UMTRI-90-1-2

THE MICHIGAN HEAVY TRUCK STUDY

EXECUTIVE SUMMARY

A Joint Project of

Michigan State University
Department of Civil and
Environmental Engineering

Richard W. Lyles
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University of Michigan
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FINAL REPORT

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16. Abstract

This report presents an analysis of the travel, crash frequencies, and crash rates of large trucks registered in Michigan. The project focused on the travel and crashes of Michigan-registered trucks in Michigan. The travel data are from the UMTRI Michigan Truck Trip Information Survey (MTTIS). Crash frequencies are from the computerized file of police accident reports maintained by the Michigan State Police, supplemented by data on the state-of-registration of involved trucks compiled by Michigan State University. The project was undertaken jointly by UMTRI and the Michigan State University Department of Civil and Environmental Engineering.

The research approach and survey methods are described. Estimates of the travel and population of Michigan-registered tractors are presented, along with crash frequencies for several subsets of interest. The factors addressed in the risk analysis are: truck type, crash severity (fatal, injury, property-damage-only [PDO]), road type (limited access, major artery, other), urban/rural, day/night. The results indicate that the bobtail tractor configuration has the highest risk on all parts of the Michigan highway system. Crash rates for singles and doubles are quite similar overall, though the doubles rate is higher for casualty crashes on major artery and other roads. Limited access roads had the lowest rates, followed by major arteries, and other roads. Crash rates were lower in urban areas than rural. Overall, daytime rates were higher than nighttime. Casualty crash rates were higher at night, but PDO rates were higher during the day in both urban and rural areas, but particularly urban. Traffic density appears to explain the higher overall daytime rate.

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SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

1. Introduction

Major changes have taken place in the trucking industry over the past several years. In 1980, federal legislation significantly relaxed the regulation of trucks in the interstate segment of the industry, and the 1982 Surface Transportation Assistance Act (STAA) allowed the use of double-trailer combinations on interstate highways, required states to regulate trailer length instead of overall length, and established the Motor Carrier Safety Assistance Program (MCSAP). More recently, the Commercial Motor Vehicle Safety Act of 1986 established national standards for commercial driver licenses.

Not all of the national changes had the same impact on Michigan since the state has long had some of the most liberal truck size and weight regulations. For example, double-trailer combinations weighing up to 164,000 pounds have operated legally in Michigan for many years. In fact, since states bordering Michigan have had more restrictive regulations, a significant, and unique, intrastate industry segment has existed in Michigan. Notwithstanding the existence of this intrastate fleet, national deregulation will still affect truck operations in Michigan. The use of double trailers and the experience of other combinations operating in Michigan is of significant interest both within the state and nationally.

At the same time, there is the general perception that large trucks are simply not safe—there are questions about the safety of these vehicles and what, if anything, should, or can, be done to make them safer. The actual "numbers" in Michigan show that crashes involving large trucks increased 81% from 1982 to 1986, but then decreased in 1987 and 1988. For the entire period from 1982 to 1988, the number of truck crashes increased by 64%. During the same period, *all* traffic crashes increased by about 40%. Over the same period of time, economic conditions have improved substantially in the state, as has truck travel. In the face of so many changes, the problem is to identify the significant factors associated with truck crashes.

Despite the high interest in truck safety, there are still significant gaps in the current knowledge about truck crash rates and the causal factors involved—both nationally and in Michigan. In this context, a joint project by the University of Michigan Transportation Research Institute and the Michigan State University Department of Civil and

Environmental Engineering was undertaken to develop statistical information on crashes, travel, and the risk of crash involvement for Michigan-registered trucks in Michigan. Operationally, the objectives of the study can be defined as calculating disaggregate truck crash rates (in terms of crash involvements per million vehicle-miles traveled) for combinations of the following variables:

truck types	1. bobtails—tractors without trailers, 2. singles—tractor and semitrailer combinations, and, 3. doubles—tractor, semitrailer, and full-trailer combinations;
roadway types	1. limited—free, limited access highways, 2. major—principal and other through highways and other four-lane divided highways (not included in 1), and, 3. other—all other streets and roads;
rural/urban	1. rural—population code of 2,500-5,000 or less 2. urban—population code greater than 5,000; and,
day/night	1. day—6:00 AM-9:00 PM 2. night—9:00 PM-6:00 AM

In general, Michigan State University (MSU) was responsible for the crash data while the University of Michigan's Transportation Research Institute (UMTRI) was responsible for exposure data. Both the accident and the travel data spanned the twelve-month study period beginning in May, 1987, and ending in April, 1988.

2. Truck Crashes in Michigan

In Michigan, all traffic crashes that occur on public roads are reported on a common form (UD-10, Traffic Accident Report) by the investigating officer. The data from the forms are then further interpreted (e.g., road classification codes) and entered in a computerized file which is maintained by the Michigan Department of State Police (MSP). These files are made available by both MSP and the Michigan Department of Transportation (MDOT). The MDOT has several versions of the file (e.g., one has physical location data) which are then available for researchers and others.

MSU was basically responsible for assembling and preparing the crash data for the study year. The preparation included a considerable manual effort because of significant coding errors which occurred when trucks were classified by type—involvement of singles was under-reported by approximately 20%. Manual review was also required to separate trucks registered in Michigan from those registered elsewhere, since this information is not included in the computerized files.

During the twelve-month study period there were approximately 21,900 crashes which involved a truck larger than a pickup or panel truck. Of these, just over 10,000 involved bobtails, singles, or doubles. Some of the findings regarding truck crashes in Michigan are summarized below. The findings noted here are based on crash frequencies and are not adjusted for exposure, as are crash rates. These frequencies indicate the sizes of different aspects of the truck crash problem, and how they compare with all traffic crashes. Findings based on crash rates, which identify configurations and operations with higher associated risks, are discussed later.

Overall

About 5% of all crashes in Michigan involve a truck larger than a pickup or panel truck. These accidents can be classified by the type of truck as follows.

Table 5-1
Distribution of Truck and All Crashes in Michigan

Truck Type	Crashes	Percent
Straight	10,993	2.7%
Bobtail	458	0.1%
Single	8,883	2.2%
Double	678	0.2%
All Trucks	21,827	5.3%
All Crashes	408,066	100%

Straight trucks (trucks with a cargo body mounted on the power unit chassis) are involved in about half of the truck crashes in Michigan. The other half are tractor configurations (bobtail, single, and double).

Types of Crashes

About 57% of non-truck-involved crashes involved two or more vehicles compared to 79% of all truck-involved crashes.

Other prevalent crash types appear to be most related to the type of service that the different truck types tend to provide: straights have turning, driveway, and angle-straight type crashes; singles have one-vehicle miscellaneous, two-vehicle turning, and (overall) two-vehicle crashes; and doubles have more overturning and other two-vehicle crashes (e.g., rear-end).

A far greater percentage of single-vehicle non-truck crashes occurred at night (about 50%) than did single-vehicle truck crashes (about 25%). Conversely, a higher percentage of truck-involved multi-vehicle crashes (46%) occurred during non-rush-hour daytime hours (9:00-3:00) than did non-truck-involved multi-vehicle crashes (32%).

Severity of Crashes

Trucks appear to be overrepresented in both fatal and property-damage-only crashes. While the absolute number of fatal crashes involving trucks is quite low (a total of 179 in 1988 for all types of trucks), the proportion of crashes that result in fatalities is about twice as high for trucks as it is for non-trucks. Crashes involving trucks appear to be more serious when the truck is vehicle-2 (the less at-fault vehicle) versus when it is vehicle-1 (the more at-fault vehicle).

Driver Age

In general, drivers of doubles are older than singles drivers, who are in turn older than the drivers of straights. (Note that this finding is based only on the ages of drivers who are involved in crashes.)

Roadway Type

In general, non-truck crashes were more likely to occur on the local road portions of the highway network (city streets and county roads) than were truck-involved crashes. For non-truck crashes, this is consistent regardless of severity level. For truck-involved crashes, however, fatals were somewhat more likely to occur on the non-local system (e.g., 40% of the fatals were on Interstate, and U.S.- and Michigan-numbered routes versus 33% of "B-injury" crashes).

3. Truck Travel in Michigan

In order to develop crash involvement rates, accurate exposure data (e.g., vehicle-miles of travel) as well as accurate crash frequencies are needed. Although MDOT collects vehicle count data at numerous counting stations, it is impossible to accurately disaggregate these data according to the variables cited above. Thus, new exposure data were collected by UMTRI in the Michigan Truck Trip Information Survey (MTTIS). The basic data came from telephone interviews of tractor owners (or their representatives) conducted during the study period. It should be noted that while the ultimate goal of the survey was to be able to estimate differential travel by truck type (i.e., bobtails, singles, and doubles), the unit of observation for the survey was the truck tractor (i.e., the power unit of a tractor-trailer combination). The travel estimate was then based on how that tractor was used; i.e., how much mileage, if any, was logged by the tractor without a trailer (as a bobtail), by the tractor pulling a single trailer (as a single), and finally by the tractor pulling two trailers (as a double).

The sample of owners for the MTTIS was drawn from the vehicle registration file maintained by the Michigan Department of State as of February, 1987. The target group consisted of the owners of truck tractors with an empty weight over 6,000 pounds—basically all medium- and heavy-duty truck tractors registered and operating in Michigan. The survey data were collected during four telephone interviews over the course of the study period: basic descriptive information on the company and the vehicle was obtained on the first interview, as well as actual travel information. The travel data consisted of information about loading, type of trailers, route covered, and other operational details. In all, travel information was collected on four randomly selected days spaced over the 12 month period for each of the sampled tractors. The route descriptions allowed mileage to be broken down by road type, time of day, and area type. Using this technique, travel estimates were generated for the three tractor configurations of interest for different combinations of road type, time of day, and area (urban-rural). In addition to travel characteristics, data were also obtained about the drivers (e.g., age and training). This methodology has been used successfully in the past in the context of the analysis of nationwide truck-involved fatal crashes.

The registration file indicated that there was a total of approximately 34,600 truck tractors registered in Michigan at the beginning of the study period, and detailed travel data were collected on a random sample of 1,085 of these. Findings concerning the travel patterns of trucks in Michigan are summarized below:

<u>Travel Characteristics</u>

It is estimated that Michigan-registered tractors traveled approximately 883 million miles within the state during the study period—an average of approximately 25,500 miles annually in Michigan.

It is estimated that 10,000 tractors in Michigan (just under 30%) are registered to gross over 80,000 pounds.

Tractors with semitrailers (singles) account for over 88% of the total travel with doubles accounting for 10.4% and bobtails just 1.2%.

Approximately one-half of the travel by singles is on limited access highways during the day (27% rural, 23% urban) and almost another 25% is on major highways during the day (17% rural, 8% urban). The highest percentage of night travel (by highway and area type) is on limited access highways in rural areas (5.5%). Overall, about 59% of the singles travel was on limited access roadways.

The distribution of travel by doubles is very similar to that of singles, with the principal exception that about 11% of doubles travel is on limited access highways in rural areas at night. Overall, doubles traveled on limited access highways about 64% of the time—about 5% more than the comparable figure for singles.

A consideration of the travel of all tractors broken down by the approximate gross combination weight of the vehicle indicates that the 20-40,000 pound group (virtually all empty, or nearly empty, singles) accounts for about 39% of all travel, the 40-80,000 pound group accounts for about 43%, and about 14% of all travel is at weights in excess of 80,000 pounds.

For singles, nearly 44% of the travel is while empty or very lightly loaded while about 20% is in the 40-60,000 and 60-80,000 ranges (each) and about 10% occurs at weights over 80,000 pounds.

For doubles, the distribution of travel by weight is somewhat different. About 43% of the travel is while empty. The percentages are lower for intermediate weights, rising gradually to 26% in the 140-160,000 pound range. This indicates that doubles are very likely to be running fully loaded in one direction and returning empty—a typical pattern for the commodities carried by the very heavy trucks (e.g., gravel).

Driver Characteristics

The distribution of driver age shows that only 3.5% of the drivers are 24 or younger, while about 14% are 25-29, and 18% are 30-34. The percentages then drop gradually until 50-54 which accounts for 10.5%, and then more abruptly as only 6% are 55-59, about 2% are 60-64 and less than 0.5% are over 64.

With driver "training" defined as a combination of classroom and on-the-road training, approximately 54% of the drivers had no such training. Only about 15% had such training—the remainder, about 31%, were unknown. (The drivers themselves could not always be interviewed, and this information was often unknown to the actual interviewees.)

Of the drivers who had training (15%), about two-thirds received it from the employer (either current or previous), truck-driving schools accounted for about 18%, and the military for less than 10%. In other words, less than 3% of all drivers surveyed had received training at a truck driving school. For-hire haulers and companies that operate in interstate commerce may have a higher proportion of trained drivers, but the large amount of missing data makes firm conclusions on that score impossible.

4. Truck Crash Rates Michigan

The crash involvement and exposure data were combined to produce differential truck crash rates for various combinations of the stratifying variables described above. Remember that the exposure survey covered only travel in Michigan by tractors registered in Michigan. Thus, only crash involvements of Michigan-registered tractors were used for the rate calculations. About 62% of the tractors involved in crashes in Michigan were registered in Michigan.

In addition to the rates based on all combinations of these variables, rates based on only casualty crash involvements, or property-damage-only crash involvements were also calculated. The calculated rates for all police-reported, Michigan-registered tractor crash involvements, in their most disaggregate form, are shown in table 5-2 (this is a repeat of table E-1 in Appendix E). The rates are presented as crash involvements per million miles traveled.

Table 5-2
Overall Tractor Crash Rates
(all involvements)
Michigan-Registered Tractors on Michigan Roads

Travel Category			Bobtail		Single		Double	
			Crashes	Rate	Crashes	Rate	Crashes	Rate
Rural	Day	Limited	17	8.1	768	3.8	86	3.7
Rural	Day	Major	41	19.5	971	7.5	112	7.4
Rural	Day	Other	69	265.4	948	29.8	86	26.8
Rural	Night	Limited	9	37.5	200	4.8	25	2.6
Rural	Night	Major	8	114.3	182	10.3	17	7.1
Rural	Night	Other	14	233.3	89	69.0	6	27.3
Urban	Day	Limited	40	15.2	455	2.6	66	3.1
Urban	Day	Major	36	38.7	445	7.4	41	7.4
Urban	Day	Other	65	45.1	926	15.5	53	10.7
Urban	Night	Limited	4	10.8	63	2.1	4	1.2
Urban	Night	Major	0	0.0	64	9.4	5	10.9
Urban	Night	Other	11	122.2	68	18.0	8	23.5
Total			314	30.3	5,179	6.8	509	5.7

While some of the rates in this table should be interpreted with care given that the sample sizes are small, the results from table 5-2 (and related analysis not shown here) can be summarized:

In virtually all instances, bobtail crash involvement rates are far higher than those for singles and doubles.

