COMPARISON OF MICHIGAN FATAL AND NON-FATAL CAR-INTO-TRUCK ACCIDENTS

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by

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16. Abstract

The objective of the study was to determine how non-fatal car-into-truck accidents differ from fatal car-into-truck accidents. A random sample of 100 Michigan non-fatal car-into-truck accidents for 1976, filtered to include only passenger car rear-end of side impacts on a large truck or tractor-trailer, was drawn for comparison with the 94 fatal car-into-truck accidents in Michigan during 1972-1976 which were included in a prior study. The accident reports were examined and drivers and witnesses were interviewed by telephone in order to confirm accident configurations; whether car underride had occurred, and, if so, to what degree. For each case relative impact speeds were estimated. The chief finding was that in the non-fatal accidents, underride occurs much less frequently and when it does occur, it usually is of minor or moderate degree. Other findings: Whereas fatal crashes were mostly at night on straight rural roads, at relative impact speeds averaging 35 mph, non-fatal crashes were mostly in daytime, on urban roads and intersections, at relative impact speeds averaging 10 mph and often on trucks and trailers of a design that prevents underride. It was concluded that priority should be given to increasing conspicuity of trucks and trailers at night and that trailer design should adapt to configurations which impede underride.

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We particularly wish to cite the following for their professional assistance: Captain Paul J. Ruge, Commander, Traffic Services Division, Michigan State Police; Lieutenant Jack Warder, and Mrs. Connie L. Fitzgerald of that division.

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1. INTRODUCTION

Auto accidents in which a passenger car underrides[1] the overhanging bed of a truck or trailer continue to inspire a search for countermeasures which will allay the often fatal results of such crashes. The increasing popularity of small-size passenger cars as one way to overcome the fuel shortage crisis is one reason why the National Highway Traffic Safety Administration and others are taking a harder look at the problem and are considering some form of rules which would reduce the incidence of underrides.

A 1977 study published by the Highway Safety Research Institute covering fatal car-into-truck accidents[2] concluded that presently used anti-underride devices were of little value in the fatal accidents reviewed in the study, and that even improved devices, while they would reduce the incidence of underride, would not eliminate all of the fatalities in car-into-truck collisions. The study further suggested that, in view of the circumstances surrounding these fatal accidents, making trucks and trailers more conspicuous, especially at night, could potentially reduce the frequency of such accidents.

As a complement to the previous study, this study examines the characteristics of non-fatal car-into-truck accidents and compares them with the earlier results.

Such factors as accident frequency, vehicle types, relative impact speeds, crash configurations, car and truck drivers, roadway types, and environmental conditions, are again examined with the objective of learning how fatal and non-fatal car-into-truck accidents differ.

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[1] Underride, for the purposes of this study, occurs when, as a result of a collision with a truck or trailer, a portion of the passenger car passes under the edge of the truck or trailer bed.

[2] Car-Truck Fatal Accidents in Michigan and Texas, Daniel J. Minahan and James O'Day, Report No. UM-HSRI-77-49, 1977.

2. BACKGROUND

Prior to the 1977 study on fatal car-into-truck accidents, the two general sources of information about underride accidents were (1) the selected in-depth case studies sponsored by MVMA, NHTSA, and the Canadian Department of Transport; and (2) state and federal files of truck accident reports. Although the latter reports were reasonably thorough when they covered fatal accidents, they contained little detail regarding underride.

The aforementioned 1977 study started with the police accident reports of car-into-truck collisions for selected years within the states of Michigan and Texas. Because it was known that these reports would rarely specify whether underride had occurred, the authors arranged to procure, as supplemental data, any on-scene photographs taken during the investigation of the accident. Such photographs are routinely taken as part of Michigan fatal accident investigations, but were seldom available for the Texas investigations. The Texas accident report form did provide more detail in regard to vehicle damage. For both states, the accompanying death certificates often described the exact cause of death in enough detail to permit a conclusion to be drawn regarding underride.

By contrast, for non-fatal accident investigations all police reports are relatively meager in data, particularly when no injuries were incurred or when the involved vehicles can be driven from the accident site. On-scene photographs are almost never available.

In order to determine whether underride occurred in non-fatal car-into-truck collisions, the police accident reports must be supplemented, where possible, by the personal observations of vehicle occupants, witnesses, and investigating police.

3. METHODOLOGY AND SOURCES FOR THE STUDY

Data sources for this study consist of accident reports and telephone interviews with the involved car drivers, car passengers, and truck drivers, as well as witnesses to, Michigan car-into-truck accidents.

For each of several years now, HSRI has created a computerized annual file of all Michigan accidents in which a large truck was involved, as derived from the accident reports prepared by all Michigan police agencies. This truck accident file was searched for a random sample of non-fatal, two-vehicle, car-into-truck accidents for the year 1976. The year 1976 was chosen so that the data base and the accident report form would be consistent with the data base and the accident report form used in the aforementioned fatal car-into-truck study which included, in addition to Texas cases, 94 Michigan fatal cases for the five year period, 1972-1976.

Like in the prior study, the computer developed sample excluded crashes in which the truck was the striking vehicle as well as all head-on collisions. Presumably, by design of the file, small trucks, such as pick-ups, light delivery vans, motor homes, etc., would not appear in the sample. Copies of the original accident reports were reviewed and hand filtered to ensure the sample met the above criteria. The sample, when filtered of non relevant or erroneous reports, totaled about 168 cases.

Aided by the interview form shown in Appendix A, trained telephone interviewers contacted and questioned drivers, passengers, and witnesses.

In general, the telephone interview procedure went very smoothly. Calls were made when people normally would be at home and in a relaxed mood. Nearly all persons contacted were cooperative. Only a few (about 2%) refused to respond, suspicious that the interviewers were fronting for insurance, credit bureau, or police agencies. A major stumbling block was that many of the persons sought (about 14%) had unlisted telephone numbers or no longer lived at the address indicated on the accident report. Directory services partially resolved the problem. As

was anticipated, non residents of Michigan, especially truck drivers, were most difficult to locate. But the biggest reduction in the sample (about 24%) surfaced during interviews--the "truck" actually was a pick-up or van that had been incorrectly encoded on the accident report. Eventually the sample narrowed down to 100 usable cases.

The results of the telephone interviews and the information on the accident reports were entered on a data sheet, as shown in Appendix B.

As in the prior study, cases again were classified according to (1) side or rear collision, (2) whether underride had occurred (definitely yes,[3] probably yes, probably no, definitely no). For this study, underride was further delineated by extent or degree as none, minimal, moderate, severe, catastrophic. These degrees of underride will be defined later in the study.

The basic data used in the earlier fatal accident study was reviewed and entered on this same form to facilitate comparison. From these completed forms the data were entered into the computer for analysis.

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[3] "Definitely yes" and "definitely no" means that, judging by all the data reviewed, there was no doubt that underride did or did not occur. "Probably yes" and "probably no" means that, judging by all the data reviewed, underride seemed likely or unlikely, but that complete evidence was not available.

