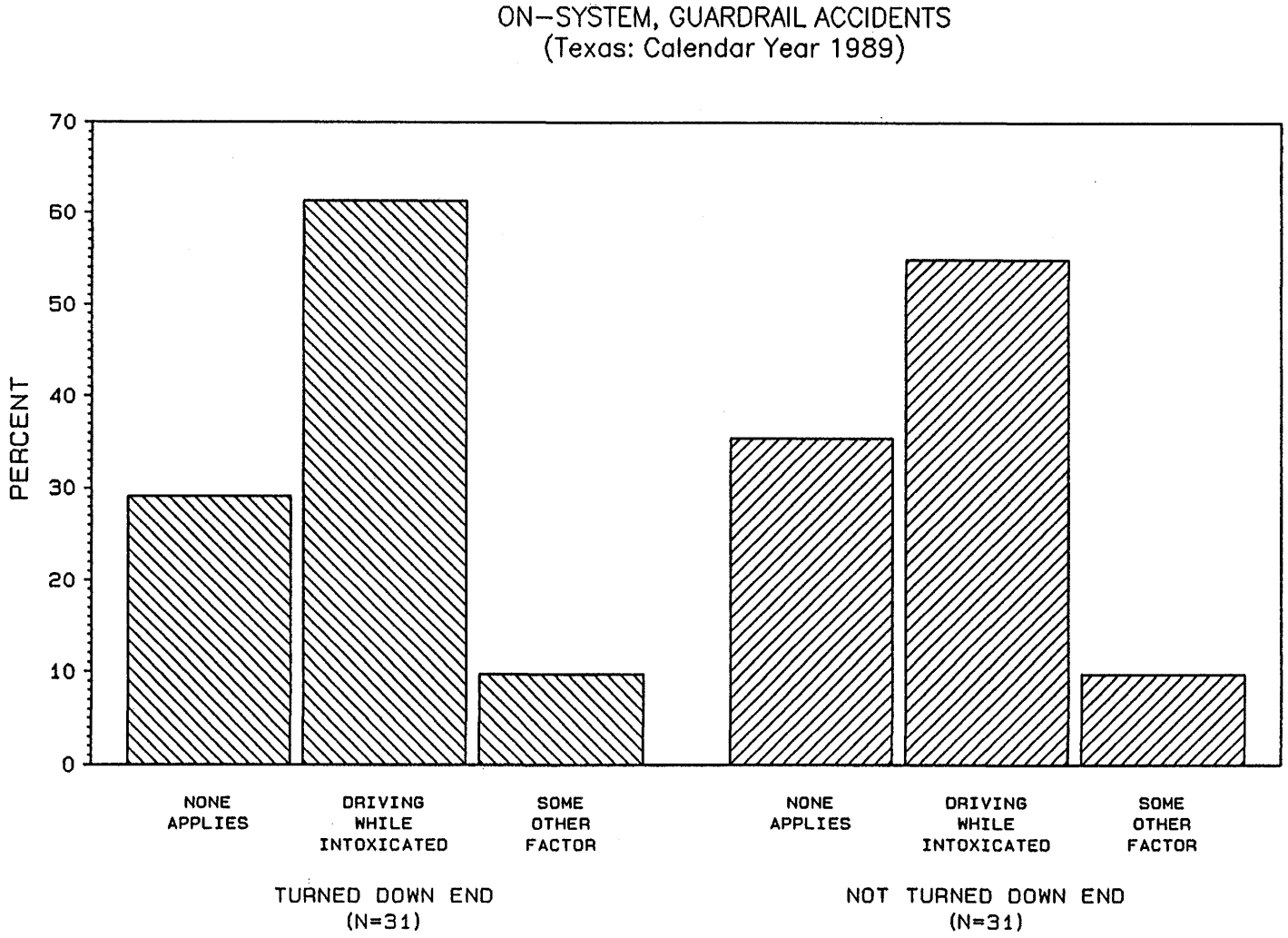


Figure 22: SINGLE VEHICLE, FATAL, GUARDRAIL ACCIDENTS (N=62)
BY CONTRIBUTING FACTOR (2) AND POINT OF IMPACT

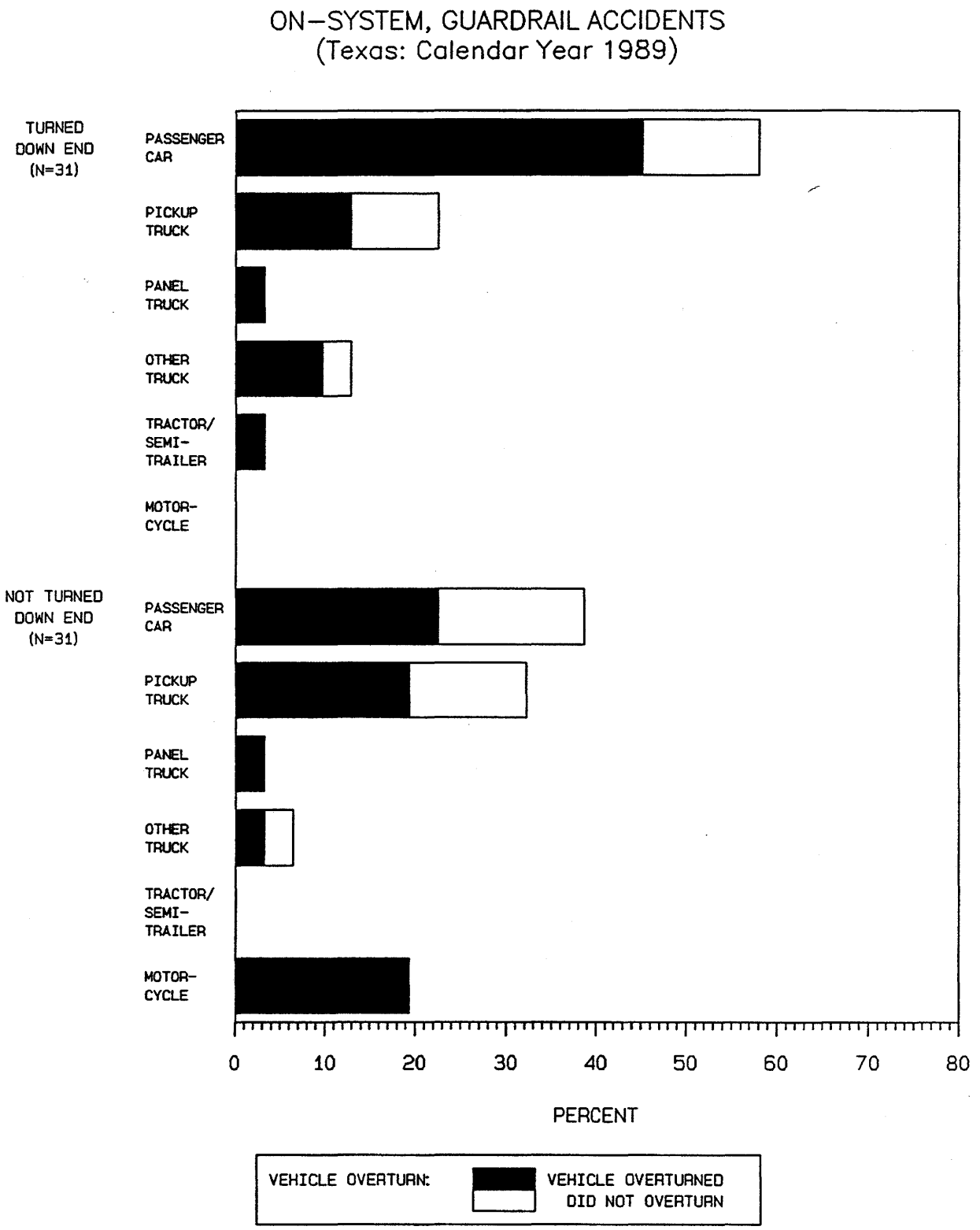


Figure 23: SINGLE VEHICLE, FATAL, GUARDRAIL ACCIDENTS (N=62)
BY VEHICLE TYPE, OVERTURN AND POINT OF IMPACT

Table 9(a): Details on 39 Fatalities Recorded in 32 Fatal Accidents Involving Turned-Down Guardrail Ends

| | Drivers | | | Vehicle Occupants | | |
|---|---|---|---|---|---|---|
| Vehicle Type | Ejected | Not Ejected | Unk/NA | Ejected | Not Ejected | Unk/NA |
| Passenger Car | 4 | 11 | 1 | 5 | 3 | 1 |
| Pickup Truck | 1 | 3 | - | 3 | - | - |
| Panel Truck | - | 1 | - | - | - | - |
| Other Truck | 2 | 1 | - | - | 2 | - |
| Tractor/Semi | 1 | - | - | - | - | - |
| Motorcycle | - | - | - | - | - | - |
| | 8 | 16 | 1 | 8 | 5 | 1 |

Table 9(b): Details on 49 Fatalities Recorded in 46 Fatal Accidents Not Involving Turned-Down Guardrail Ends

| | Drivers | | | Vehicle Occupants | | |
|---|---|---|---|---|---|---|
| Vehicle Type | Ejected | Not Ejected | Unk/NA | Ejected | Not Ejected | Unk/NA |
| Passenger Car | 6 | 11 | - | - | 6 | - |
| Pickup Truck | 7 | 2 | 1 | 1 | 1 | - |
| Panel Truck | 1 | - | - | - | - | - |
| Other Truck | 3 | - | - | - | - | - |
| Tractor/Semi | - | 1 | - | - | - | - |
| Motorcycle | - | - | 7 | - | - | - |
| | 17 | 14 | 8 | 1 | 7 | - |

In addition to the 47 fatalities shown above, one (1) pedestrian was killed in these 46 accidents and one (1) individual sitting in the driver's seat of a parked car was also killed. (Note: When a parked car is struck by a motorvehicle in transit, that accident is characterized as a single vehicle accident – vehicle information is collected only on the striking vehicle.)