Rates for doubles are generally somewhat lower than those for singles. It should be noted that this is the case regardless of whether all, one-vehicle, or multi-vehicle crashes are considered although the breakdown by number of vehicles involved is not shown in table 5-2. The same differential holds regardless of whether the truck in the crash was noted as vehicle-1 (the more-at-fault vehicle in the crash) or vehicle-2 (the less-, or not-at-fault vehicle) in the crash.

Although there are just over 300 bobtail involvements, the highest rates tend to be at night, generally in rural areas, and, most clearly, on the lowest class of roadway.

Singles involvement rates are always higher for lower classes of roadways—rates for major highways are typically two to three times higher than for limited access highways; and rates for other highways are typically seven to ten times higher than for limited access highways.

Singles involvement rates for night conditions are, at worst, about twice as high as for daytime conditions—typically for rural, other roads. The difference between night and day is not as distinct for urban areas. Generally, urban rates are lower than rural rates regardless of roadway class.

The results noted for singles are reasonably consistent regardless of whether the involvement is as vehicle-1 or vehicle-2.

Although limited by sample size considerations, doubles rates are lower than singles in most instances—the principal exception (from table 5-2) is on urban, limited access roads during the day.

Further analysis indicated that doubles rates were higher than singles in some specific situations such as: for one-vehicle involvements, rural limited access highways during the day; and for multi-vehicle involvements, rural major roadways during the day and urban limited access roadways during the day. It is interesting to note that the higher one-vehicle crash rate is primarily due to rollover crashes, a crash type for which doubles are well-known.

Table 5-3
Overall Tractor Casualty Crash Rates
(all involvements)
Michigan Tractors on Michigan Roads

Travel Category			Bobtail Crashes	Bobtail Rate	Single Crashes	Single Rate	Double Crashes	Double Rate
Rural	Day	Limited	7	3.3	188	0.9	21	0.9
Rural	Day	Major	12	5.7	241	1.9	31	2.1
Rural	Day	Other	22	84.6	200	6.3	26	8.1
Rural	Night	Limited	2	8.3	63	1.5	11	1.2
Rural	Night	Major	0	0.0	61	3.5	5	2.1
Rural	Night	Other	7	116.7	22	17.1	2	9.1
Urban	Day	Limited	9	3.4	107	0.6	13	0.6
Urban	Day	Major	4	4.3	92	1.5	11	2.0
Urban	Day	Other	7	4.9	118	2.0	17	3.4
Urban	Night	Limited	0	0.0	23	0.8	1	0.3
Urban	Night	Major	0	0.0	19	2.8	0	0.0
Urban	Night	Other	4	44.4	19	5.0	6	17.6
Total			74	7.1	1,153	1.5	144	1.6

Rates considering only casualty crashes are shown in table 5-3. The results shown in this table (which repeats table E-2 in the Appendix E) and from related analysis (not shown here) can also be summarized:

> Although there is an even greater scarcity of bobtail data, bobtail rates are higher than those for either singles or doubles. The ratio of the rates is about the same as it was when all (casualty and non-casualty) crashes were considered. In contrast to the set of all crashes, when only casualty crashes are examined, the overall doubles rate is higher than the singles rate. More specifically, it appears that doubles rates are higher than singles for day conditions in both rural and urban situations, and regardless of roadway class. Sample sizes for the disaggregated rates are, however, very small.
>
> When a differentiation between involvement as vehicle-1 and vehicle-2 was made, both singles and doubles have higher rates as vehicle-2 (vs. involvement as vehicle-1) in casualty crashes than they did for all crashes; and doubles have a lower involvement rate as vehicle-1 than singles (in casualty crashes).

While the disaggregated casualty crash rates shown in table 5-3 are of considerable interest, the sample sizes are, as noted, quite small in some instances. However, the crash and travel data can also be aggregated by the key variables and yield rates such as daytime rates for different truck types regardless of roadway class and urban/rural classification. The results of calculating such aggregated rates are given below in summary form. All rates are given in crashes per million vehicle-miles.

Table 5-4
All and Casualty Crash Rates
by Truck Configuration

	all crashes	casualty crashes
bobtails:	30.30	7.15
singles:	6.79	1.51
doubles:	5.69	1.61
total:	6.96	1.59

The above rates serve to highlight the fundamental differences between the different types of trucks and the impact of including property-damage-only (PDO) crashes in the rate calculation. The bobtail rates are clearly far higher than those for combination trucks, and inclusion of the PDO crashes tends to "wash out" some of the differences between truck types. When PDOs are included, the singles rate is considerably higher than the doubles rate—however, when only casualty crashes are considered, the differences between singles and doubles are very small.

Table 5-5
All and Casualty Crash Rates
by Truck Configuration and Urban/Rural Area

	all crashes		casualty crashes	
	urban	rural	urban	rural
bobtails:	28.21	32.71	4.34	10.35
singles:	5.99	7.42	1.12	1.82
doubles:	4.93	6.21	1.34	1.79
total:	6.22	7.54	1.19	1.90

The aggregation of urban and rural rates (regardless of roadway type and time of day) shows that, in general, rural rates are higher than those in urban areas (regardless of truck type and whether PDOs are considered). Furthermore, in both urban and rural areas the bobtails rates are still far higher than combination trucks. The rates for singles and doubles are very similar to each other although both have higher rural rates. The ratio of rural to urban rates is greater when only casualty crashes are considered (for both singles and doubles). It should also be noted that as PDO crashes tend to "drive" the overall rates, singles crashes also tend to dominate when, for example, the total rate is considered.

Table 5-6
All and Casualty Crash Rates
by Truck Configuration and Time of Day

	all crashes		casualty crashes	
	day	night	day	night
bobtails:	28.33	51.11	6.45	14.44
singles:	6.82	6.57	1.43	2.04
doubles:	6.08	3.97	1.63	1.53
total:	7.02	6.55	1.51	2.07

The differences between day and night rates are somewhat less clear than the other aggregated rates considered to this point. Overall, when all crashes are considered, the night rates are lower than the day rates, although this is not the case for bobtails. For combination trucks, there is more of a difference for doubles than for singles—i.e., the night doubles rate is much lower than the day rate. However, when only casualty crashes are considered, the night rates are higher for both bobtails and singles. The doubles rate is still somewhat lower at night than during the day. The "total" rate shows that when only casualty crashes are considered, combination trucks tend to have higher night rates—this is, however, driven by bobtails and singles.

Table 5-7
All and Casualty Crash Rates
by Truck Configuration and Road Type

	all crashes			casualty crashes		
	limited	major	other	limited	major	other
bobtails:	13.11	26.81	85.95	3.37	5.05	21.62
singles:	3.28	7.80	21.03	0.84	1.94	3.72
doubles:	3.16	7.47	17.55	0.80	2.01	5.85
total:	3.37	8.02	21.87	0.86	1.99	4.20

The aggregated rates by roadway type show a clear and consistent trend: the lower the road class, the higher the crash rate, regardless of truck type or whether all crashes or only casualty crashes are considered. The similarity between the rates for singles and doubles should also be noted although there is some divergence between the two when the lowest road class is considered.

5. Principal Findings and General Conclusions

As with any study of this magnitude, there is a host of sometimes confusing and/or contradictory results. However, it may be argued that there are several dominant findings that resulted from the project, notwithstanding some relatively minor variations. With regard to the three truck types that were considered,

- the bobtail configuration clearly has the most serious problem safely negotiating the highway system; and
- the performance of single and double truck configurations are generally quite similar to one another in terms of overall safety on the highway system.

In addition to the differences (or lack of them) that are attributable to truck type, there are also effects that are due to differences in the truck operating environment. In this study, environmental effects were limited to the type of roadway, the time of day, and whether the trucks were operating in rural or urban areas. The principal effects that were attributed to variation in these parameters are:

- the most significant and consistent effect appeared to be due to the type of roadway since crash rates for all types of trucks were highest on other roadways and lowest on limited access highways (generally regardless of variation of other variables);

- crash rates were generally lower in urban areas than they were in rural areas, regardless of truck type;

- at more aggregated levels, nighttime crash rates were lower than daytime rates for combination trucks (although the differential was greater for doubles) but higher for bobtails; overall, casualty rates were higher at night;

- there was some evidence of interaction among environmental variables, especially when the day and night rates were considered, that affected singles rates (i.e., several singles rates were higher at night).

- drivers under age 25 or over 60 were over-involved in crashes; the highest risk was shown for drivers aged 19-20, who were over-involved by a factor of 5.

Some of the findings reported above confirm earlier work. Of greater importance, however, is the general finding that the crash rates for singles and doubles are not radically different from one another, though part of the reason that doubles have relatively low crash rates is that most of their travel is on limited access roads, the safest in the highway system. It was also found that the other factors that appear to affect the relative safety of one type of truck have similar effects on the others as well. This is especially interesting since Michigan has liberal truck weight regulations and considerable experience with doubles on the highways. This is not to say that there are not specific instances when doubles do not perform as well as singles, but that in general they appear to present a similar degree of risk.

Perhaps the most significant and somewhat unexpected finding was the degree of degradation of relative truck safety when lower classes of roadway were considered: the crash rates on the lowest class of roadway were five to seven times higher than those on the limited access system. This far overshadows the effects of truck type or any of the other environmental factors.

6. Implications for Truck Crash Countermeasures, Highway Safety Policy, and Future Work in Michigan

The implications for truck crash countermeasures, highway safety policy, and future work in Michigan are varied. Given that the work just completed provides an accurate overview of the truck safety problem in Michigan, the most important implications for the future are the need for more specificity in future work and the need to move forward in developing, implementing, and evaluating countermeasures.

Improvements in Crash Data

In order to move forward with work in truck safety in Michigan, one of the key areas needing attention is data collection. Although the crash data available in Michigan are among the best in the nation, there are some shortcomings which were highlighted during this study. Specifically in regard to trucks, the data are inadequate in terms of describing the vehicle itself—truck tractor and trailer descriptions lack specificity (e.g., trailer type, tractor description, length and width, number of axles). Perhaps even more importantly (and of concern beyond just trucks) is the need to be able to effectively and efficiently merge data from the various files that are maintained by the state—e.g., crash data, vehicle registration data, and driver information.

The proposed Michigan Supplemental Truck and Bus Traffic Accident Report promises to remedy some of these problems by providing additional information on operating authority, gross vehicle weight rating, vehicle configuration, and cargo body type. Vehicle combination weight, length, width, and number of axles are not included on the form. The amount of detail on the physical characteristics of the truck that the supplemental report will provide is minimal, but it is an important first step toward capturing more complete information.

This study uncovered some evidence that suggests very few of the truckers on Michigan roads have had any driver training. Currently, there is no accident data on the driver training of truckers involved in crashes, though with the Commercial Driver License program and the growing emphasis on driver training, there will be a need to evaluate the safety impact of driver training schools.

As it stands at this point, the current data cannot be used to evaluate other key issues that have come up in the last several years—for example, it is virtually impossible to assess the impact of longer and/or wider trucks on Michigan's highways. Issues related to carrier type, e.g., examining the safety experience of inter- versus intrastate carriers, cannot be undertaken using currently available data. Further, it would be difficult, if not impossible, to differentiate the effect of increased numbers of doubles operating on Michigan roadways as a result of the 1982 Surface Transportation Assistance Act (STAA) from the pre-STAA doubles that were already allowed in Michigan.

Improvements in Truck Exposure Data

The exposure data gathered by UMTRI for this study are unique for the state and for a specific time period. Beyond these data, currently there are no viable truck exposure data being collected in Michigan that can be used for anything more than the grossest statewide analysis. If further rate-based work is to be done on truck safety in Michigan, particularly given the dynamic nature of the trucking industry, a methodical data collection plan needs to be implemented which will permit the calculation of vehicle miles of truck travel differentiated by truck type, roadway class, and selected other environmental variables. These data should include all trucks using Michigan roads.

Further Work on the Relationship between Truck Crashes and Geometry

One of the original objectives for the current project had been exploration of the relationship between roadway geometry and truck type. As noted earlier, as the project progressed, problems with data reduction acted to curtail the scope of what was studied. This project has, however, confirmed that restrictive geometry (as measured by which class of road is being considered) is a serious problem in truck safety. In fact, examination of some crashes showed that even the low crash rates for limited access highways may be overstated. For example, it was shown that a sizable number of one-vehicle crashes involving doubles resulted from overturns on ramps.

More work is required which is addressed to identifying those geometric characteristics which are specifically related to truck crashes. This should include not only consideration of the characteristics of the crashes and the roadways but also truck loading and travel characteristics. For example, the crash potential on ramps is related not only to the interaction between truck type per se and ramp geometry but also to the specifics of the truck configurations and their loads.

7. Conclusion

The work on the travel and safety of Michigan trucks presented in this report has covered considerable ground. The survey has determined the number of Michigan trucks and how they are distributed by licensed weight and the type of company which operates them. Travel information at a level of detail unavailable elsewhere has been collected and analyzed. The work also included a survey of the men and women who drive the trucks included in the study, to determine their level of training. Moreover, the Michigan crash experience of trucks spanning nearly a decade has been examined and compared to the rest of the motor vehicle population. Some problems in the collection and coding of that data have been identified. The study also presented data which speak to the role of the truck in motor vehicle crashes, and the size and seriousness of the truck safety problem, compared to other vehicles on the road.

But the main product of this study, the focus of the work, has been on the factors which affect the probability of crash involvement for Michigan tractors. For this, a substantial framework which can support future work has been constructed. By calculating and comparing crash rates in different circumstances, the role of the different tractor configurations has been clearly delineated. The bobtail configuration, a tractor without a trailer, has the highest crash rate of any configuration, sometimes several times higher. Overall, singles are similar to doubles, though there are differences between road types. Road type itself has been shown to have a large impact on crash rates. Some types of roads are much safer to operate on than others. The interstate highway system and other roads built to that standard are clearly the safest, while the U.S.- and State-numbered routes have crash rates about twice as high, and the remainder of the road system has rates nearly seven times as high. The more complicated impact of nighttime operations has also been explored. Casualty crash rates were higher at night, but PDO rates were higher during the day, when traffic densities are higher. And despite the fact that urban areas typically have higher traffic densities, rural areas generally had higher involvement rates than urban areas.

While this study has been comprehensive, by no means has it been exhaustive. Many questions remain. The analysis can be extended in several productive directions. The impact of carrier type, gross vehicle weight, and trailer cargo body are all opportunities for further research. Limitations in the information available from the UD-10, Traffic Accident Report, prevented this study from investigating carrier type, particular types of cargo bodies, or the impact of gross vehicle weight on the probability and seriousness of a crash. In an era of deregulation, differences in the safety record of various categories of truck operators will be of increasing interest, as well as an evaluation of any safety benefit from driver training schools. There is also considerable interest state wide in such combinations as Michigan gravel trains, not only in terms of load spillage, but also given the great weights at which these vehicles operate. The crash rates of tank trailers, particularly doubles, should also be examined—for example, the association between gross weight, road type, and rollover is an important safety issue.