4. RESULTS

Data for this study came from the reports covering all fatal collisions in which a passenger car rear-ended or angle-impacted a large truck or tractor/trailer combination in Michigan during the period 1972-1976 and from 100 randomly selected non-fatal crashes of the same configuration in Michigan during 1976.

Table 1 divides these car-into-truck fatal and non-fatal collisions by type: (1) Car-into-truck (or tractor/trailer) from the rear; (2) Car-into-truck (or tractor/trailer) from the side. The total number of such accidents is compared for the fatal and non-fatal groups, showing the number of collisions which involved underride.

Table 1
Michigan Fatal vs. Non-Fatal Car-Into-Truck Crashes

Vehicle Type	Fatal 1972-1976		Non-Fatal 1976	
	All	Underride	All	Underride
Car Rear-ended Truck Trailer	48	41	51	22
Car Angled Truck/Trailer	46	30	49	11
Total	94	71	100	33

Whether underride had occurred in the fatal accidents was determined in the earlier study by careful review of on-scene photographs, injury descriptions on death certificates, and all pertinent details in the accident reports. However, for the non-fatal accidents, because no photographs or death certificates were available, the occurrence and degree of underride was determined by responses from the interviewees (car drivers, truck drivers, or witnesses) regarding what happened and what damage the passenger car incurred, together with a careful review of the accident report.

Table 1 groups together both "definite" and "probable" underrides Degree of underride will be considered later.

The most obvious finding in Table 1 is that, given about an equal number of fatal and non-fatal car-into-truck accidents, underride occurs less than half as often in non-fatal as in fatal accidents.

5. DISCUSSION

This section of the report covers in detail the distribution of the many factors that distinguish the 94 fatal and 100 non-fatal Michigan car-into-truck rear and side collisions. The objective is to accent their differences.

In order to parallel the discussion approach with the earlier study on fatal car-into-truck collisions, comments again are grouped according to the topics: who was involved in the accidents, what vehicles were involved, when did the accidents occur, where did the accidents occur, and how (or why) did the accidents occur.

Who

Passenger car drivers in the non-fatal accidents were aged 16 through 82, very similar to the 15 to 90 age spread among the fatal accidents, and likewise peaked at the lower age groups. Over half were 30 or under. However, a larger percentage of the non-fatal drivers (30% vs. 20%) were females. Again, in over half the cases the passenger car occupant was a lone male.

There was no observable difference in truck driver age among the fatal and non-fatal cases. Again, the age spread was relatively uniform from 20 to 55.

Whereas one-third of passenger car drivers in the fatal car-into-truck collisions had been drinking (consistent with reported drinking involvement in all Michigan fatal accidents), only about 10% of the drivers in the non-fatal crashes had been drinking, and none, apparently, to the extent that a breathalyzer test was deemed necessary.

Table 2 shows the distribution of injuries and fatalities to the occupants of cars and trucks in the 194 fatal and non-fatal accidents, according to the severest injury in each vehicle.

In 65 (65%) of the non-fatal crashes no one in the car was injured, whereas in every one of the fatal crashes a car occupant was killed or injured. (Three of the fatal crashes were so labeled because the truck driver was killed as a result of ejection or rollover in a severe side collision.) However, in non-fatal crashes, only five truck drivers out

Table 2
Fatality and Injury Occurrences
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Accidents	Severest Injury Passenger Car						Severest Injury Truck					
	K	A	B	C	O	Unk.	K	A	B	C	O	Unk.
1972-1976 Fatal (94 cases) . .	91	1	1	1	0	0	3	5	3	13	70	0
1976 Non-Fatal (100 cases) . .	0	8	12	14	65	1	0	0	2	3	95	0

of 100 incurred any injury, and those were of the B or C level, i.e.,. ninety-five percent received no injury.

What

Table 3 shows, by vehicle type, the numbers of trucks and tractor-trailers involved in the 194 fatal and non-fatal crashes reviewed in the study.

The trucks and tractor-trailers in Table 3 have been grouped under the broad headings--Standard and Specialized--some perhaps a bit arbitrarily. Note that a majority of the non-fatal crashes (62%) involved passenger car contact with trucks only or with specialized vehicles that, by inherent design, are relatively impervious to underride (tankers, furniture vans, step vans, car transporters, gravel haulers, etc.); whereas the majority of fatal crashes (63%) involved passenger car contact with semi-trailers of designs that are easy to underride. This observation will be discussed in detail later on.

Table 4 shows the passenger cars involved in the crashes, categorized according to the groupings indicated on police accident reports.

As Table 4 indicates, full size sedans predominate in both the fatal and non-fatal crashes. However, in the non-fatal crashes considerably fewer compacts and no sport cars or jeep types, but more

Table 3
Trucks/Tractor-Trailers Involved
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Vehicle Type	Fatal Accidents		Non-Fatal Accidents	
	Number	Percent	Number	Percent
Standard				
Straight Truck	18	19	16	16
Van Truck	1	1	11	11
Tractor Only	2	2	0	0
Semi-Flat Bed	8	9	16	16
Semi-Van	47	50	21	21
Semi-Bulk Hauler	3	3	1	1
Pole Trailer	1	1	0	0
Specialized				
Dump Truck	5	6	7	7
Garbage Truck	3	3	2	2
Tank Truck	2	2	9	9
Furniture Van	0	0	2	2
Step Van	1	1	5	5
Cement Mixer	0	0	1	1
Semi-Gravel Hauler	1	1	1	1
Semi-Car Transporter	0	0	4	4
Semi-Low Boy	0	0	2	2
Semi-Tanker	2	2	2	2
Total	94	100	100	100

Table 4
Passenger Car Types Involved
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Passenger Car Type	Fatal Accidents		Non-Fatal Accidents	
	Number	Percent	Number	Percent
Full Size Sedan	53	57	59	59
Intermediate	20	21	31	31
Compact	17	18	8	8
Sport Car	3	3	0	0
Jeep Type	1	1	0	0
Total	94	100	100	100

intermediates, were involved. This may be a forewarning as the total vehicle population tends toward smaller and smaller passenger cars.

When

While the earlier study revealed that the car-into-truck fatal crashes occurred mostly at night (71%), the opposite is true of the non-fatal crashes (79% occurred during daytime). This observation reinforces the finding that reduced visibility at night is a large factor in fatal crashes but is much less a factor in non-fatal crashes.

Table 5 shows the daytime and nighttime statistics for fatal and non-fatal crashes.

Table 5
Light Conditions
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Accidents	Day		Night	
	Number	Percent	Number	Percent
1972-1976 Fatal (94 cases) . .	27	29	67	71
1976 Non-Fatal (100 cases) . .	79	79	21	21

Table 6 pursues the question "When?" by grouping "Hour of Day" for each of the 194 fatal and non-fatal car-into-truck accidents into five major time periods which tend to identify the reasons why passenger car drivers would be in the traffic stream.