## CONCLUSION

On the basis of the analyses carried out in this study, it appears that accidents on turned-down guardrail ends are a significant safety problem. It is estimated that in a typical year (e.g., 1989) some 736 accidents occur on turned-down guardrail ends on the Texas, state-maintained highway system. In these 736 accidents, it is estimated that 278 vehicles overturn. It is further estimated that 43 individuals are killed and another 85 sustain incapacitating (A-Level) injuries in these accidents.

Granted that a significant number of accidents occur on turned-down guardrail ends – and granted that an unsatisfactory number of vehicle overturns, deaths and serious injuries are associated with these accidents – it should also be understood that the degree to which vehicle overturns and driver/occupant deaths and injuries could be reduced by replacing turned-down guardrail ends with other end treatments (e.g., breakaway cable terminals) is unknown. The analyses contained in this report suggest that accidents (particularly fatal accidents) on turned-down guardrail ends tend to be associated with high speeds, drunk driving, darkness, sleeping/fatigued drivers etc. How effective any guardrail end treatment will be in averting vehicle overturn and driver/occupant death and injury, given these antecedent factors, is deserving of further study and evaluation.

## REFERENCE

Griffin, L.I. Estimating the Effectiveness of Occupant Protection Safety Devices from State Accident Data. Conference on the Collection and Analysis of State Highway Safety Data, San Diego, CA, March 1990.

# APPENDIX

(Bound Separately)