Dealing with these issues requires additional data. Information on, for example, the cargo body, gross weight, and carrier type of trucks involved in crashes would have to be assembled. There may be some further work necessary as well to keep current with the changing trucking industry and to extend the analysis to all trucks operating on Michigan roads. But the necessary research techniques and methodologies have been established and demonstrated, in part by the present study. Moreover, by detailing the structure of trucking in Michigan and by identifying major factors affecting truck safety, the work represented by this report has laid a firm foundation that can support the exploration of future truck safety issues.

UMTRI-90-1-1

THE MICHIGAN HEAVY TRUCK STUDY

A Joint Project of

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FINAL REPORT

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Michigan Office of Highway Safety Planning, or the U.S. Department of Transportation, Federal Highway Administration, or the U.S. Department of Transportation, National Highway Traffic Safety Administration.

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15. Supplementary Notes

An Executive Summary was distributed separately as UMTRI-90-1-2. This material is included in the full report, UMTRI-90-1, as Section 5.

16. Abstract

This report presents an analysis of the travel, crash frequencies, and crash rates of large trucks registered in Michigan. The project focused on the travel and crashes of Michigan-registered trucks in Michigan. The travel data are from the UMTRI Michigan Truck Trip Information Survey (MTTIS). Crash frequencies are from the computerized file of police accident reports maintained by the Michigan State Police, supplemented by data on the state-of-registration of involved trucks compiled by Michigan State University. The project was undertaken jointly by UMTRI and the Michigan State University Department of Civil and Environmental Engineering.

The research approach and survey methods are described. Estimates of the travel and population of Michigan-registered tractors are presented, along with crash frequencies for several subsets of interest. The factors addressed in the risk analysis are: truck type, crash severity (fatal, injury, property-damage-only [PDO]), road type (limited access, major artery, other), urban/rural, day/night. The results indicate that the bobtail tractor configuration has the highest risk on all parts of the Michigan highway system. Crash rates for singles and doubles are quite similar overall, though the doubles rate is higher for casualty crashes on major artery and other roads. Limited access roads had the lowest rates, followed by major arteries, and other roads. Crash rates were lower in urban areas than rural. Overall, daytime rates were higher than nighttime. Casualty crash rates were higher at night, but PDO rates were higher during the day in both urban and rural areas, but particularly urban. Traffic density appears to explain the higher overall daytime rate.

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TABLE OF CONTENTS

SECTION 1
OVERVIEW AND STUDY DESIGN

1.1 Introduction

The trucking industry has experienced fundamental changes in the past decade. Shifts in the regulatory environment in which trucking operates has transformed the industry. In 1980, the economic regulation of interstate trucking by the Interstate Commerce Commission was significantly relaxed. The Surface Transportation Assistance Act (STAA) of 1982 permitted the use of double-trailer combinations on the interstate highway system, required states to regulate the length of trailers in combination vehicles instead of overall length, and established the Motor Carrier Safety Assistance Program. The Commercial Motor Vehicle Safety Act of 1986 established national standards for a commercial driver's license to operate the largest trucks.

These developments have had an important impact on the trucking industry. In response to the relaxation of economic regulation of interstate carriers, there has been a dramatic increase in the number of trucking companies. At the same time, competitive pressures have driven many weaker companies out of business. The STAA has resulted in significant expansion of the role of double-trailer combinations, particularly on the interstate highway system, as well as pressure to expand the amount of non-interstate roadways open to them. The Commercial Driver's License program (CDL) will limit truckers to a single driver's license and enforce uniform licensing requirements. The trucking industry is probably as dynamic currently as it ever has been in its history.

The impact of these changes on Michigan has been conditioned by the special circumstances in Michigan. The state has long had some of the most liberal size and weight regulations for trucks in the United States. Michigan allows double-trailer combinations to operate at gross combination weights up to 164,000 pounds, while states bordering Michigan have had more restrictive regulations. This has resulted in a significant intrastate segment of the Michigan trucking industry which operates vehicles designed to conform to the Michigan regulations. Thus, Michigan has had more experience with double-trailer combinations than other states. But, despite the liberality of Michigan weight laws, deregulation at the federal level has raised the issue of deregulation of intrastate trucking in Michigan.

Many of these changes have raised national concerns about their impact on truck safety. It has been suggested that deregulation will lead to lowering safety standards, the proliferation of inexperienced operators, and pressures to cut corners to compete. Double-trailer combinations are commonly perceived as inherently more threatening than smaller trucks. And the CDL is certainly a reflection of popular concern about the ability and quality of the drivers of large trucks.

The safety of large trucks is also an issue in Michigan. Crashes in Michigan involving large trucks increased 81% over the period 1982-1986, though they declined about 9% during 1987-1988. All traffic crashes increased by about 40% from 1982 to 1988. Over the same period of time, economic conditions have improved substantially in the state and truck travel has increased as a result. In the face of so many changes, the problem is to identify the significant factors associated with truck crashes. Yet, for all the interest in large-truck safety, little is accurately known about the risk of crash involvement, or the factors which significantly influence this risk, either at the national level or in Michigan.

In 1986, the Michigan Office of Highway Safety Planning initiated a project to address these problems. The project was undertaken jointly by the Michigan State University Department of Civil and Environmental Engineering and the University of Michigan Transportation Research Institute (UMTRI). The objective of the joint project was to develop statistical information on crashes, travel, and the risk of crash involvement in Michigan of truck-tractors registered in Michigan. For this study, risk is estimated as the number of vehicles involved in crashes per million vehicle-miles traveled, or the crash involvement rate. By calculating crash rates for various types of trucks on different types of roads in rural versus urban areas and during the night as opposed to day, the relative risk associated with each of these factors can be estimated.

1.2 Study Design

Michigan crash data are recorded in the field by state and local enforcement agencies on a common form (the UD-10, Traffic Accident Report, reproduced in Appendix A). The data are transferred from these forms along with other interpretative data to a computer record by the Michigan State Police (MSP), and made available to researchers and other users by MSP and the Michigan Department of Transportation (MDOT). Although the accident files are not without some problems (see Section 3 for a discussion of problems affecting this project), they can be used to identify the types of vehicles involved in each crash that occurs. In addition, the accident file contains considerable information about the drivers, vehicles, causes, and location of each crash. After manipulation and "cleaning," the accident data files provide a reasonably accurate assessment of crash frequencies in Michigan. These data can be used to arrive at the numerator of a crash rate—typically expressed as crashes per million vehicle miles. The preparation of the accident files for this project was basically the responsibility of MSU.

The missing component in most crash rate studies, and especially in those addressing truck-involved crashes, is accurate exposure data. That is, how many vehicle-miles of travel have been logged by the type(s) of vehicles in question? For truck studies, most of the data used are approximations based on traffic counts from truck weigh stations or from mechanical counters at general vehicle counting stations (e.g., stations for estimating annual daily traffic). Accurate data by truck category, let alone further stratified by roadway type, are typically unavailable. To overcome this shortcoming, UMTRI developed a survey method where mileage figures are obtained directly from the owners and/or operators of a sample of tractors registered in Michigan. UMTRI conducted the Michigan Truck Trip Information Survey (MTTIS) to provide travel data for this project.

Tractors were selected for the MTTIS from trucks registered in Michigan as of February 28, 1987. (A tractor is a large truck without a cargo body of its own, but with a fifth wheel to attach and pull semitrailers. This definition will be used throughout the report.) Trucks not registered in Michigan were not included in the sample. The scope of the present study is limited to trucks registered in Michigan involved in crashes in Michigan. Accordingly, the correct measure of exposure for calculating rates is the travel in Michigan of trucks registered in Michigan, which is precisely what the MTTIS surveyed. The study covers the twelve-month period from May 1987 through April 1988. The exposure survey is described in detail in Section 2.

The purpose of the project, as stated earlier, was to develop crash rates for Michigan-registered trucks operating on Michigan's highway network. More specifically, UMTRI/MSU were to determine differential truck crash rates for combinations of the following variables:

truck types

1. bobtails—tractors without trailers,
2. singles—tractor and semitrailer combinations, and
3. doubles—tractor, semitrailer, and full-trailer combinations;

roadway types	1. limited access—free, limited access highways,	
	2. major artery—principal and other through highways and other four-lane divided highways (not included in 1), and	
	3. other—all other streets and roads;	
rural/urban	1. rural—population code of 2,500-5,000 or less	
	2. urban—population code greater than 5,000; and	
day/night	1. day—6:00 A.M.-9:00 P.M.	
	2. night—9:00 P.M.-6:00 A.M.	

These are the definitions of the variables which were used in the analysis. They will be referred to frequently throughout this report, and the definitions may be repeated where appropriate for clarity's sake. But in every case, whether the definition is repeated or not, the definitions will be those given above.

At a series of meetings early in the project (1986) between the research team, OHSP, and several other agencies and/or interested parties (e.g, user groups), several hypotheses were developed. These hypotheses were modified as the project progressed—primarily by practical limitations imposed by the data being collected. The operational hypotheses are discussed in general terms below and the original list is contained in Appendix B.

The operational hypotheses generally addressed the extent to which trucks were over- or underinvolved in highway traffic crashes. More specifically, this was expressed in terms of total crashes, total casualty crashes, casualty crashes on specific types of highways (e.g., limited access vs. major artery), single-vehicle casualty crashes, and nighttime casualty crashes. Other hypotheses were directed to the age and experience level of the truck driver and whether there was a difference in crash rates between large fleets and privately owned trucks.

The material for this report could not be efficiently organized around the operational hypotheses, and so they will not be directly discussed in the body of the report. Some could not be addressed within the scope of the study. For others, the results of exploring the underlying issues went beyond the particular hypotheses. The hypotheses concerning truck involvements relative to those of other vehicle types are addressed in Section 3. Material relevant to the hypotheses covering driver age, single-vehicle crashes, and nighttime crashes is presented in Section 4. The hypothesis concerning the effect of truck configuration on crash involvement is covered in Section 3 and Section 4.

The hypotheses concerning the so-called "green routes," company type and trucks licensed for over 80,000 pounds could only be partially addressed. Section 3 includes a discussion crash frequencies on "green routes," truck routes designated by MDOT. Section 2 includes material about those questions drawn from the travel data. This section also presents material about the age and training of truck drivers.

Several of the issues that had been originally identified could not be addressed. These included concerns with truck combinations of specific length and with specific types of trailers which could not be addressed due to limitations of the data. Dealing with these questions directly would require a significant expansion of the detail available from the crash data.

1.3 Overview of Truck Crash Experience in Michigan

In 1982 there were just under 300,000 motor vehicle crashes in Michigan. Of these, 4.4% (about 13,000) involved some kind of truck larger than a pickup or panel truck. In 1988, the most current year for which all crash data are available, there were over 410,000 total crashes in Michigan, of which 5.2% involved a large truck (21,233). Table 1-1 compares truck crashes with all crashes for the years 1982 to 1988.

TABLE 1-1
Truck Crashes and All Crashes, 1982-1988

Vehicle	1982	1983	1984	1985	1986	1987	1988
All	295,195	300,990	335,303	387,069	400,840	397,388	410,587
Trucks	12,928	13,696	16,497	21,307	23,412	21,427	21,233
	(4.4)	(4.6)	(4.9)	(5.5)	(5.8)	(5.4)	(5.2)

NOTE: Figures in parentheses show truck percentage of all crashes.

Overall, truck crashes increased by 64% from 1982 to 1988, although the number of such crashes peaked in 1986 and decreased in the following two years. All crashes increased by 39% from 1982 to 1988. The number of such crashes declined in 1987, but reached a new high in 1988. Figure 1-1 shows the percent increase in the number of crashes, using 1982 as the base year.

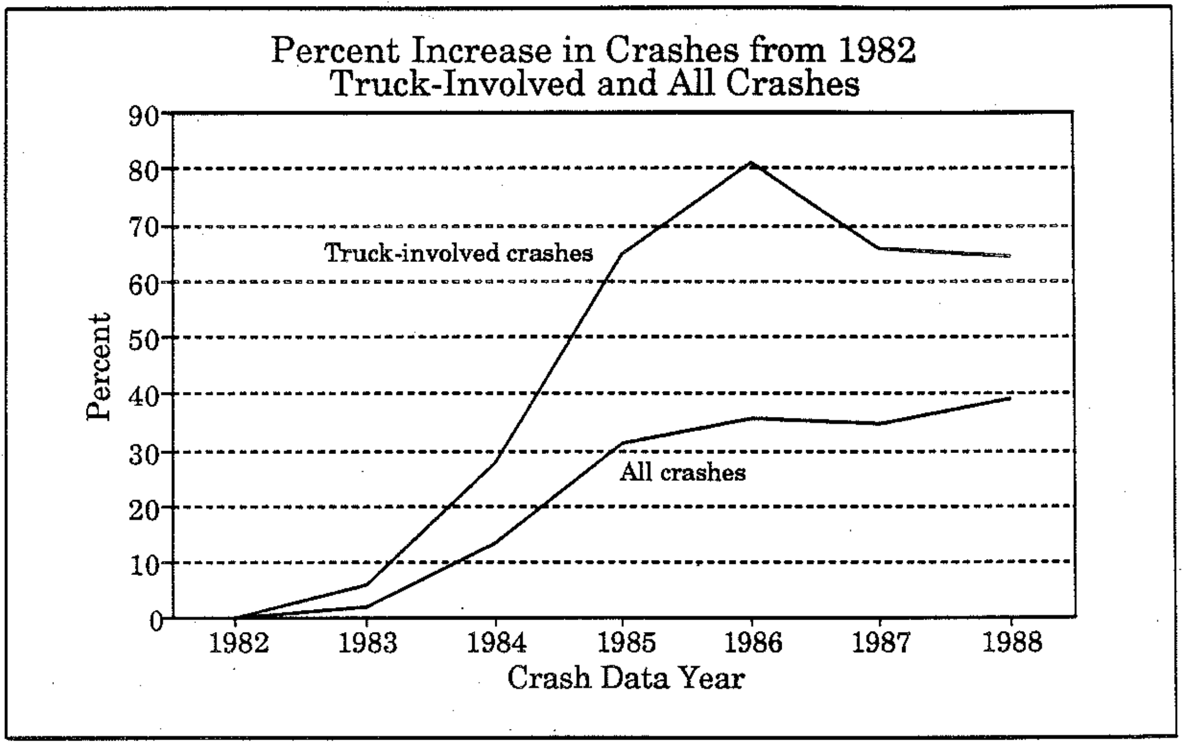

Figure 1-1

Table 1-2 breaks down the trucks involved in crashes by truck type. The number of singles (tractor and semitrailer combination) involved in crashes in 1982 is imprecise because of data irregularities which are likely to have caused an undercount of up to 20%. With this in mind, the number of singles was probably about 6,000. The number of doubles involved in crashes was 333 (2.4% of truck crashes). Errors in how "bobtails" (tractors operating without a trailer) and singles were coded caused gross errors in both categories through 1986. In 1988, 42.3% of the trucks (almost 9,000) were singles and 3.5% were doubles (just under 750). The percentage of crashes involving any kind of truck has remained reasonably stable at around 5 to 5.5% over the past five years. Double involvement has remained reasonably constant as a percentage of all crashes (0.1-0.2%), as a percentage of all truck crashes (from a low of 2.4% in 1982 to a high of 3.5% in 1988), and as a percentage of all combination truck crashes.