The time groupings and parenthetical designations certainly would not apply to all drivers on the road. However, Table 6 does reinforce the finding that most of the non-fatal crashes occurred during daylight, while most of the fatal crashes occurred during darkness. Table 6 data also substantiate the findings regarding who was driving. The non-fatal car drivers generally were following a daily routine, at times when more

Table 6
Accident Occurrences by Hour of Day
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Hour of Day	Fatal		Non-Fatal	
	Number	Percent	Number	Percent
0600-1059 (to work/school)	14	15	23	23
1100-1559 (Shopping) . . .	10	11	45	45
1600-1959 (Going home) . .	18	19	14	14
2000-0059 (On the town) .	33	35	9	9
0100-0559 (Closing bars) .	19	20	9	9
Total	94	100	100	100

women drivers are on the road, and at times when drinking is much less of a factor.

Where

As Tables 7 and 8 reveal, most of the accidents studied, both fatal and non-fatal, occurred either on straight sections of highway or at intersections. Only five non-fatal crashes occurred on curves. In most cases the terrain was flat--typical of Michigan. Most of the fatal crashes occurred in rural areas on straight-aways, whereas most of the non-fatal crashes occurred in urban areas, both on straight-aways and at intersections. These factors will pertain to a later discussion on relative impact speeds.

Table 9 lists the highway types involved under three broad groupings. All of the accidents, fatal and non-fatal, occurred on paved surfaces, either asphalt or concrete.

Table 7
Accidents by Highway Location
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Accidents	On Straight-Aways		At Intersections		On Curves		Total
	No.	%	No.	%	No.	%	
1972-1976 Fatal (94 cases) . .	61	65	33	35	0	0	94
1076 Non-Fatal (100 cases) . .	45	45	50	50	5	5	100

Table 8
Accidents by Geographic Location
Michigan Fatal/Non-Fatal Car- Into-Truck Crashes

Accidents	Rural		Urban		Total
	Number	Percent	Number	Percent	
1972-1976 Fatal (94 cases) . .	55	59	39	41	94
1976 Non-Fatal (100 cases) . .	27	27	73	73	100

In the non-fatal crashes, multi-lane, non-limited access streets and roads in urban areas predominated (47%).

Probably because most of the non-fatal car-into-truck crashes occurred during daylight, ramp or private driveway involvement on straight-aways was less a factor in these accidents than in the fatal crashes. Table 10 shows the distribution of driveway-ramp involvement.

Table 9
Accidents by Highway Type
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Accidents	Interstate or Interstate Quality		Multi-Lane Not Limited Access		2 Lane 2 Way		Total
	No.	%	No.	%	No.	%	
1972-1976 Fatal (94 cases) . .	39	41	24	26	31	33	94
1976 Non-Fatal (100 cases) . .	24	24	47	47	29	29	100

Table 10
Driveway/Ramp Involvements
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Accidents	Straight-Away Accidents	Driveway/Ramp Involved	
		Number	Percent
1972-1976 Fatal (94 cases) . .	61	21	34
1976 Non-Fatal (100 cases) . .	45	10	22
Total	106	31	29

How and Why

Using the technique described in the methodology section, the findings of underride versus no underride were developed for the 100 non-fatal car-into-truck/trailer crashes and then summarized for comparison with the previously studied 94 fatal crashes, as shown in Table 11.

Some underride occurred in 76% of the fatal car-into-truck crashes but in only 33% of the non-fatal crashes. Trailer underriding, especially rear end underriding, predominated in both fatal and non-fatal underrides. Among the non-fatal crashes underride occurred least when the passenger car side angled a truck.

Degree of underride, as appraised for each of the 194 car-into-truck trailer cases, was graded according to the following scale:

a None

b Minimal (Between the bumper and the hub of the front wheels).

c Moderate (Between the hub of the front wheels and the middle of the hood).

d Severe (Between the middle of the hood and up to the A pillars).

e Catastrophic (Beyond the A pillars into the passenger compartment).

Table 11
Accident Configuration Versus Underride
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Configuration	Underride-Yes Probably Yes				Underride-No Probably No				Sub-Total Underride			
	Fatal		Non-Fatal		Fatal		Non-Fatal		Yes		No	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Car Rear-ended Truck	13	14	9	9	3	3	17	17	22	11	20	10
Car Rear-ended Tlr.	28	30	13	13	4	4	12	12	41	21	16	8
Car Angled Truck . .	5	5	3	3	12	13	30	30	8	5	42	22
Car Angled Tlr. . .	25	27	8	8	4	4	8	8	33	17	12	6
Total	71	76	33	33	23	24	67	67	104	54	90	46

In six cases the rear of the passenger car underrode a truck or trailer (as a result of multiple impacts). For those cases, the following scale was used:

a None

b Minor (One foot or less of the trunk or rear deck).

c Moderate (Up to three feet or less of the trunk or rear deck).

d Severe (More than three feet of the trunk or rear deck).

In the statistical tabulations, these backward underride cases were added to the frontal underride cases of equivalent degree. No backward underrides, incidently , extended to the passenger compartment.

Figure 1 shows the degree of underride, determined for each of the 194 cases, plotted in graphical form. The graphic representation emphasizes that in fatal car-into-truck crashes underride usually occurs and often is catastrophic in degree, whereas, in non-fatal crashes of this type, underride usually does not occur and, if it does, it is seldom catastrophic in degree.

A variety of circumstances or combination of circumstances precipitated the 194 fatal/non-fatal car-into-truck accidents reviewed in this study. From the available data each pre-crash situation was reconstructed. Figure 2, a floating bar graph display, summarizes what were judged to have been the pre-crash circumstances in the accidents studied.

In most of the fatal and non-fatal rear-end collisions, the truck or tractor/trailer was leading in traffic, and under such circumstances, trailers were rearended more often than trucks. When the truck or tractor/trailer, while leading, was stopped, slowing, or in the process of changing direction, the majority of the non-fatal rearends (67%) were into trucks, whereas the majority of the fatal rearends (65%) were into trailers.

Regarding intersection accidents, it seems immaterial whether the truck or tractor/trailer entered from the right or left relative to the car.