TABLE 1-2
Truck Crashes by Truck Type, 1982-1988

Type	1982	1983	1984	1985	1986	1987	1988
Straight	5,901	5,866	6,782	9,833	11,942	10,774	10,289
	(42.7)	(40.7)	(39.0)	(46.1)	(51.0)	(44.3)	(48.5)
Bobtails	1,598	1,709	2,022	2,522	2,249	450	454
	(11.6)	(11.9)	(11.6)	(11.8)	(9.6)	(1.8)	(2.1)
Singles	4,345	4,880	6,195	7,109	7,223	8,726	8,971
	(31.4)	(33.9)	(35.6)	(33.4)	(30.9)	(35.9)	(42.3)
Doubles	333	398	512	610	664	668	741
	(2.4)	(2.8)	(2.9)	(2.9)	(2.8)	(2.7)	(3.5)

NOTE: Figures in parentheses show truck type percentage of truck crashes for the year.

It is clear that truck crashes represent a relatively small percentage of all crashes occurring in any given year. They are, however, increasing at a rate that is higher than the overall increase in crashes. While these data provide an overview of recent truck crash history in Michigan, it remains an open question as to just how large a safety issue truck operations really constitute. It is within this context that the study was undertaken.

1.4 Overview of Truck Travel in Michigan

Based on the travel survey, there were 34,577 tractors registered in Michigan as of February 28, 1987. The total travel of these trucks in Michigan during the 12-month study period is estimated to be 883 million miles, or an annual average of about 25,500 miles in Michigan for each tractor. This information is summarized in table 1-3.

Table 1-3
Tractors Registered in Michigan
as of February 28, 1987

Number of Tractors	34,577
Average Annual Miles in Michigan	25,500
Total Travel in Michigan	883,230,000

Travel in Michigan by tractors registered in Michigan was classified by several of the factors to be addressed in the study. Over 88% of the tractor travel was accumulated with a single semitrailer, while double trailers were used for 10.4% of the tractor travel. Sixty percent of the tractor travel was on interstate or other limited access roads. Major arteries and numbered U.S. and state routes that were not limited access were used for 28% of the travel, with the remainder on other county roads and city streets. Overall, 44% of the travel was in urban areas with the remaining 56% in rural areas. Only 14% of the travel was between 9 P.M. and 6 A.M., the time period used to characterize night travel.

Almost a third of Michigan's tractors are licensed to gross over 80,000 pounds, though only about 14% of their travel is at such heavy weights. Of the 118.8 million miles of travel during the study year at gross weights over 80,000 pounds, 62% was accumulated by singles and 38% by doubles. The study showed that most operations at weights over 80,000 pounds are conducted by private firms. Overall, private companies, as opposed to for-hire haulers of freight, account for most of the tractor mileage accumulated in Michigan by Michigan-registered tractors, but their preponderance among the heavy-licensed tractors is even greater. Still, for-hire companies, whether interstate or not, are responsible for almost 45% of the tractor travel.

1.5 Report Organization

The remainder of this report provides a more detailed description of the various aspects of the study. The travel survey conducted by UMTRI, called the Michigan Truck Trip Information Survey, is described in Section 2. Section 2 covers the sample design and survey methods, estimates of the number of tractors and their annual travel in Michigan, distributions of travel by truck type, road type, day/night, rural/urban, and gross combination weight, and some survey results on driver training. The crash data developed by MSU from the information on the Michigan UD-10 traffic accident report form are presented in Section 3. Historical truck crash trends and a comparison of the study year with other years are covered in this section, along with distributions by crash type, crash severity, vehicle type, and driver age. The crash and travel information are combined for tractors to calculate crash rates. The resulting crash rates are presented in Section 4. Crash rates are calculated separately by road type, truck configuration, rural/urban, and day/night. Rates for single-vehicle and multiple vehicle crashes are presented for all police-reported crashes and casualty crashes only. Crash rates are also calculated by age of the driver in Section 4. Section 5 presents a summary of the findings and recommendations are made with regard to traffic crash records and further research.

Table and figure references are given in a hyphenated form such as 2-1 or C-2. The letter or number before the hyphen indicates the section of the report containing the figure or table. Summary figures and tables are included in the body of the report, so that figure 2-1 refers to the first figure in Section 2. However, the large number of supporting tabulations are in Appendices C-E, and are referenced as C-1 to indicate the first table in Appendix C. Appendix A contains the UD-10 accident report form, and Appendix B has the original list of hypotheses developed prior to the study. Appendix C contains tables showing travel distributions that support the analysis presented in Section 2. Tables of crash frequencies supporting the analysis in Section 3 are in Appendix D, and Appendix E has tables of travel, crash frequencies, and crash rates which contain the underlying data analyzed in Section 4.

SECTION 2

TRUCK TRAVEL IN MICHIGAN

2.1 Introduction

In this section, the population and travel of trucks registered and operating in Michigan will be described, along with some information about the age and training of Michigan truck drivers. The source of this information was the Michigan Truck Trip Information Survey, a telephone survey of trucks sampled from Michigan Department of State registration files. First, the survey protocol and procedures will be described. Then, the Michigan truck population is discussed in some detail. The distribution of tractors by company type and licensed weight is discussed. Travel distributions by road type, time of day, population area type, vehicle configuration, and cargo loading are presented. Finally, the drivers of the trucks will be considered. Distributions of travel by age category will be presented, as well as discussions of the proportion of drivers who have been trained and the type of training they received.

The purpose of this section is to present an overview of trucks and trucking in Michigan, to provide a background for the discussion of crashes and crash rates which follow in later sections. The Michigan truck population is unique among the states. Generous Michigan weight laws regulate gross weight per axle and the total number of axles on a combination, but do not directly limit the gross weight of a tractor-trailer combination. The result is that Michigan licenses tractors to far higher weights than other states, sometimes to weights exceeding 160,000 pounds. Moreover, an understanding of the ways trucks are used in Michigan is essential to interpreting their safety experience. Subsequent sections of this report will present crash distributions and rates. The material in the present section provides a context for those discussions.

2.2 The Michigan Truck Trip Information Survey

The Michigan Truck Trip Information Survey (MTTIS) was initiated in May of 1987 to collect information on the population and travel of heavy-duty tractors registered and operating in Michigan. A random sample of trucks for the survey was drawn from registration files maintained by the Michigan Department of State. The target group for the study consisted of tractors with an empty weight over 6,000 pounds. Since virtually no tractors have an empty weight under 6,000 pounds, the study population for the MTTIS covers basically all medium- and heavy-duty tractors registered and operating in Michigan. Straight trucks registered at 80,000 pounds or more were also initially included in the survey. Only 30 were sampled and they were later dropped from the analysis since that number is too small to form a statistically meaningful sample.

The survey was conducted through a series of telephone interviews. UMTRI staff, who had been trained in the fundamentals of trucks and truck operations, contacted each owner. During the first interview, questions covered the basic physical description of the truck—weight, length, cab style, number of axles, and so on. In addition, information was collected about the type of company operating the truck and the typical operations of the truck over the course of a year. After this initial phase, each truck operator was re-contacted during the year on four randomly selected days for information on the actual use of the truck during a twenty-four hour period. For each of these survey days, the interview, in effect, followed the truck during its operations. Questions covered the type and amount of cargo, when it was loaded or unloaded, the type of trailers used, the age and experience of the driver, and so on. Detailed route descriptions were later traced on specially prepared maps, and the actual mileage of the truck for that day was broken down by the time of day, road type, and the type of area, rural or urban, in which the truck traveled.

The result is a data file that provides a detailed picture of trucks and trucking in Michigan. The file contains information on 1,055 tractors registered in Michigan. Of the sample trucks, 71.1% are owned by firms that operate in interstate commerce, while 27.4% operate only within the state of Michigan. For-hire trucking firms own 475 or 45.0% of the sample trucks; private companies operate 564 (53.5%); and 16 (1.5%) are rental vehicles. These tractors took 8,464 trips on their survey days. The total travel of the tractors on survey days was 470,017 miles, all on Michigan roads. Survey interviews gathered sufficient detail about the time of day and the route covered that 96.1% of the travel could be categorized according to road type, time of day, and area of operation. The detail thus accumulated can be used to answer important questions about trucking in Michigan. How many tractors are registered to operate in Michigan? How many miles do they travel in the state, what kind of roads do they use, and how heavily loaded are they? What role do the combinations registered for more than 80,000 pounds play? How many of the drivers receive driver training, and where do they typically get it? The answers to these and related questions are crucial to evaluating the safety of heavy trucks in Michigan.

2.2.1 Sample Design

The file of truck registrations maintained by the Michigan Department of State as of April 1987 was used to draw a sample for the study. The file consisted of all registrations of commercial tractors with an empty weight greater than 6,000 pounds and "other" trucks, i.e., straight trucks, licensed to operate at a weight of 80,000 pounds or more. Trucks participating in the International Registration Plan (IRP) with Michigan as a base state were included. After processing to eliminate duplicate registrations and a few vehicles mistakenly included, the file consisted of 40,796 trucks. This was the "sampling frame" from which the original sample of 1,522 trucks was drawn.

An examination of the expiration dates of the vehicles in the registration file showed that 15,421, or about 37.8%, of the registrations had expired. The registration year for large trucks in Michigan runs from February 28th in one year to February 28th in the next, so registrations for all large trucks expire at the same time. It was thought that the April tape would be current and complete, but a pilot survey determined that of the truck registrations which had ostensibly expired, about 70% had been renewed for the current year. Apparently not all of the transactions renewing registrations had been received and processed by the time the tape was made. Many of the unprocessed registrations were for IRP trucks.

Since the pilot study showed that many of the registrations listed as expired had actually been renewed, it was decided to include expired registrations in the sampling frame. The sampling frame was divided into three groups, or strata, which were sampled separately. The strata employed were: Currently registered, expired IRP registration, and expired non-IRP registration. Selection was made by means of an interval procedure with a random start. The actual sample sizes drawn from each strata were chosen based on the estimated rate of renewed registrations in the expired strata and a projected non-response rate, to ensure that there would be about 1,000 completed cases of trucks with valid current registrations at the end of the survey. Table 2-1 shows the breakdown of the original sampling frame and the number of registrations drawn from each category.

Table 2-1
Original Sampling Frame of Michigan Truck Registrations by Sampling Strata and Sample Size

	Registrations		Sample Size	
	N	Percent	N	Percent
Current Registration	25,375	62.2	819	53.8
IRP Expired	10,484	25.7	456	30.0
Non-IRP Expired	4,937	12.1	247	16.2
Total	40,796	100.0	1,522	100.0

In June of 1987 another tape file of the appropriate truck registrations was obtained. It was expected that the processing of registrations for February would be substantially complete on the June tape. Thus the June tape could be used to determine reliably the population of trucks registered on February 28, 1987. Again the tape was processed to eliminate duplicate registrations and to eliminate a few registrations that did not fit the original filter. Of the original sample of 1,522 trucks, 212 were still listed as expired on the June tape. Accordingly, those 212 expired registrations were deleted from the survey as non-sample vehicles. On the other hand, the June tape contained 1,054 trucks with expiration dates after February 28 that were not included in the April tape. The 1,054 additional registrations that should have been on the original tape were treated as an addition to the sampling frame. The additional registrations were sampled and 34 more trucks were added to the sample, bringing it up to 1,344.

2.2.2 Response Rates and Population Estimates

Table 2-2 shows the disposition of the final sample along with some population estimates. A total of 1,556 registrations was sampled from Michigan truck registration files. Of that total, 212 (13.6%) had expired registrations and thus should not have been included among current registrations. Another 59 were non-sample vehicles on other grounds—one was a light truck, 12 had been destroyed, and 46 were straight trucks with licensed weights under 80,000 pounds. Of the 1,285 remaining registrations, relatively complete information was obtained on 1,085. Two hundred cases could not be completed, due to an inability to locate the owner or the owner's refusal to cooperate. Considering just the 1,285 valid registrations in the sample, the completion of 1,085 cases amounts to a response rate of 84.4%. As noted above, there were 30 straight trucks licensed to gross over 80,000 pounds among the completed cases which were dropped from the file used for this analysis. These straight trucks were deleted after all the weighting procedures had been gone through, so that their elimination would not affect the weights.

Table 2-2
Michigan Truck Trip Information Survey Sample Cases And Population Estimates

	Sample Cases		Population Estimates	
	N	Percent	N	Percent
Complete	1,085	69.7	30,014	71.7
Incomplete	200	12.9	5,590	13.4
Non-Sample	59	3.8	1,705	4.1
Expired Reg	212	13.6	4,541	10.9
Total	1,556	100.0	41,850	100.0

The right-hand side of table 2-2 shows estimates of the population of heavy trucks, straights and tractors, in Michigan. This portion of the table represents, in effect, a "virtual truck registration" file. The population estimate given in the "Total" row was generated from the truck registrations sampled from the April tape plus the additional 1,054 registrations on the June tape which should have been on the April tape. The total, 41,850, is the number of registrations which would have been on the April tape if all registrations had been received and processed by then. Of that total, 4,541 registrations were expired and so should not be counted among current registrations. An additional 1,705 registrations were for light trucks or for vehicles that had been destroyed. The sum of the remaining two figures, which were estimated from the valid cases in the sample, represents the number of straight trucks (licensed for 80,000 pounds or more) and tractors operating in Michigan. There are 35,604 such trucks with Michigan registrations. Tractors account for 34,577 of the Michigan truck population. The remaining 1,027 are straight trucks with licensed weights of 80,000 pounds or more.

2.2.3 Survey Data Collection

Data collection began in May of 1987. Survey interviewing was conducted by telephone whenever possible. Mail versions of the interview forms were used only when the interview could not be completed by telephone. The survey work consisted of two phases. The first phase was the initial contact with the owner. As part of the initial contact, interviewers secured the owner's cooperation, confirmed the sample vehicle's identification, obtained descriptive information on the company and truck, and made arrangements to call back for a detailed travel survey on each of four randomly selected days.

During the second phase of the survey, travel information was collected on the survey vehicles over the course of a year. The survey year ran from May 3, 1987, to May 2, 1988, and was divided into four quarters. Each truck was assigned a "date code," indicating the day for which travel information would be gathered in each quarter. The "date codes" (1-89) correspond to the 89 days of a trip quarter. Date codes were randomly assigned to each vehicle at the time of selection. The list of selected vehicles was sorted by owner, and date codes were assigned in such a way that adjacent vehicles on the list, which could possibly have been operated by the same owner, were not given consecutive date codes. Short, two- or three-day "break periods" were introduced between quarters to allow the staff to prepare for the next quarter of interviewing. The start date for each trip quarter was chosen so that the survey day of any particular vehicle did not fall on a weekend more than twice over the course of the survey year.

Data collection for the trip file went forward at the same time as the initial contacts were being made. During the first quarter of interviewing, both the initial contact and the first quarter of travel information were collected. Questions covered the driver's age and experience, cargo weights and types, the number and type of trailers, and the route followed for the twenty-four hours of the truck's survey day as determined by its date code. In the case of private carriers, the owner was asked if the truck was operated for-hire on that day, and if so whether the trip was interstate and what type of regulatory authority was used. During the third and fourth quarters of the survey, there were additional questions concerning the source and type of the driver training. If the truck was not in use on its survey day, interviewers took the travel information from the most recent day the truck was used prior to the survey day. This strategy made it much more likely that travel data would be collected on each truck during each quarter. In a few cases, the truck operator knew when the truck was last in use but could not recall how the truck was used on that particular day. In these cases, information was collected on the use of the truck on an average day. Those trips were coded so that this "typical" information could be distinguished from information about actual travel on a survey day. In some other cases, the owner did not even know when the truck was last used and so could only give typical trip and frequency of use information. Those trips were also assigned special codes.

The exposure data of interest are the miles accumulated by various configurations according to road type, time of day, population type, and so on. A "trip" was defined to permit the aggregation of miles traveled for any configuration of interest. A new "trip" began whenever there was a change in driver, operating authority, vehicle configuration (e.g., adding or changing trailers, lowering or raising lift axles), or cargo type or amount. Thus, for example, if the driver changed, or cargo was loaded or unloaded, or one trailer type was exchanged for another, the interviewer began a new trip form to track the mileage accumulated by the new configuration. For example, one tractor took 17 trips on one of its survey days. Sixteen times over the course of the day, the configuration of the vehicle changed in a significant way—cargo was loaded or unloaded, the driver changed, a new trailer was added, and so on. Each of the 17 trips was mapped separately, so that travel for each of the 17 configurations can be characterized as to amount, time of day, road type, and area of operation.

The response rate in collecting travel information was reasonably high. Of the 1,055 tractors on which trip calls were made, at least one quarterly trip interview was completed for 986, a response rate of 93.5%. The goal was to complete four trip calls on each tractor over the course of a year, for a total of 4,220 potential travel days. Interviews on a total of 3,603 travel days were actually completed, for a survey day response rate of 85.4%.

2.2.4 File Weighting Procedures

Weights were calculated to permit the estimation of totals for the whole population of tractors in Michigan from the sample of cases in the MTTIS. Calculation of weights for vehicle population totals was quite straightforward. Trucks were sampled from the registration file by strata. The strata were: Currently registered, expired IRP registration, and expired non-IRP registration. An interval selection procedure was used within each stratum. The resulting "sample weight" is simply the sampling frame total for a particular stratum divided by the number of vehicles selected from that stratum. Table 2-1 presented at the beginning of this section shows the frame totals and sample sizes for each stratum. The only adjustment factor calculated for these weights was for "non-contact," that is, a correction for cases that could not be completed. There were 200 such cases. The "final contact weight" is simply the product of the original sampling weight times the non-contact adjustment. This is the weight that is used to produce Michigan population totals for all vehicle-level variables.

A number of weights and inflation factors were calculated to permit the estimation of annual mileages for the Michigan tractor population from the sample of travel on survey days. The weight variable used in producing these annual mileage estimates is basically the product of the vehicle weight used in calculating population totals times a factor that inflates the survey day mileage to an annual basis. This weight was produced by correcting for survey of trips that could not be completed and then inflating the mileage from the four travel survey days up to an annual basis. A complete discussion of weighting procedures can be found in *Michigan Truck Trip Information Survey*, Daniel F. Blower and Kenneth L. Campbell, UMTRI Report 88-48.

2.3 POPULATION AND TRAVEL

2.3.1 Population Estimates and Annual Travel

Table 2-3 below shows some population estimates of trucks registered in Michigan as of February 28, 1987, the sampling date for the MTTIS. The first section of the table shows the number of vehicles estimated to be registered in Michigan. The next two sections give some estimates of their travel. The population of tractors and straight trucks is shown separately and within each power unit type broken down by licensed weight. As mentioned above, straight trucks registered for less than 80,000 pounds were not sampled. There are roughly a thousand straights registered to gross more than 80,000 pounds. There are nearly 35,000 tractors, of which about 30% take advantage of the Michigan weight laws by being licensed to gross over 80,000 pounds.

Table 2-3
Trucks Registered in Michigan
as of February 28, 1987

Registered Weight	Straight Truck	Tractor
Number of Trucks		
Up to 80,000	Not Sampled	24,687
More than 80,000	991	9,890
Average Annual Miles in Michigan		
Up to 80,000	Not Sampled	21,315
More than 80,000	34,547	36,100
Total Travel in Michigan (Miles)		
Up to 80,000	Not Sampled	526,200,000
More than 80,000	34,220,000	357,030,000

The travel figures in the table represent only travel in Michigan. They are from the MTTIS, which surveyed the Michigan travel of trucks registered in Michigan. Thus, during the survey, when a vehicle crossed the state's borders, its mileage was no longer recorded. Looking at the tractor figures, those licensed for 80,000 pounds or less average about 21,000 miles in the state. Nationally, all tractors average about 50,000 miles a year, so clearly, much of the travel of these Michigan tractors occurs out of state. Tractors licensed for more than 80,000 pounds put on about 36,000 miles a year in the state. This is about 70% more in-state travel than the other group, which is as expected since such tractors could not legally operate to their capacity outside of the state without special permits. Though the combinations registered at the heavier weights *average* more miles in Michigan, the lighter ones accumulate more *total* miles here, 526 million to 357 million miles. The total travel of all tractors nationwide is about 50 billion miles per year.

2.3.2 Population and Travel Estimates by Company Type

Data gathered in the MTTIS permit the population and travel of Michigan tractors to be analyzed by company type. Companies were classified across a series of dimensions: whether the company or owner ever operates trucks across state lines; whether the firm is a private carrier or a public freight hauler; and what type of regulatory authority, if any, covers the truck owner's operations. The first dimension, crossing state lines, should be fairly clear. If any of the truck owner's trucks ever cross state lines, the company is considered to be interstate. The distinction between private carriers and public freight haulers is equally simple. For-hire companies are those whose business is to move freight. Private firms use their trucks to haul only their own goods. Farmers, construction firms, and automobile manufacturers are all examples of private carriers under the MTTIS definition. Finally, for-hire firms are further split by the type of regulatory authority covering their tractors' operations. For-hire firms operating across state lines come under the jurisdiction of the Interstate Commerce Commission (ICC), while such firms operating entirely within Michigan are regulated by the Michigan Public Service Commission (MPSC). In either case, companies are classified as either *authorized* or *exempt.* Exempt carriers typically haul time-critical freight such as perishable goods and air freight or operate in specific commercial zones. Authorized carriers are basically all other for-hire freight haulers falling under the appropriate agency's jurisdiction. In the table and figures in this section, any company referred to as authorized or exempt is implicitly for-hire. For-hire firms which are interstate are either authorized by or exempt from ICC regulations; intrastate for-hire trucking businesses are similarly either regulated by or exempt from the regulations of the MPSC.

Classifying truck operators in this way is useful in understanding trucking operations. The intersection of the categories gives a good idea of how the vehicles are used. For example, an interstate authorized for-hire hauler operates quite differently from a private intrastate firm; the differences include the type of truck and trailer used, the kind of roads used, and the sort of cargo moved. This company type identification can be useful in profiling the Michigan tractor population: identifying the population operated in interstate commerce; the proportion falling under Federal regulation and that overseen by the State of Michigan; and the size of the tractor population operated by private business and by public carriers.

Table 2-4
Michigan Tractors by Company Type and Licensed Weight

Company Type	Licensed Up to 80K	%	Licensed Over 80K	%	Total	%
InterPriv	7,344	29.75	3,446	34.84	10,790	31.21
InterAuth	10,513	42.58	2,275	23.00	12,788	36.98
InterExempt	281	1.14	149	1.51	429	1.24
IntraPriv	5,492	22.25	2,783	28.14	8,275	23.93
IntraAuth	469	1.90	900	9.10	1,369	3.96
IntraExempt	185	0.75	273	2.76	458	1.32
DailyRental	403	1.63	64	0.65	467	1.35
Total	24,687	100.00	9,890	100.00	34,577	100.00

NOTE: Company type code labels are constructed as follows: The "inter" prefix means interstate; "intra" refers to intrastate operations. "Priv" identifies private carriers; "auth" means authorized; and "exempt" indicates exempt from regulations.

Table 2-4 shows the population and percent distribution of Michigan tractors by company type. Private carriers, whether inter- or intrastate, own the majority of the state's tractors. About 55% (19,065) of Michigan-registered tractors are operated by private firms. Most of those, 10,790, are owned by firms that operate interstate. ICC-authorized carriers account for a substantial fraction (37%) of the population, as would be expected. But MPSC-authorized carriers, those labelled "IntraAuth" in the table, are only a small part of the Michigan tractor population, less than 4%. "Exempt" tractors, whether exempt from ICC or MPSC authorization, and those used as daily rental units together make up another 4%.

It appears that tractors licensed to gross over 80,000 pounds are more often useful to private companies. In fact, almost 63% of these extra-heavy combinations are operated by private companies. The proportion owned by for-hire trucking companies is still substantial, about 36%, but that is less than the for-hire percentage of all tractors. So there is a tendency for the heavy-licensed tractors to be associated with private ownership. Of the tractors licensed to gross 80,000 pounds or less, the majority are still owned by private, non-trucking companies, but the for-hire proportion is over 46%. See table 2- 4.

The weight laws of most other states are significantly more restrictive than Michigan's. In light of that, it may be surprising that almost 60% of the tractors licensed for GCWs over 80,000 pounds are owned by firms that cross state lines. Super-heavy combinations can go into some areas of bordering states, so it is possible that the high proportion of heavy-licensed tractors owned by interstate firms reflects those operations to a limited extent. More likely, however, is that while some of a company's tractors may cross state lines (and consequently the company is coded interstate for the MTTIS company variables), tractors licensed at the heavier weights are used just for in-state hauling. Almost three-quarters of the tractors licensed for 80,000 pounds or less are operated by companies or individuals that go interstate. For all Michigan-registered tractors, the figure is 70%.

Figure 2-1 shows the distribution of travel for Michigan-registered tractors by company type for three tractor configurations: bobtail, single, and double. (Table C-1 in Appendix C documents this and the following two figures.) The percentages in the figure sum to 100 for each tractor configuration, to display the amount of travel for a given configuration attributable to each company type. Interstate businesses account for most of the miles (almost 75%) by singles, fairly evenly divided between authorized carriers and private businesses. Companies that operate across state lines also account for majority of doubles travel, but by a narrower margin, 54% to 46%. Moreover, only about 16% of doubles travel is by ICC-authorized firms, whereas such firms account for 36% of singles travel. Note also that intrastate authorized firms are responsible for almost the same percentage of doubles travel, 13.5%, as interstate authorized trucking companies. And almost two-thirds of doubles travel is by private businesses, whether inter- or intrastate. So, overall, the use of singles is dominated by interstate firms, with much of that being ICC-authorized trucking companies. Doubles, on the other hand, appear to be much more tailored to in-state operations, and the tendency of such configurations to be operated by private businesses is more pronounced.

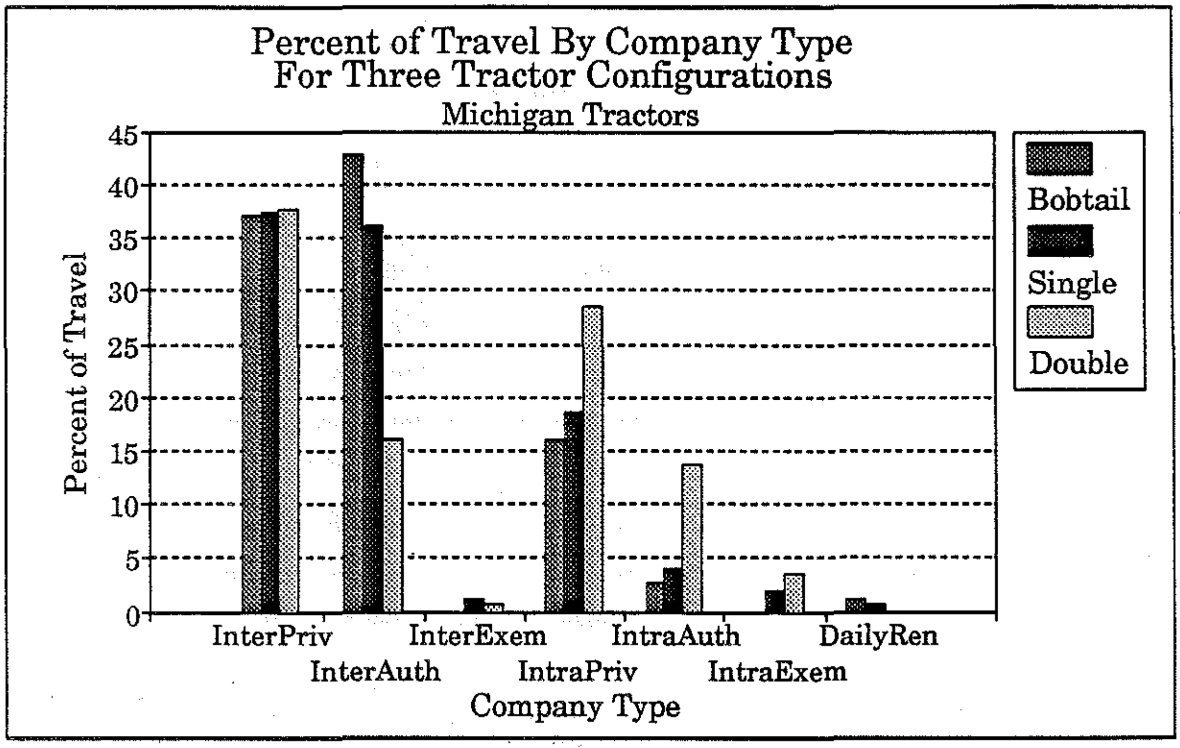

Figure 2-1

If the travel of tractors by company type is split between those licensed up to 80,000 pounds gross combination weight and those licensed over that weight, some interesting patterns emerge. The bulk of singles travel, 65%, is by tractors licensed up to 80,000. This leaves a substantial proportion for what are sometimes called "Michigan specials," but still the preponderance is by tractors that could be licensed in any state. Almost 90% of the doubles travel, on the other hand, is by tractors licensed for over 80,000 pounds. When doubles units are configured in Michigan, apparently the intention is almost always to operate them at the super-heavy weights.