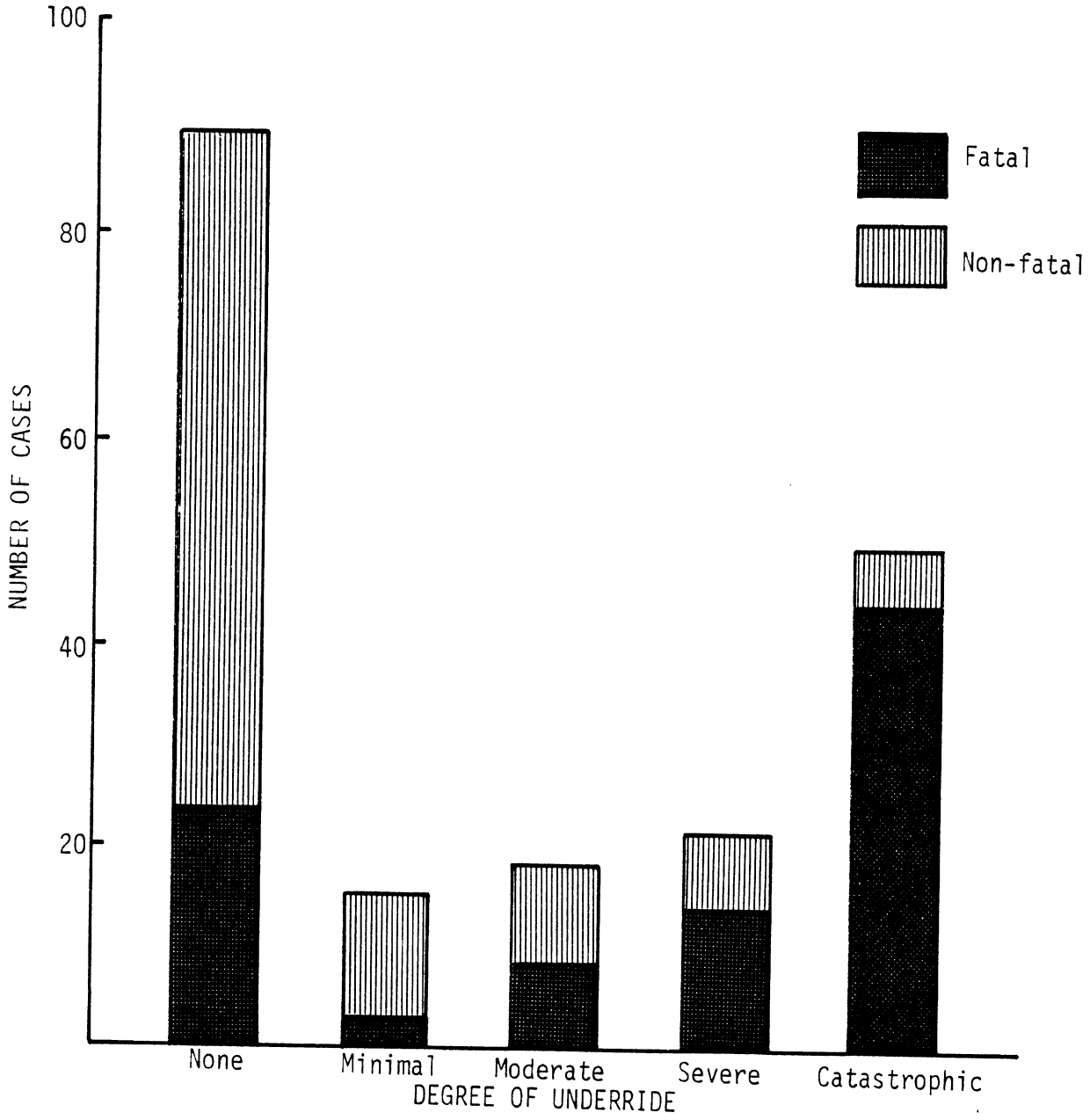


Figure 1. Fatal vs. Non-Fatal Underride

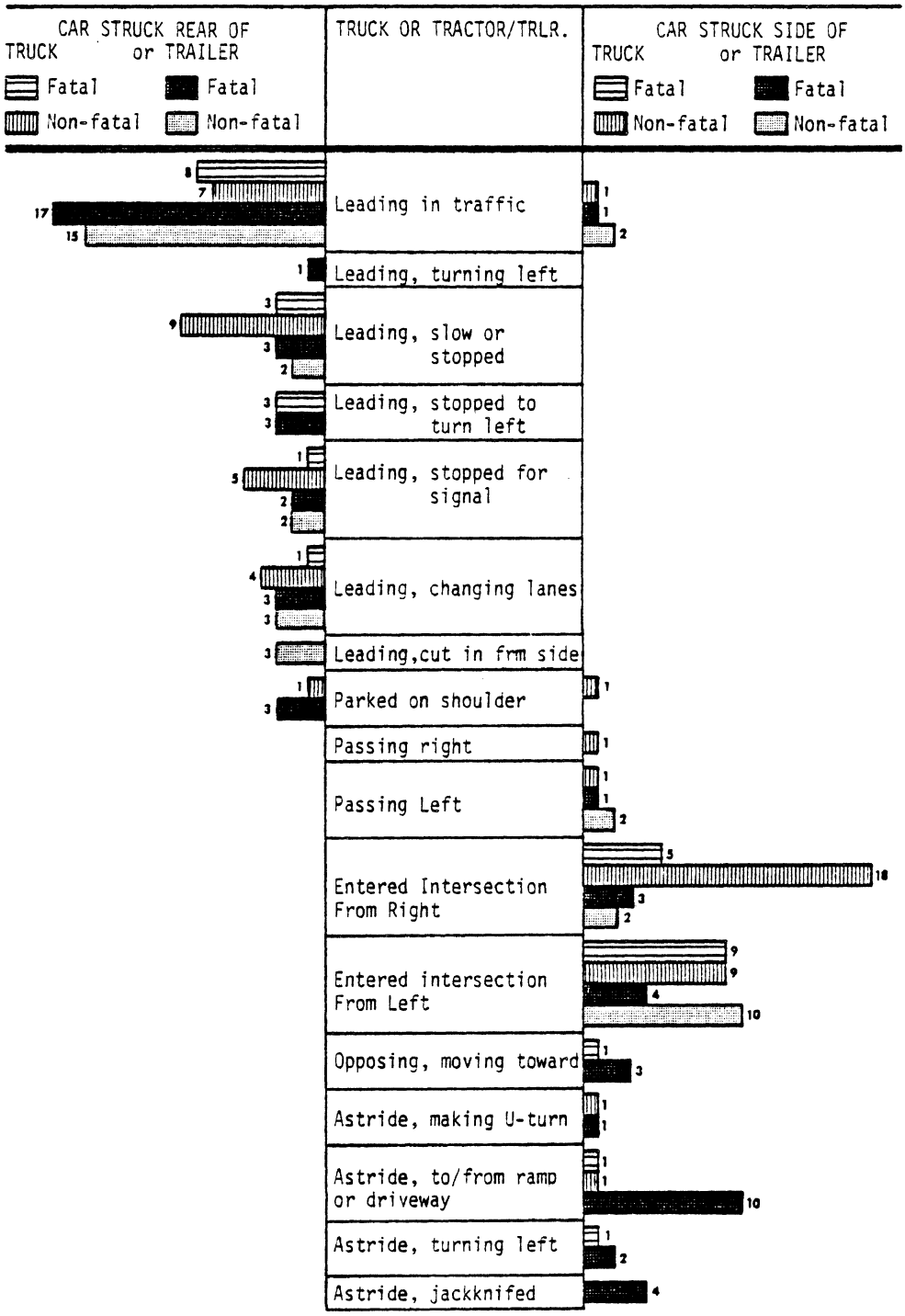


Figure 2. Pre-Crash Circumstances

Figure 2 indicates that the worst situation confronting a car driver is a tractor/trailer astride the road, whether it be the result of exiting or entering a ramp or driveway, making a U-turn, or having jackknifed out of control. Such situations led to 17 fatal side crashes into trailers and one non-fatal side crash--luckily, into the tractor.