The following two figures show the distribution of travel by company type for tractors licensed up to 80,000 and tractors licensed over 80,000 pounds. The distributions of travel sum to 100 for each configuration type, just as in the previous figure. The figures are shown together and with the same scale of the vertical axis so that the reader can see how the distributions change depending on the licensed weight of the tractor.

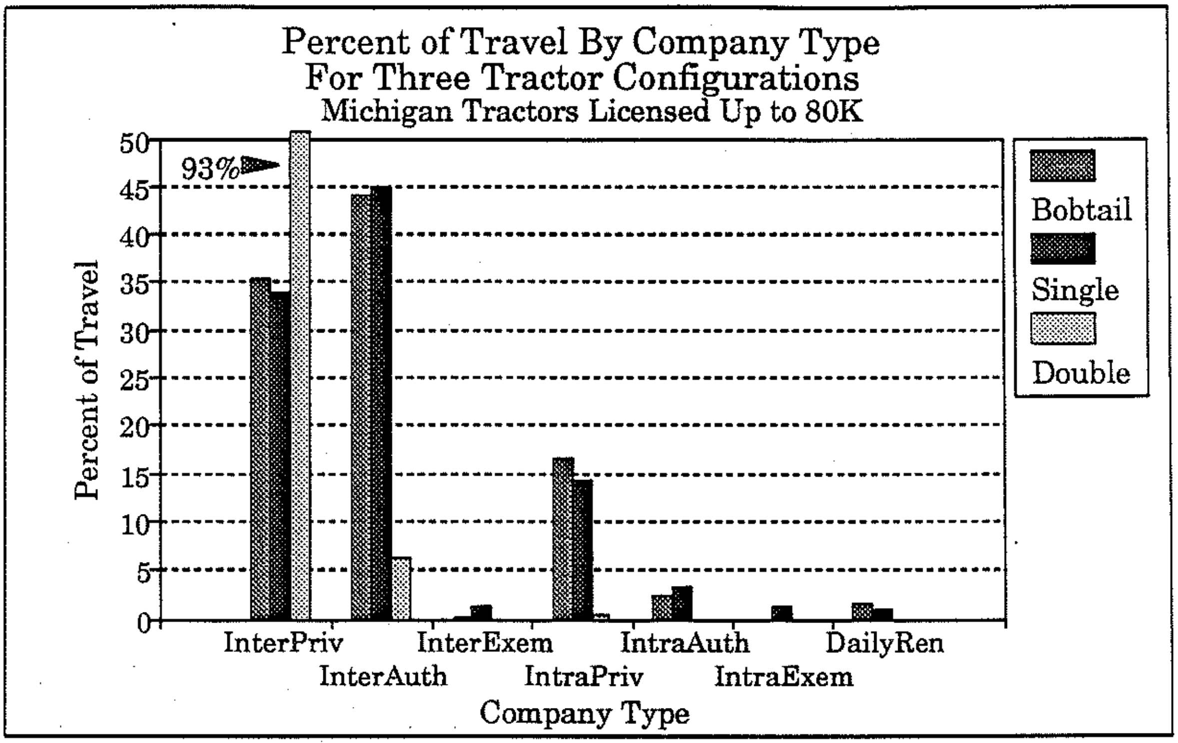

Figure 2-2

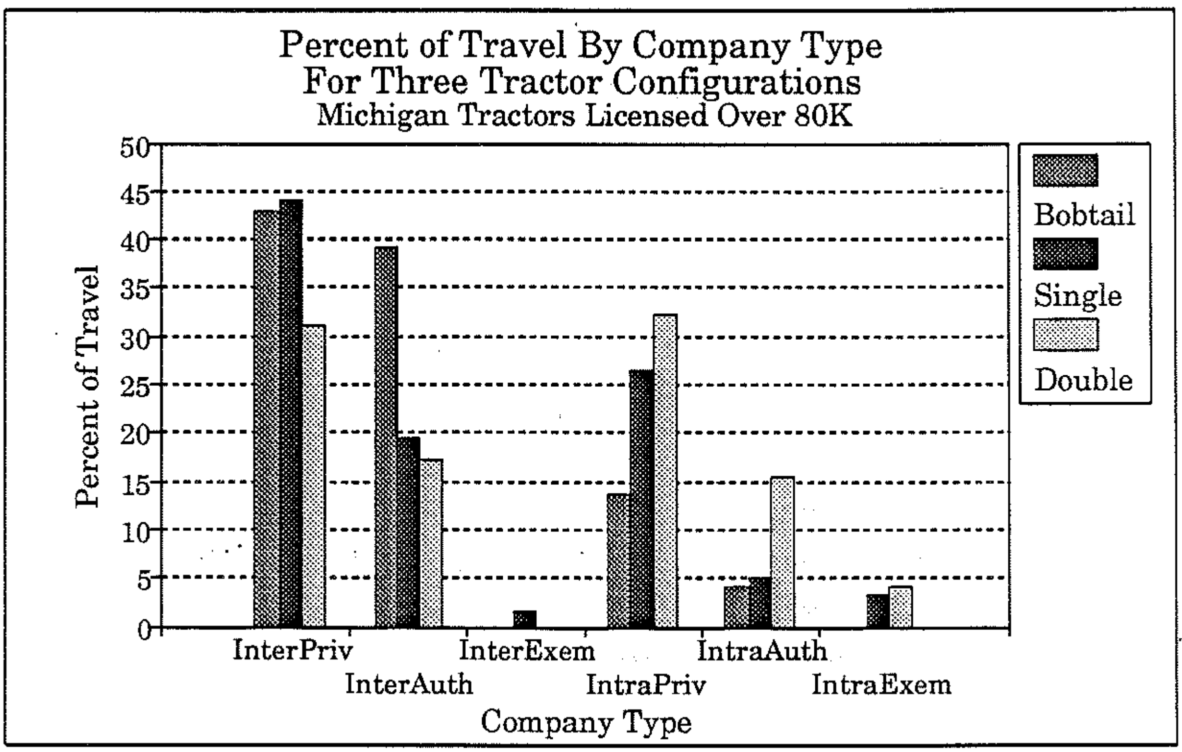

Figure 2-3

The most striking bar in figure 2-2 is the one representing the proportion of doubles travel by interstate private firms. Virtually all doubles travel by tractors licensed for up to 80,000 pounds is by interstate private businesses. Interstate authorized firms account for only about 6% of their travel. This is somewhat surprising, given the number of doubles run by major national freight hauling companies, but possibly they register their tractors outside of Michigan. Also, it is worth keeping in mind that the vast majority of doubles travel is by tractors licensed for over 80,000 pounds, which is summarized in figure 2-3.

The travel of singles licensed for up to 80,000 pounds is evenly split between private and for-hire operations. It is also overwhelmingly dominated by interstate operations, 80% to 20%. And the ICC-regulated companies account for almost half of the their travel. The heavy-licensed tractors, represented in figure 2-3, show different patterns. ICC firms account for a relatively small share of singles travel. Most of the singles travel is by private businesses, whether intra- or interstate.

Almost 90% of the doubles travel is with tractors licensed for over 80,000 pounds. Doubles licensed for over 80,000 pounds are clearly associated with intrastate operations, as would be expected, and with private businesses. About 70% of heavy-doubles travel is by private companies, whether inter- or intrastate. The proportion of travel by interstate authorized firms is comparatively modest, only 17.3%. Both interstate and intrastate private companies are almost twice that, at over 30% in each case. And the share of the travel of intrastate authorized companies, those regulated by the MPSC, while amounting to about 5% of all tractors, is over 15% for heavy-licensed doubles. Table C-1 in Appendix C supplies the complete breakdown of mileages and percents.

2.3.3 Travel by Travel Category and Gross Combination Weight

One of the features of the survey protocol used in the MTTIS is that travel can be broken down by road type, time of day, and population area type (urban vs. rural). In this way, differences in usage across different travel categories can be examined. This is important in studying both the normal operations of trucks in Michigan as well as the safety of trucks under different operating conditions. Table 2-5 shows the distribution of the travel of bobtail, tractor-semitrailer, and doubles combinations on Michigan roads by twelve categories of travel. An explanation of the category labels is in order. The first position gives the road type. "Limited" stands for limited access, "Major" for major artery, and "Other" for other road type. Limited access roads consist of the interstate system and other divided highways similar to interstates in that access to them is limited. The major arteries consist of U.S. and state highways and other primary routes. "Other" roads are everything else. The second position gives the time of the travel. Day was defined as the period between 6:00

A.M. and 9:00 P.M. The third position gives the area type—urban areas are FHWA-defined areas with a population greater than 4,999 people.

Table 2-5
Travel Distribution by Twelve Travel Categories
For Bobtail, Single, and Double Combinations

Travel Category	Bobtail Miles (Mil.)	Bobtail %	Single Miles (Mil.)	Single %	Double Miles (Mil.)	Double %
Limited Day Rural	2.10	20.3	204.43	26.8	23.16	25.9
Limited Night Rural	0.24	2.3	41.95	5.5	9.47	10.6
Major Day Rural	2.10	20.3	128.65	16.9	15.04	16.8
Major Night Rural	0.07	0.7	17.64	2.3	2.40	2.7
Other Day Rural	0.26	2.5	31.77	4.2	3.21	3.6
Other Night Rural	0.06	0.6	1.29	0.2	0.22	0.3
Limited Day Urban	2.63	25.4	177.25	23.2	21.16	23.7
Limited Night Urban	0.37	3.6	29.88	3.9	3.47	3.9
Major Day Urban	0.93	9.0	59.82	7.8	5.53	6.2
Major Night Urban	0.07	0.7	6.84	0.9	0.46	0.5
Other Day Urban	1.44	13.9	59.73	7.8	4.95	5.5
Other Night Urban	0.09	0.9	3.78	0.5	0.34	0.4
TOTAL	10.35	100.0	763.03	100.0	89.43	100.0

Overall, tractors pulling one trailer accumulate 88.4% of the tractor travel, tractors pulling double trailers, 10.4%. Bobtails account for only 1.2% of the total travel of tractors. The two primary travel categories for both singles and doubles are rural limited access roads during the day, and urban limited access roads, also during the day. Together, they account for about 50% of the total travel of those two combinations. Doubles put on about 11% of their travel on limited access rural highways at night, compared to 5.5% for singles. In general, the van doubles, which account for the bulk of doubles travel, tend to operate more uniformly around the clock, since their major use is in long-haul, regularly scheduled general freight transport. For both singles and doubles, the bulk of their travel is on limited access roads. Such roads account for 59.4% of the mileage of singles and 64.0% of the mileage of doubles.

A unique feature of trucking in Michigan is the regulations which permit truck-trailer combinations to operate at very heavy gross weights. No other state permits such heavy units as a regular feature of operations. Figure 2-4 shows the distribution of travel by gross combination weight (GCW) for all tractors, whether operating bobtail, with one trailer, or with two trailers. Table C-2 in the appendix documents this figure. To an extent, some of the weight categories are coextensive with certain tractor configurations. All of the travel of bobtails, tractors operating without a trailer, is in the 0-20,000 pound range. The 20-40,000 pound group consists primarily of tractors pulling a semitrailer which is empty or nearly so. Those vehicles accumulate 38.8% of the travel of tractors. Another 42.7% of the travel is at weights between 40,000 and 80,000 pounds. At that point, the distribution slopes abruptly down to the heavy combination weights. Only about 13.8% of all tractor travel is over 80,000 pounds, while about 83.7% of the mileage of tractors registered in Michigan is at weights of 80,000 pounds or less. Travel at the heavier weights is primarily by doubles. The gross weight of the remaining travel (2.5%) is unknown.

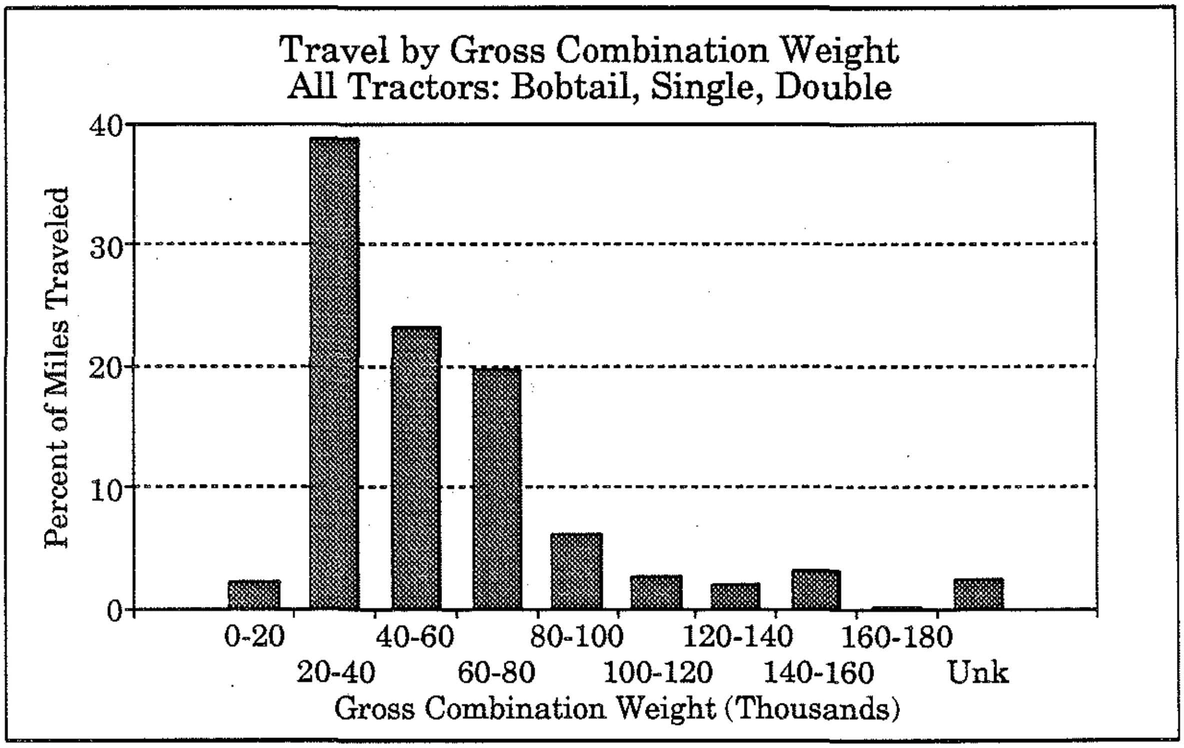

Figure 2-4

Figure 2-5 shows the distribution of travel by gross combination weight separately for the two most common tractor configurations, singles and doubles. Table C-3 in the appendix corresponds to this figure. The units included in this figure are all singles and doubles, without regard to the licensed weight of the vehicle. Recall, from table 2-3 above, that about one-third of the vehicles represented are licensed to gross over 80,000 pounds.

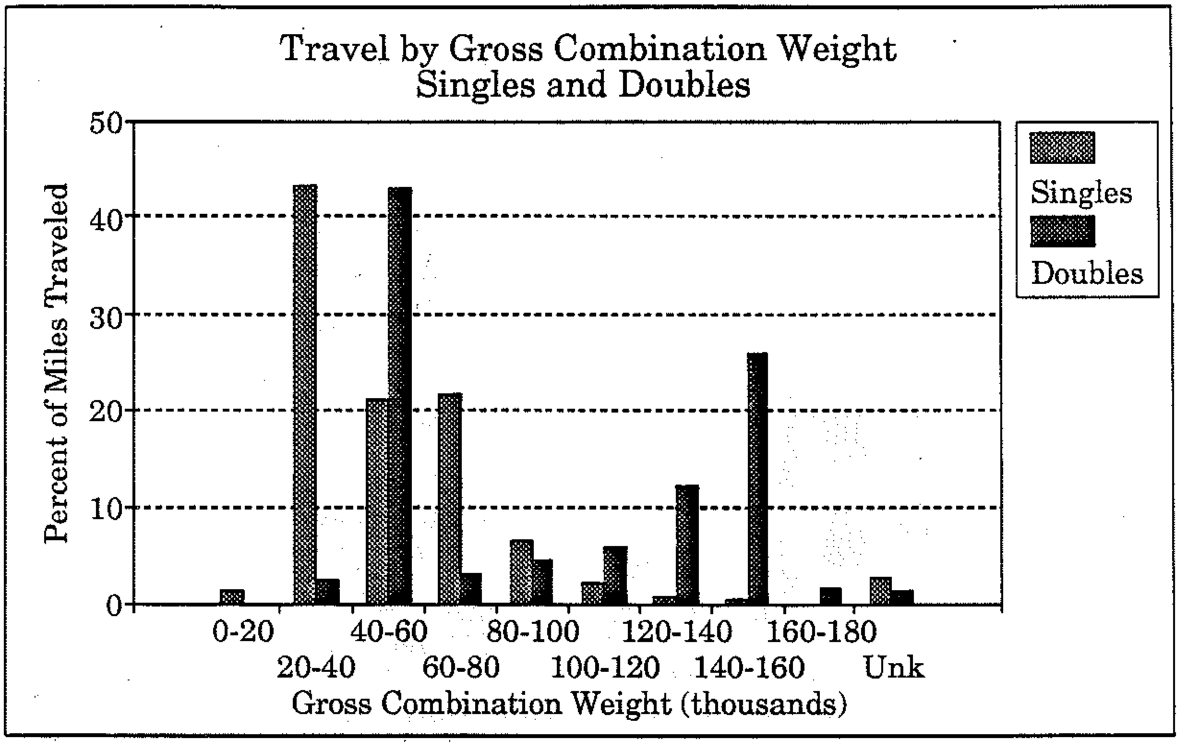

Figure 2-5

Both singles and doubles put in a surprisingly large fraction of their mileage while empty or only very lightly loaded. The empty weight of a typical tractor-semitrailer combination is around 30,000 pounds. Nearly 44% of tractor single-trailer travel is in the 20-40,000 pound gross weight range. These vehicles are probably empty or very nearly so. Roughly 20% of singles travel is in the 40-60,000 pound range and a similar percentage in the 60-80,000 pound range. Only about 10% of the travel of singles occurs at gross weights over 80,000 pounds. The distribution of travel by gross weight is somewhat different for doubles. Again, about 43% of the travel is while empty or nearly so, which for doubles is the 40-60,000 pound range. But then the percentage falls off sharply, rising again gradually to a peak of 26% in the 140-160,000 pound range. The units at the high end of the distribution, e.g., over 100,000 pounds, are almost certainly loaded to capacity. This pattern indicates that doubles typically operate fully loaded in one direction and then return empty, as would be expected given the commodities typically carried by the heaviest trucks within Michigan.

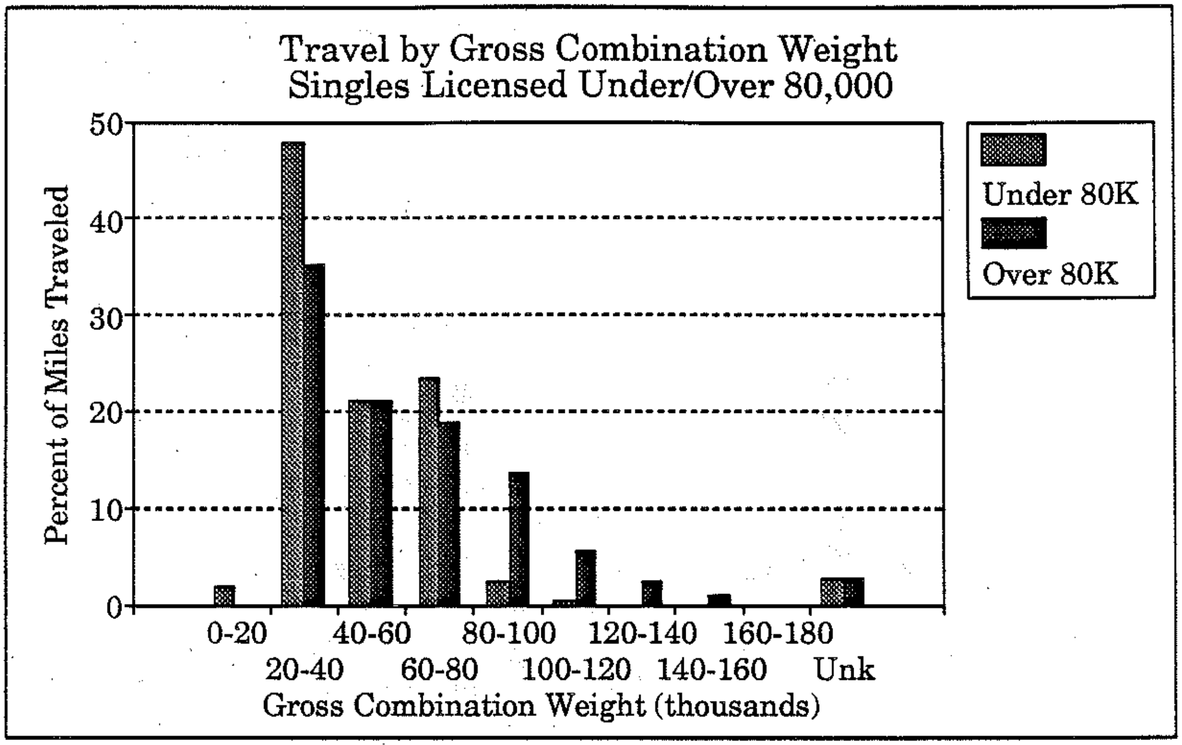

Figure 2-6

The distribution of travel by gross combination weight can be seen more clearly when it is split between combinations licensed under and over 80,000 pounds. Figure 2-6 shows the travel of tractor-semitrailers by GCW separately for tractors licensed up to 80,000 pounds and for those over 80,000 pounds. (See table C-4 in the appendix.) For the under 80,000 pound group, almost half of their travel is in the 20-40,000 pound GCW category, while 21% is in the 40-60,000 pound range, and 23% is in the 60-80,000 pound range. Note that almost 3% of the travel is at weights over 80,000 pounds, even though the tractors are not licensed to operate that heavy. Among the tractor-semitrailers licensed to operate at the heavier weights, fully 22% of their travel is at weights over 80,000 pounds. Clearly, they are getting substantial benefit from the Michigan weight laws, though they are still not taking full advantage. About 35% of the miles are accumulated while empty or nearly so (20-40,000 pounds), and the remaining mileage is fairly evenly spread from 40,000 pounds to 80,000 pounds.

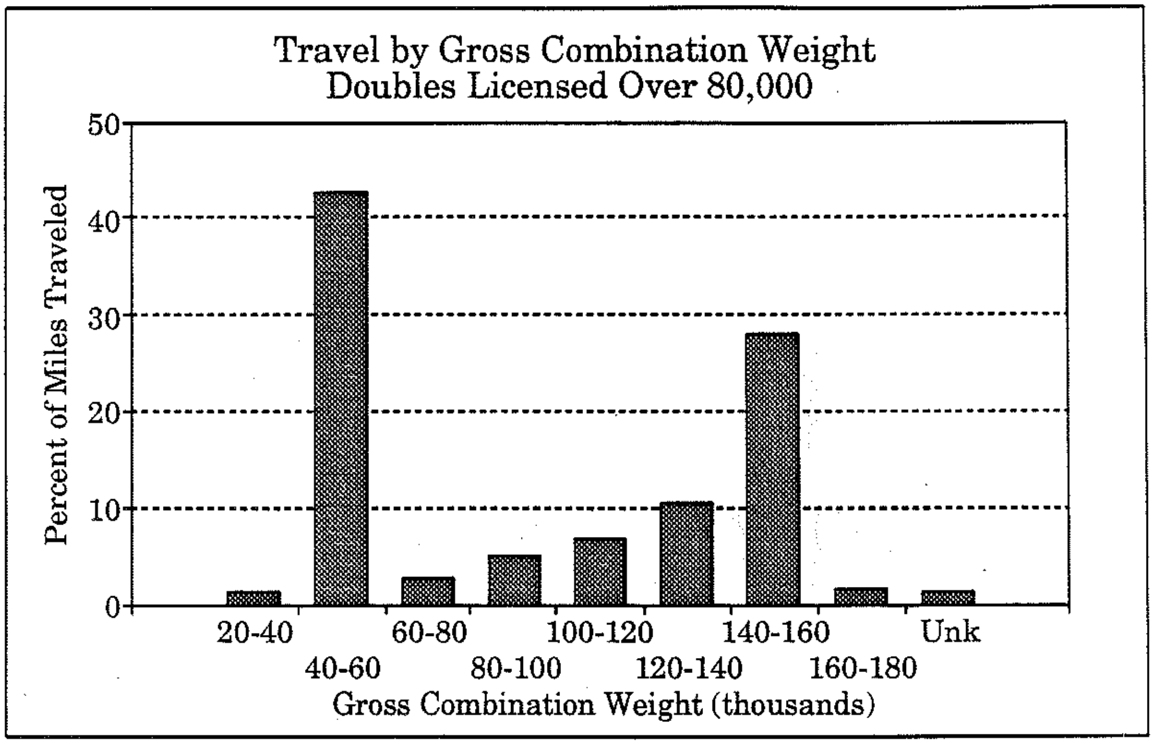

Figure 2-7

Figure 2-7 shows the breakdown of travel by gross combination weight for doubles combinations licensed for over 80,000 pounds (appendix table C-5). Doubles licensed at 80,000 pounds or less are not included in this the figure because they are based on a relatively small number of trips. Overall, there were only 35 total trips for doubles with the tractor licensed for 80,000 pounds or less. The MTTIS surveyed substantially more trips for doubles licensed to operate at over 80,000 pounds. The distribution of travel by GCW for that group shows a U-shaped curve. About 43% of the travel is at weights between 40,000 and 60,000 pounds, which for doubles means either empty or lightly loaded. Again, the doubles accumulate a substantial fraction of their mileage empty. Another 38% of the travel is at weights between 120,000 pounds and 160,000 pounds, which in most instances must be virtually at the maximum capacity of the vehicle. (Less than 2% of the travel was at a GCW over 160,000 pounds.) The intermediate weight categories account for relatively small pieces of doubles travel, ranging from 2.7% to 6.8%. This distribution is consistent with the typical operation of a double licensed at the heavy weights, running loaded in one direction with an empty return.

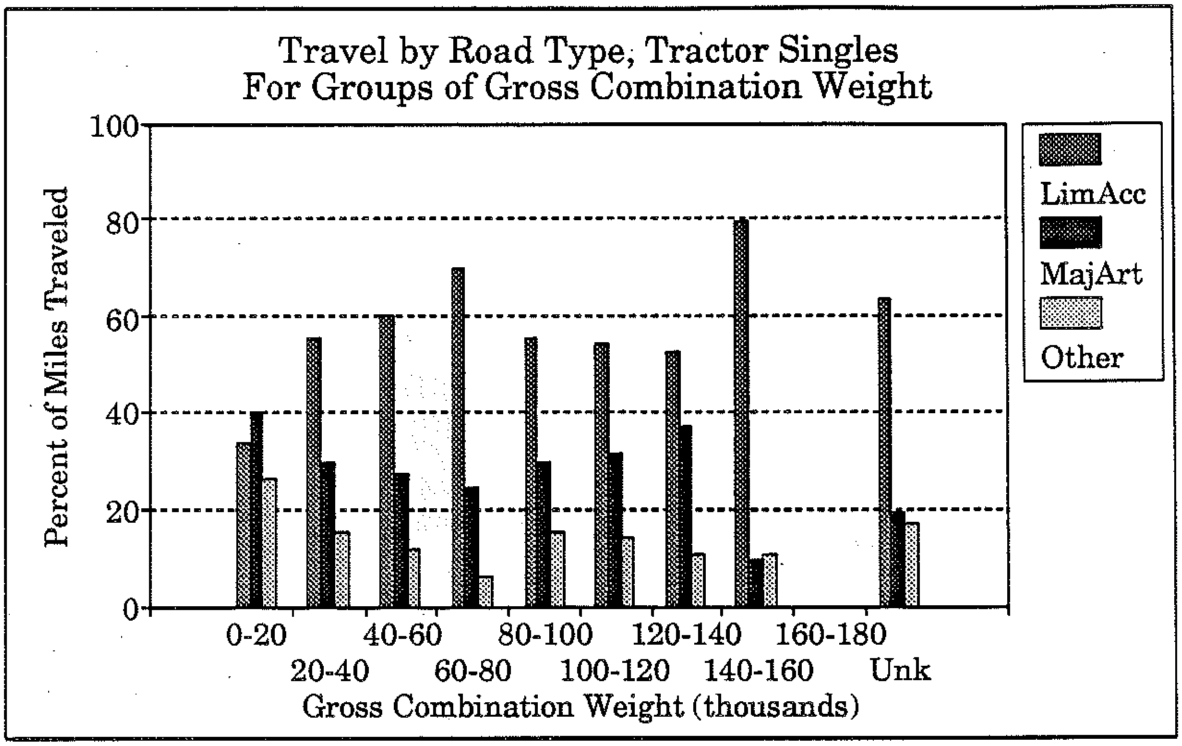

Figure 2-8

A major question related to the operations of the heavy Michigan tractor combinations is the type of roads they operate on. Crash risk varies with the type of road, as do pavement wear characteristics, both issues that have been raised for heavy Michigan doubles. The MTTIS data can be used to estimate the proportion of travel at different weights on different road types. Figure 2-8 shows the proportion of travel of tractor-semitrailers on the three different road types, limited access, major artery, and other, for various ranges of gross combination weight. The percent distribution of road type sums to 100 for each category of GCW. For example, 60% of the travel of singles in the 40-60,000 pound category is on limited access roads, 28% on major arteries, and 12% on "other" roads. For singles, limited access roads dominate for all categories of GCW except the lightest. Vehicles in the lightest category are empty and spend a greater amount of their time off the interstates, presumably on their way to loading points. The proportion of limited access travel generally increases as GCW increases, up to the 80,000 pound level. The proportion of limited access miles then levels off at around 55%. The estimate for the 140-160,000 pound category is quite high, but it is based on only 18 trips, so it is less reliable. Moreover, this figure should be evaluated in light of the travel distribution for singles as shown in figure 2-5. While 80% of the travel of singles in the 140-160,000 pound category is on limited access roads, that category accounts for only a tiny fraction of singles travel.