Figure 3 graphically presents points of impact by location and actual count, on the truck or tractor/trailer, for the 194 fatal and non-fatal crashes.

The information revealed in Figure 3 should be of value when considering the probable effectiveness of underride prevention devices.

Considering side impacts only, in a total of 46 fatal side impacts on trucks and tractor/trailers, 29 were on trailers, whereas in 49 non-fatal side impacts, only 16 were on trailers. Stated another way, a side impact into a trailer is much more likely to be fatal than is a side impact into a truck or tractor.

Regarding rearend impacts, in a total of 48 fatal rearend impacts, 32, or most, were on trailers whereas in a total of 51 non-fatal rearend impacts, 26, or half, were on trucks. In rearending a trailer, the chance of a fatal collision is greater than when rearending a truck or tractor.

A unique feature of the non-fatal crashes was the number of cases involving multiple impacts (5 vs. 1 fatal) wherein the car first struck, without underriding, the side of a tractor or truck, spun 90 to 180 degrees, then impacted backwards at another point, usually the side of a trailer. In the statistics these crashes and underride (if any) are charged to the final impact point.

All data and supporting information for both the earlier study and this study were reviewed in order to determine under what conditions underride does not occur after a car-into-truck impact. Table 12 shows the summarized results.

Table 12 indicates that when underride was absent, both in the fatal and non-fatal car-into-truck crashes, it usually was because the car impacted the truck/trailer wheels or because the truck/trailer bottom was too close to the ground for the passenger car to underride.

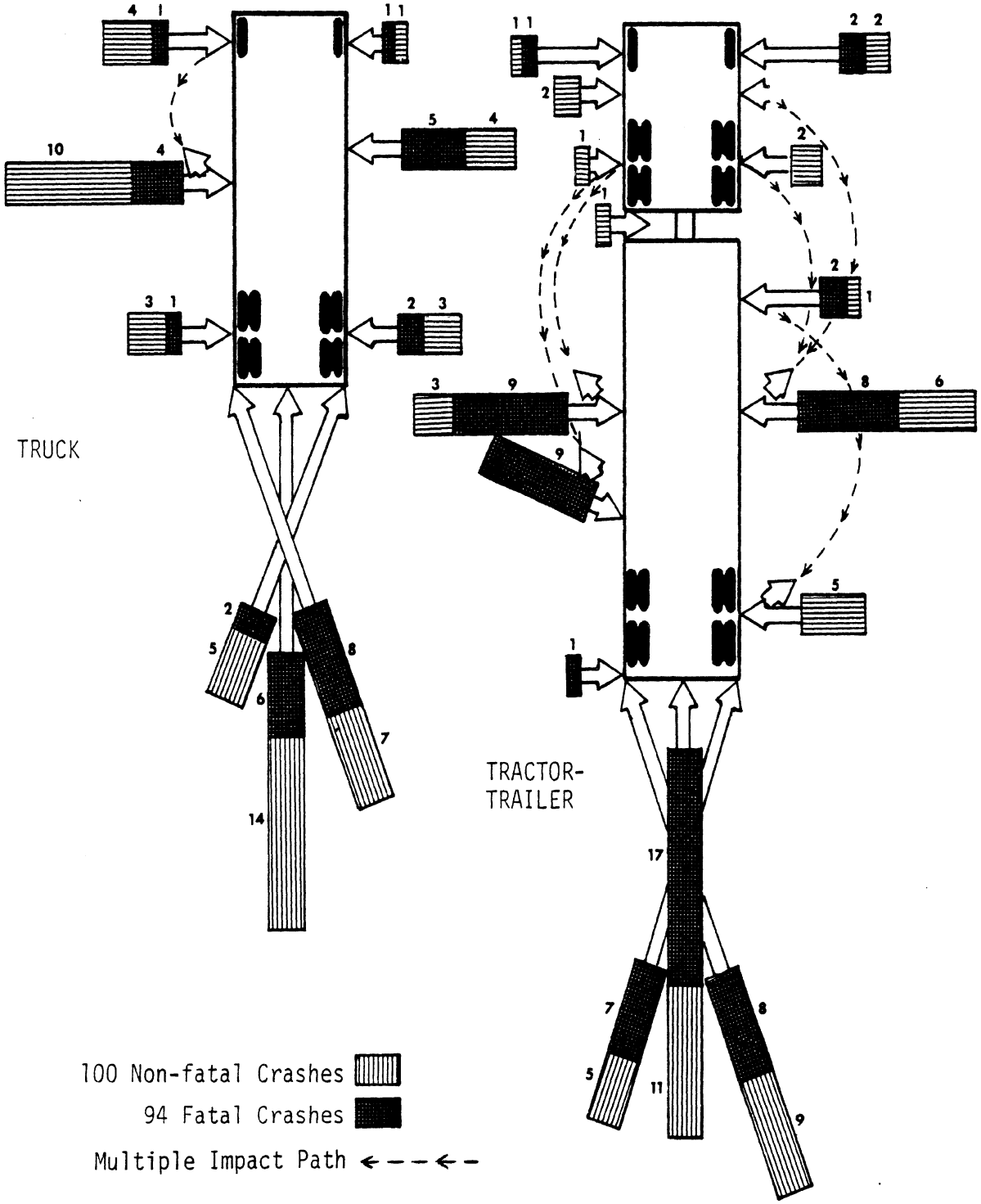


Figure 3. Impact Locations and Frequency of Impacts

Table 12
Reasons For No Underride In Some Accidents
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Reason for No Car Underride	1972-1976 Fatals (94 cases)		1976 Non-Fatals (100 cases)	
	Number	Percent	Number	Percent
Truck/Trailer Bumper	2	9	4	6
Truck/Trailer Wheels	8	35	22	33
Truck/Trailer Anti-U Device . . .	2	9	4	6
Truck/Trailer Bottom Too Close to Ground	6	26	24	36
Truck/Trailer External Equip. (Tire rack, gas tank unloading chute tailgate, stanchion, etc. . .	5	21	9	13
Car Stopped Just Before Going Under	0	0	4	6
Total	23	100	69	100%

This finding correlates with the earlier discussion regarding underride versus type of truck or tractor/trailer involved.

As Table 12 indicates, impacting external equipment such as tire racks, loading chutes, gas tanks, or trailer stanchions, prevents underride. To a much lesser extent, underride is prevented by truck/trailer bumpers and anti-underride devices, or by passenger car braking and stopping in time. In non-fatal accidents it appears that these reasons for no underride prevail more often than in fatal accidents.

That presently used anti-underride devices have little effect in stopping underrides is highly noticeable.

The two leading causes for no underride; (1) impact with the truck or trailer wheels, and (2) the truck/trailer bottom was too close to the ground, suggest that no underride in a car-into-truck/trailer crash is to some extent a matter of luck, if one considers the broad spectrum of truck designs within the overall vehicle population.

The information and data available give no positive method for estimating collision speeds. As in the earlier fatal study, relative impact speeds were estimated from a combination of sources such as (1) car driver, truck driver, or witness estimates when interviewed, (2) posted speed limits and roadway conditions at the time, (3) police accident report citations or comments, (4) interpretation of crash damage indices, (5) driver description of vehicle damage incurred. In the fatal crashes, the surviving truck driver's statements often provided the clues. But the non-fatal car drivers, when interviewed, frequently volunteered such comments as, "I stopped for the traffic light (stop sign), but slid on the wet snow (ice) into the intersection," or "I knew I was going to hit the truck, so I threw myself across the seat," or "There was not much damage to my car, because I was not going fast," or "I was not hurt even though I was not wearing a seat belt." Such remarks were carefully evaluated when relative impact speeds were estimated.

While caution is urged in using the exact values of the estimated speeds, Figure 4--which summarizes graphically the relative impact speeds for both the fatal and non-fatal car-truck crashes--is revealing.

None of the 94 fatal impacts were at less than 20 mph and none of the 100 non-fatal impacts were at more than 25 mph. The fatal impact speeds averaged about 35 mph, and the non-fatal impact speeds averaged about 10 mph, resulting in an average difference of about 25 mph in relative impact speed distribution. (The speeds in Figure 4 coincides well with the results of analyses conducted on NCSS cases, wherein it was noted that the average Delta V for non-fatal crashes was about 10 mph, and the mean Delta V for fatal crashes was about 30 mph.)

Figure 4. Fatal vs. Non-Fatal Relative Impact Speeds

Police accident reports include citations under an item entitled "Hazardous Action." When considered collectively, these citations offer clues to what precipitated, or what occurred in, these car-into-truck crashes. Few of these citations resulted in a ticket or summons. Generally, they merely reflected the investigating officer's opinion as to what caused the accident.

Table 13 compares passenger car driver citations for hazardous actions in both fatal and non-fatal car-into-truck accidents.

Table 13
Car Driver Citations
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Citation	94 Fatal Cases		100 Non-Fatal Cases	
	No.	%	No.	%
None	21	22	31	31
Failed to Yield .	1	1	6	6
Ran Signal/Stop Sign	17	18	12	12
Followed too Close	0	0	5	5
Failed to Stop in a Safe Distance	10	11	16	16
Exceeded Speed Limit	19	20	2	2
Drove Too Fast for Conditions . . .	14	15	14	14
Improper Lane Change	1	1	3	3
Other Misc. . . .	11	12	11	11
Total	94	100	100	100

The main difference between the fatal and non-fatal citations in Table 13 is "speeding." The non-fatal drivers were cited for speeding only 2% of the time, whereas the fatal drivers were cited for speeding 20% of the time--ten times more often than the non-fatal drivers.

Also it should be noted that the fatal drivers more often ran a red light or stop sign, which may also be indicative of speeding.

Other frequent violations or citations included: (1) failing to stop in a safe distance, and (2) driving too fast for conditions, of which it appears the fatal and non-fatal drivers were about egually guilty. Review of the accident reports indicates that speeding sometimes was intensified by adverse weather or road conditions.

Table 14 compares truck driver citations for hazardous actions in both fatal and non-fatal accidents.

Table 14
Truck Driver Citations
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Citation	94 Fatal Cases		100 Non-Fatal Cases	
	No.	%	No.	%
None	71	76	71	71
Failed to Yield	5	5	8	8
Ran Signal/Stop Sign	4	4	8	8
Failed to Stop in a Safe Distance . .	1	1	0	0
Improper Lane Change . . .	1	1	7	7
Other Misc. . .	12	13	6	6
Total	94	100	100	100

In both fatal and non-fatal car-truck accidents, about three out of four times the investigating police agencies considered the passenger car driver--not the truck driver--to be responsible for the accident

In comparing fatal versus non-fatal truck driver citations, improper lane changing, running a red light or stop sign, and failing to yield seem to occur more frequently in non-fatal crashes. Possibly, this is because the passenger car driver survived to give his version of what happened!

In any case, regardless of which driver is at fault, in non-fatal as in fatal car-truck crashes, it usually is the passenger car driver who loses--whether it be in injuries or vehicle damage.

Tables 15 and 16 show the distribution of weather and road surface conditions in the 194 fatal/non-fatal car-truck accidents reviewed in this study.

Table 15
Weather Conditions
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Weather	94 Fatal Cases		100 Non-Fatal Cases	
	No.	%	No.	%
Clear	80	85	76	76
Fog .	1	1	0	0
Rain	9	10	6	6
Snow	4	4	18	18
Total	94	100	100	100

Both in the fatal and non-fatal car-truck crashes, the great majority of the accidents occurred during clear weather on dry surface roadways. However, in the non-fatal crashes, bad weather and wet, snow-covered, or icy road surfaces were more often a factor.

Table 16
Road Surface Conditions
Michigan Fatal/Non-Fatal Car-Into-Truck Crashes

Road Surface	94 Fatal Cases		100 Non-Fatal Cases	
	No.	%	No.	%
Dry . .	72	77	54	54
Wet . .	16	17	22	22
Snow/Ice Covered	6	6	24	24
Total .	94	100	100	100

All the factors under discussion coalesce to form two distinct pictures of car-into-truck collisions.

Most of the fatal crashes occurred at night, on straight sections of rural interstate and multi-lane roads, at relatively high impact speeds, as surprise events, and resulted in some degree of underride. This is not surprising. Proportionately more trucks and fewer cars are on these road types at night, visibility is limited, traffic controls are few, and speeds, legally, are high.

On the other hand, most of the non-fatal crashes occurred in daytime, on both straight sections and at intersections of urban roads, at relatively low impact speeds, often as anticipated events, and resulted in little or no underride. Again, this is not surprising. Proportionately more cars and fewer trucks are on these type roads in daytime, visibility normally is good, traffic controls are many, and speeds, legally, are low.

Driver performance and the significance of citations and violations differ in these two traffic environments, especially under adverse road and weather conditions. These differences help define the underride problem.

In reviewing how these two environments differ on what happens within them the data have indicated that:

In the environment with mostly fatal crashes car contact usually is with types of vehicles that are highly vulnerable to underride, whereas in the environment with mostly non-fatal crashes, car contact usually is with types of vehicles that do not lend themselves to underride.

In neither environment are presently used anti-underride devices effective.

There is an overlapping or gray area of impact speeds (20-30 mph) that separates the two environments (see Figure 4).

It appears that a better anti-underride approach would narrow or move this gray area by changing some of the fatal collisions in the lower speed range to non-fatal collisions.

6. SUMMARY

Findings

1. Underride of any degree occurs much less frequently in non-fatal car-into-truck side and rear collisions than in similar fatal collisions. In the 194 cases reviewed in this study, underride occurred in 76% of the fatal collisions and, by definition, usually was "catastrophic" in degree (into the passenger car compartment); whereas underride occurred in only 33% of the non-fatal collisions and usually was "minor" or "moderate" in degree (not beyond the middle of the hood).

2. By configuration, 85% of the fatal rearend collisions involved underride, but only 43% of the non-fatal rearends involved underride; 65% of the fatal side impact collisions involved underride, but only 22% of the non-fatal side impacts involved underride.

3. Whereas most of the fatal crashes occurred as surprise events, at night, in rural areas, and on straight roadway sections, most of the non-fatal crashes occurred frequently as anticipated events, during daytime, in urban areas, on straight multi-lane roadways or at intersections.

4. Regarding passenger car types, in both fatal and non-fatal crashes, full size sedans predominate (about 60%), but in non-fatal crashes there appeared fewer compacts, sports, etc., and more intermediates.

5. The majority of fatal car-into-truck crashes (63%) involved passenger car contact with semi-trailers of all the standard types which are easy to underride; whereas the majority of non-fatal crashes (62%) involved passenger car contact with trucks only or with specialized vehicles (tankers, step vans, car transporters, etc.) that by design are not conducive to underriding.

6. Relative impact speeds in the non-fatal crashes were low, averaging 10 mph, and seldom exceeding 20 mph; whereas relative impact speeds in the fatal crashes were high, averaging 35 mph, and never below 20 mph. Generally the relative impact speeds reflected the traffic environment in which the crashes occurred.

7. In neither the fatal or non-fatal crashes were presently used anti-underride devices effective in stopping underride. Instead, in both the fatal and non-fatal crashes, underride was prevented largely by impact with the truck/trailer wheels or because the truck/trailer bottom was too close to the ground.

Conclusions

1. The difference in time of day (night vs. day) between fatal and non-fatal car-truck collisions reinforces an earlier study conclusion that higher conspicuity of trucks and trailers at night would reduce the chances of severe collision and thereby reduce the incidence of underride--especially fatal underride.

2. That the predominant portion (62%) of the non-fatal car-into-truck crashes involve straight trucks or other vehicles whose functional design prevents underride identifies trailers as the major part of the fatal underride problem.

3. The range of impact speeds, the extensive areas, side and rear, where these vehicles are vulnerable to underride, the ineffectiveness of currently used anti-underride devices in both fatal and non-fatal crashes, and the increasing numbers of smaller passenger cars sum up the challenge to design engineers seeking ways to prevent underride of all trucks and trailers.

4. The absence of underride in many non-fatal crashes because impact was with those types of trucks or trailers which are too close to the ground to be underridden suggests that anti-underride principles should be incorporated into the functional design of all trucks and trailers.

Recommendations

1. Implement high priority research for ways to improve the conspicuity of trucks and trailers, especially at night, in order to reduce the chance of car-into-truck collisions and, thereby, to reduce the incidence of passenger car underride.

2. Challenge truck/trailer builders to adopt an inherent anti-underride configuration in truck/trailer design for all types of cargo loads.

APPENDIX A

Non-Fatal Car-Truck Underride Study - Questions for Car or Truck Driver in Telephone Survey

Interviewed ( ) Car Driver
( ) Truck Driver
( ) Witness

MSP No. ___ ___ ___ ___ ___ ___

Accident Date __ __/__ __/__ __

1. What kind of truck was involved:

( ) straight truck, stake
( ) straight truck, van
( ) tractor only
( ) tractor + semi trailer flatbed
( ) tractor + semi trailer
( ) tractor + semi trailer van
( ) other _____

Special Vehicle:
( ) cement mixer
( ) gravel hauler
( ) car transporter
( ) garbage/trash hauler
( ) low boy
( ) other _____

2. What part of the truck/trailer was contacted?
3. Did the car make contact straight on or at an angle?
4. Did any portion of the car underride the truck? ( )Yes ( ) No
( ) Don't Know
5. If yes to Q.4 how far under the truck did the car go?
( ) just beyond the bumper
( ) to the radiator or hood ornament
( ) to the engine block
( ) to the middle of the hood
( ) to the windshield
( ) to the roof
6. Was the hood pushed against the windshield? ( ) Yes ( ) No
( ) Don't Know
7. Did the truck have an anti-underride device or special bumper?
( ) Yes ( ) No ( ) Don't Know
8. If the car did not underride the truck what was the reason?
( ) stopped by the truck bumper
( ) stopped by the truck wheel(s)
( ) stopped by the truck anti-underride device

8. Continued

( ) truck bottom was too close to ground to underride

( ) stopped by the tailgate, tire rack, spare tire, unloading chute, or other equipment on truck

( ) car stopped just before going under

9. If the truck had an underride guard or special bumper--describe it:

( ) horizontal bar in rear ( ) all the way across

( ) only in the middle ( ) ____ ft. short of corner edges

( ) __ __ inches above ground ( ) wrap around bumper

( ) low to ground ( ) other _____

10. What major items on the car were damaged?

( ) headlight(s) ( ) hood

( ) radiator ( ) windshield

( ) left ( ) right front wheel(s)

( ) left ( ) right fender(s)

( ) roof ( ) Left (right) door

( ) engine ( ) other _____

11. Was the car driver and/or passengers wearing: ( ) seat belts

( ) shoulder belts

( ) Yes ( ) No

( ) Don't Know

12. If not belted, did car driver and/or passengers move, duck down, etc. in order to avoid injury?

( ) Yes ( ) No ( ) Don't Know

APPENDIX B

Car into Truck/Trailer Underrides Worksheet

Column

1-6 MSP Case No. ___ ___ ___ ___ ___ ___

7 Area location ( )1 Urban ( )2 Rural

8 Time ( )1 Day ( )2 Night

9 Highway location ( )1 Straightaway ( )2 Intersection ( )3 Curve

10 Driveway or Ramp Involved ( )1 Yes ( )2 No

1-12 Posted Speed Limit ___ ___ MPH

3-14 Type of truck/trailer:

( )01 Straight truck, stake
( )02 Straight truck, van
( )03 Straight truck, dump
( )04 Tank truck
( )05 Tractor only
( )06 Tractor & Semi Trailer, flat bed
( )07 Tractor & Semi Trailer, van
( )10 Tractor & Semi Trailer, tank
( )11 Step van (mail, milk, ice cream, etc.)
( )12 Other _____

Special Vehicle:

( )13 Cement Mixer
( )14 Gravel Hauler
( )15 Car transporter
( )16 Garbage/Trash Hauler
( )17 Low Boy/Heavy Equipment Hauler
( )20 Pole Trailer
( )21 Furniture Van
( )22 Other _____

15 Type passenger car: ( )1 Intermediate ( )2 Compact ( )3 Sport ( )4 Carry-All ( )5 Jeep Type ( )6 Full Size Sedan

16 Truck/Trailer Movements Prior to Crash:

( )01 Leading in Traffic
( )02 Leading Turning Left
( )03 Leading Slowing or Stopped in Traffic
( )04 Leading Stopped for Left Turn
( )05 Leading Stopped for Signal/Stop Sign
( )06 Leading Changing Lanes
( )07 Parked on Shoulder or Curb
( )10 Passing Right
( )11 Passing Left
( )12 Entered Intersection--Fr. Right
( )13 Entered Intersection--Ft. Left
( )14 Opposing, Moving Toward
( )15 Astride, Turning Left
( )16 Astride, Making U-Turn
( )17 Astride, to/from Drive/Ramp
( )18 Astride, Jack Knifed
( )20 Other _____
( )21 Leading, Stopped w/Mech. Problems

18-19 Passenger Car Movements Prior to Crash:

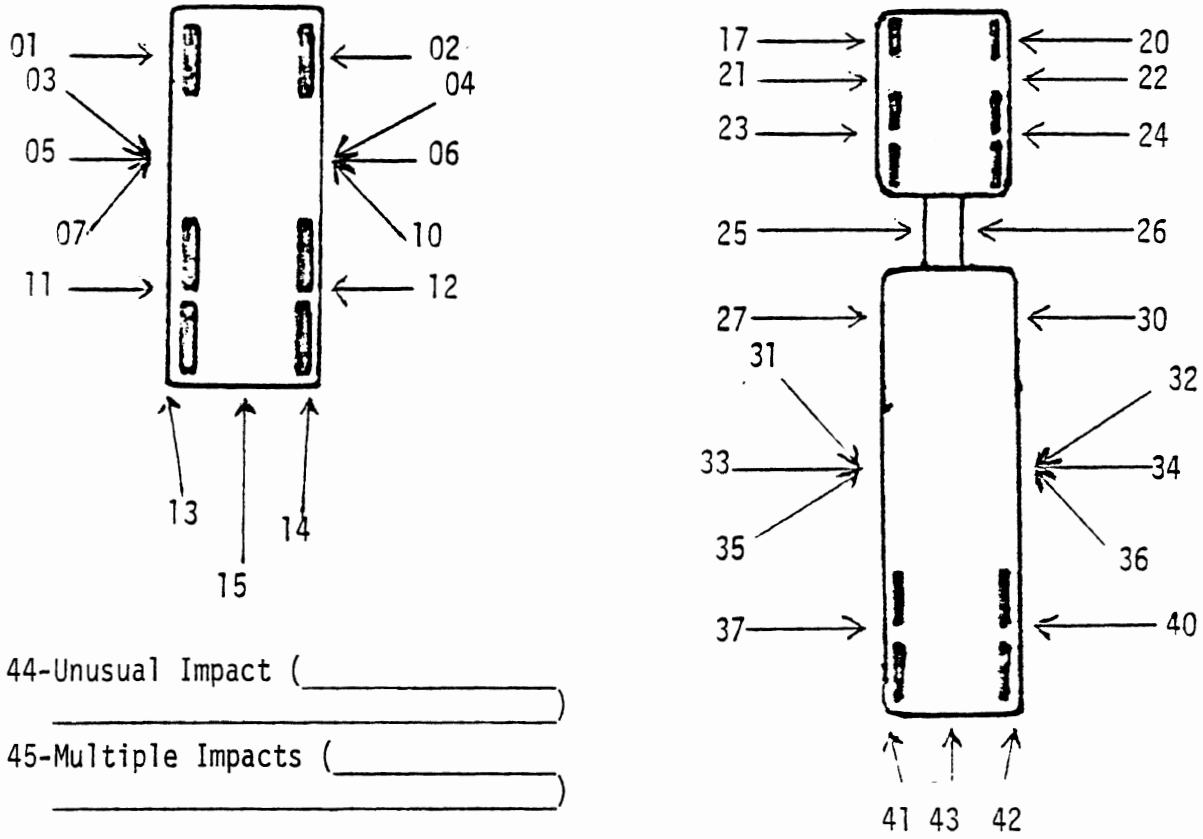
( )01 Following in Traffic
( )02 Following, Changing
( )03 Passing Right
( )04 Passing Left
( )05 Turning Right
( )06 Turning Left
( )07 Entering Intersection From Right
( )10 Entering Intersection From Left
( )11 Other _____
( )12 Opposing, Moving Toward
( )13 Opposing, Turning Left
( )14 Opposing, Crossed Center Line

20 Impact Type: ( )1 Rear End ( )2 Side Impact

Column

21-22 Point of Impact on Truck/Trailer:

TRUCK/TRAILER IMPACT POINT DIAGRAM



44-Unusual Impact (_____)

45-Multiple Impacts (_____)

23-24 Estimated Relative Impact Speed ___ ___ MPH

25 Underride ( )1 Yes, Definite ( )3 No, Definite
( )2 Yes, Probably ( )4 No, Probably

26 Degree of Underride:
( )0 None
( )1 Minor (Between bumper & front wheel hubs)
( )2 Moderate (Between front wheel
( )3 Severe (Between Center of Hood and A-pillars)
( )4 Catastrophic (beyond A-pillars)

Back-End Underride:
(From rear bumper into trunk)
( )5 Minor (1 ft-)
( )6 Moderate (1-3 ft)
( )7 Severe (3 ft+)

27 Reason for No Passenger Car Underriding:
( )1 Truck/Trailer Bumper
( )2 Truck/Trailer Wheel(s)
( )3 Truck/Trailer Anti-Underride Device
( )4 Truck/Trailer Bottom Too Close To Ground
( )5 Tailgate, Tire Rack, Spare Tire, Gas Tank, Unloading Chute, Trailer Stanchion, Snow Plow, Blade, or other equipment on truck/trailer
( )6 Passenger Car Stopped Just Before Going Under

Column

28 Total Number Passenger Car Occupants _____

29 Worst Injury in Passenger Car as taken from Police Report:
( )0 O, ( )1 A, ( )2 B, ( )3 C, ( )4 K

30 Passenger Car Use of Restraints

( )1 yes ( )2 No ( )3 Driver only ( )4 Passenger(s) only

31-32 Passenger Car Driver: Age ___ ___

33 Sex ( )1 Male ( )2 Female
DUIL ( )1 Yes ( )2 NO

35-36 Passenger Car Driver Citation:

( )00 None
( )01 Failed to Yield
( )02 Ran Stop Sign/ Traffic Signal
( )03 Following too close
( )04 Failed to Stop in Safe Distance
( )05 Speeding
( )06 Driving too fast for conditions
( )07 Improper Lane Changing
( )10 Other _____

37-38 Truck Driver Citation:

( )00 None
( )01 Failed to yield
( )02 Ran Stop Sign/
( )03 Failed to stop in safe distance
( )04 Speeding
( )05 Improper Lane Changing
( )10 Other _____

39 Weather/Visibility ( )1 Clear ( )2 Fog ( )3 Rain ( )4 Snow

40 Road Surface ( )1 Dry ( )2 Wet ( )3 Snowy/Icy
( )4 Other _____

41-44 Hour of Day __ __ __ __

45-46 Unique Aspects: ___ ___ (_____)

47 Fatal Accident: ( )1 Yes ( )2 No

48 Highway Type: ( )1 Interstate ( )2 Multi-Lane, Non-limited Access
( )3 Two-Lane, Two-Way