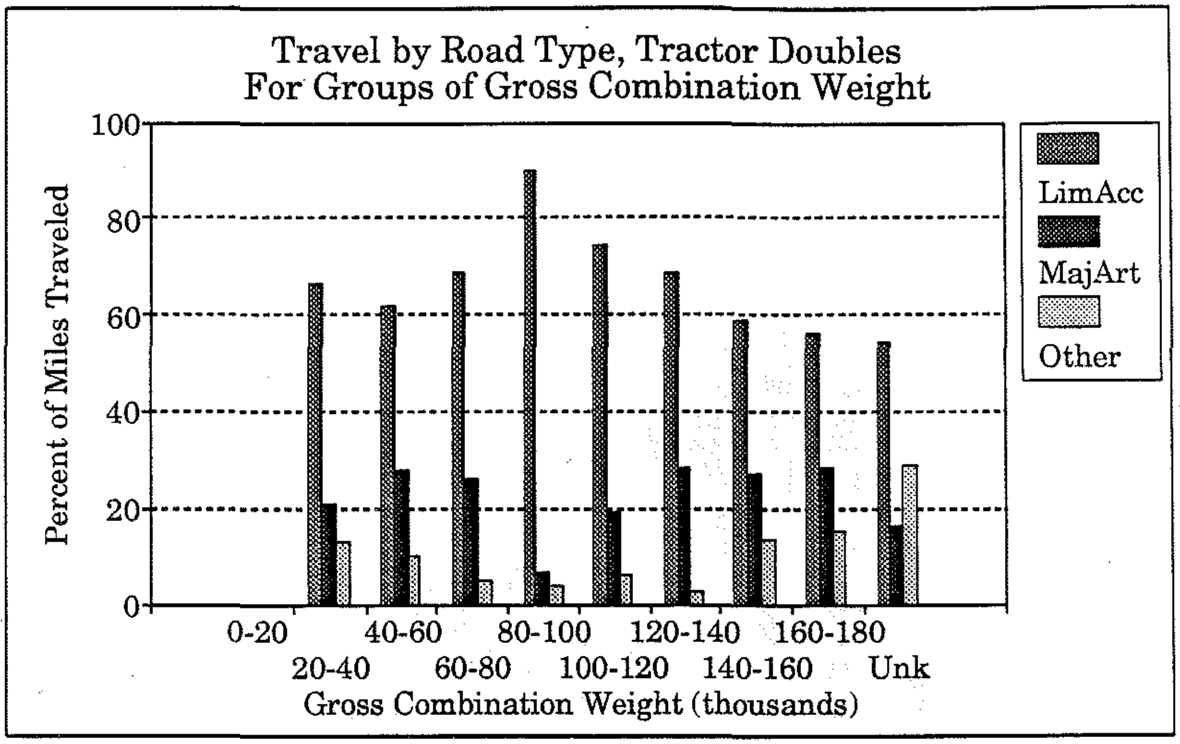

Figure 2-9

Figure 2-9 repeats the analysis for tractors with two trailers. The pattern is quite similar to that of singles, though at all GCWs an even higher proportion of the travel of doubles is on limited access roads. There is some tendency for more travel on major artery and other roads at the lighter and heaviest weights, though for some of categories the estimates are based on relatively few trips. (See table C-6 in the appendix.) Overall, for all gross combination weights, the great majority of doubles travel is on limited access roads, which are typically the safest and best engineered.

2.4 Michigan Truck Drivers And Driver Training

2.4.1 Travel by Driver Age

Young drivers have been shown to be significantly over-involved in fatal truck crashes in comparison to all drivers. In a national study of fatal truck crashes, drivers younger than 19 were over-involved by a factor of four, while 19- and 20-year olds were over-involved by a factor of six. In general, drivers have been shown to be over-involved up to age 25.[1] In combination with crash data from police accident reports, a similar analysis can be performed using the MTTIS travel data. Crash rates by age will be presented in section 4.

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[1] *Fatal Crash Involvement Rates by Driver Age for Large Trucks*, Campbell, Kenneth L. and Arthur C. Wolfe. UMTRI-88-43.

The remainder of this section will describe the truck driving population by age and examine the nature of their exposure to driver training.

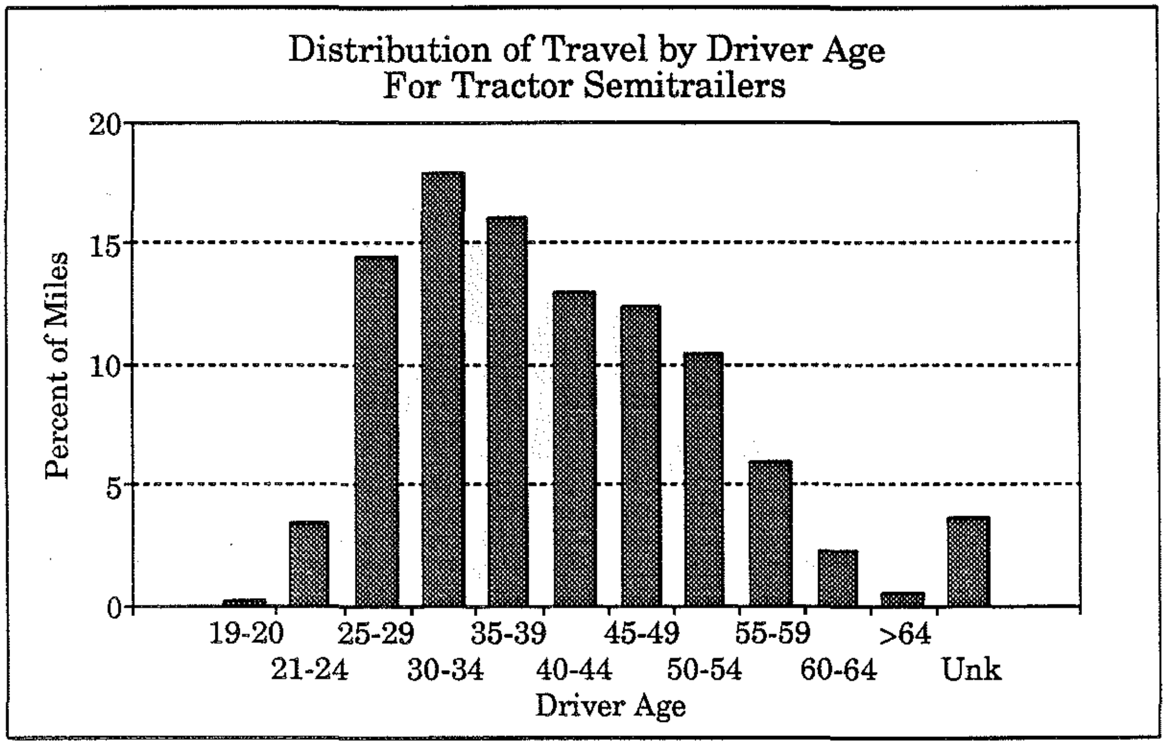

Figure 2-10

Figure 2-10 shows the distribution of tractor semitrailer mileage by driver age. The information in the figure is presented in tabular form in table C-7 in the appendix. There were no drivers in the survey who were under the age of 19, 19- and 20-year olds accounted for only .24% of the travel, and drivers under 25 accumulated only 3.64% of the tractor semitrailer travel. By far the majority of miles driven is by drivers between 25 and 54, with the 30-34 age group accounting for the greatest share. Drivers over 64 accounted for less than a half percent of the mileage of tractor-semitrailers in Michigan.

2.4.2 Estimates of Truck Driver Training

During the third and fourth quarters of the trip portion of the MTTIS survey, a series of questions was added to the interview about the type of training the driver had. The entry question was simply whether the driver had ever had any formal training in driving a truck. The definition of "training" for the purposes of this question was fairly broad. The training had to include some sort of classroom work, in order to exclude cases where the "training" consisted of a brief drive around the block. But there were no requirements concerning accreditation of any school involved or, indeed, that the training had to be from a truck driver's school. Company training programs were acceptable for the purposes of this question. Similarly, the training could be in any type of truck, not necessarily the type driven during the survey.

Overall, the results from the driver training questions were mixed. The driver had no training in 53.8% of the cases, and only 15.2% of the drivers had received some training in truck driving at some point in their career. But in almost 31% of the cases, it was unknown whether the driver had any formal training. A large proportion of the unknowns occurred because interviewers were unable to talk directly with the driver of the truck.

Such a large percentage of unknown cases raises the question of how to handle them. One approach is to assume that the distribution of training in the population of unknown cases is the same as in the population of cases where the question was answered. This assumes that the unknowns are essentially randomly distributed, in which case it is legitimate to simply exclude the unknowns and recalculate the percentages. But adopting the assumption of randomly distributed unknowns does not appear to be safe in this instance, since most of the unknowns occurred when the interviewer was unable to talk directly with the driver. Those were most often cases which involved larger firms, where a truck dispatcher or some other supervisor handled trucking operations. In that case, the person interviewed could not be expected to know the background of every driver. Such firms, with more extensive trucking operations, might place more emphasis on hiring trained drivers. So while any particular driver may not be trained, their drivers in general would be more likely to have had driver training than the rest of the truck driving population. If this assumption is correct, that is, that drivers who work for large companies and who therefore were more often unavailable for direct interview are more likely to have had driver training than other truck drivers, then unknown cases would not be randomly distributed, since it would be more likely that a driver for which the training question was unknown would have had training than the general truck driver population. Moreover, leaving the unknowns in the analysis provides more conservative estimates. The estimate of 15% for drivers with training represents a floor for the estimate. It may be that the true number is higher, if the correct answer were known for all the unknowns, but it is very unlikely that it is lower. In any case, for the purposes of this report it seemed safest to simply show the proportion of unknown cases along with the rest of the categories, rather than introducing a false sense of precision by eliminating them.

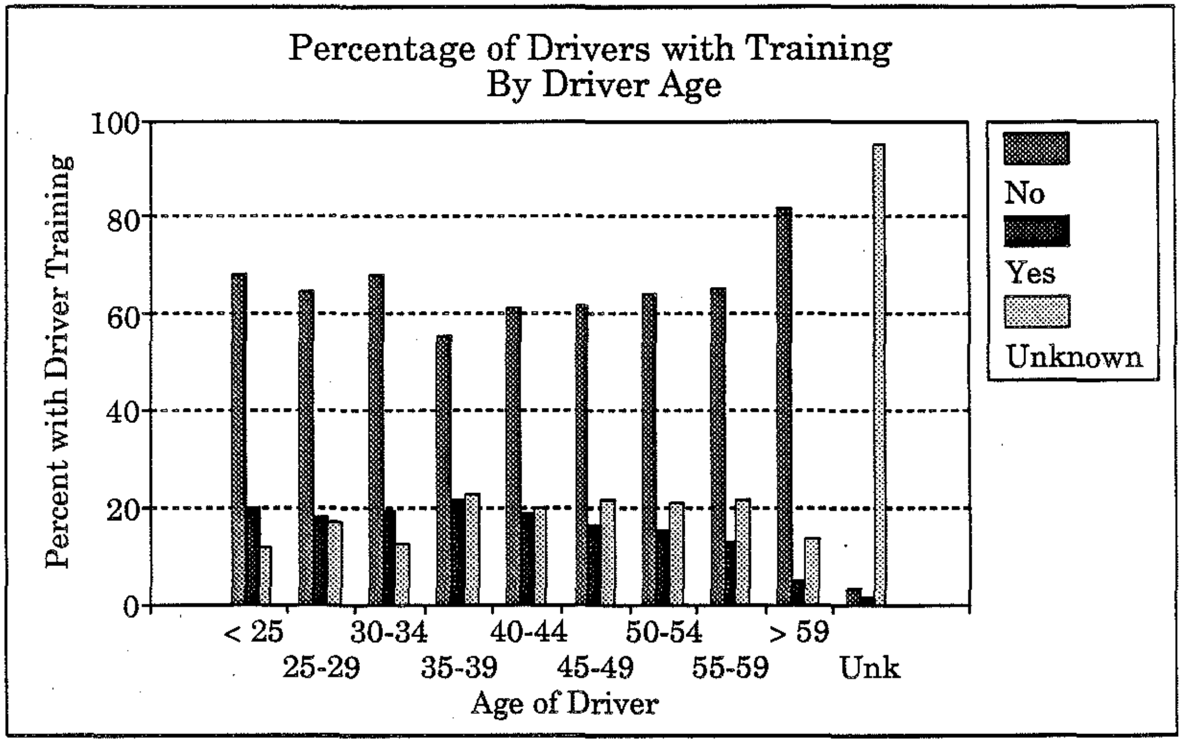

Figure 2-11

Figure 2-11 above shows the percentage of drivers with driver training for various age groups. The supporting data are in table C-8 in the appendix. The percents in each age category sum to 100. Thus, for example, 68% of drivers age 30 to 34 have not had driver training, 20% have, and the answer is unknown for the remaining 12%. At all ages, a large majority of the drivers had no formal training in driving a truck. Moreover, there does not appear to be much of a relationship between the age of the driver and the likelihood that he had been trained. Overall, groups younger than 44 do tend to have a larger proportion of trained drivers than groups older than 44. Only 5% of drivers older than 59 were trained, while on average about 20% of drivers under 40 had received some formal training in driving trucks. But the overall differences are relatively slight, and proportion of unknowns is large.

2.4.3 Source of Driver Training

For those drivers who had been trained, the source and type of training was recorded. The possible choices were: (1) training from a company, (2) from a truck driver school, (3) from some combination of company and school, and (4) from the military. Figure 2-12 shows that a very large majority, 66.7%, of those with training received it from an employer, either the current one or some prior employer. Truck driving schools trained 17.5% and the military provided training for 9.5% of the drivers. Recalling that only 15.2%

of all the drivers surveyed had any sort of formal training in driving trucks, whether from an employer, the military, or a school, we can calculate that schools trained 17.5% of that 15.2%, or 2.7% of Michigan truck drivers. This is a minimum figure, of course, since the training status of almost 31% of the drivers is unknown. Even so, it seems clear that employers provide the bulk of driver training, when the driver is trained at all, and that driving schools have had only a small impact on the whole population of truck drivers thus far. See table C-9 in the appendix.

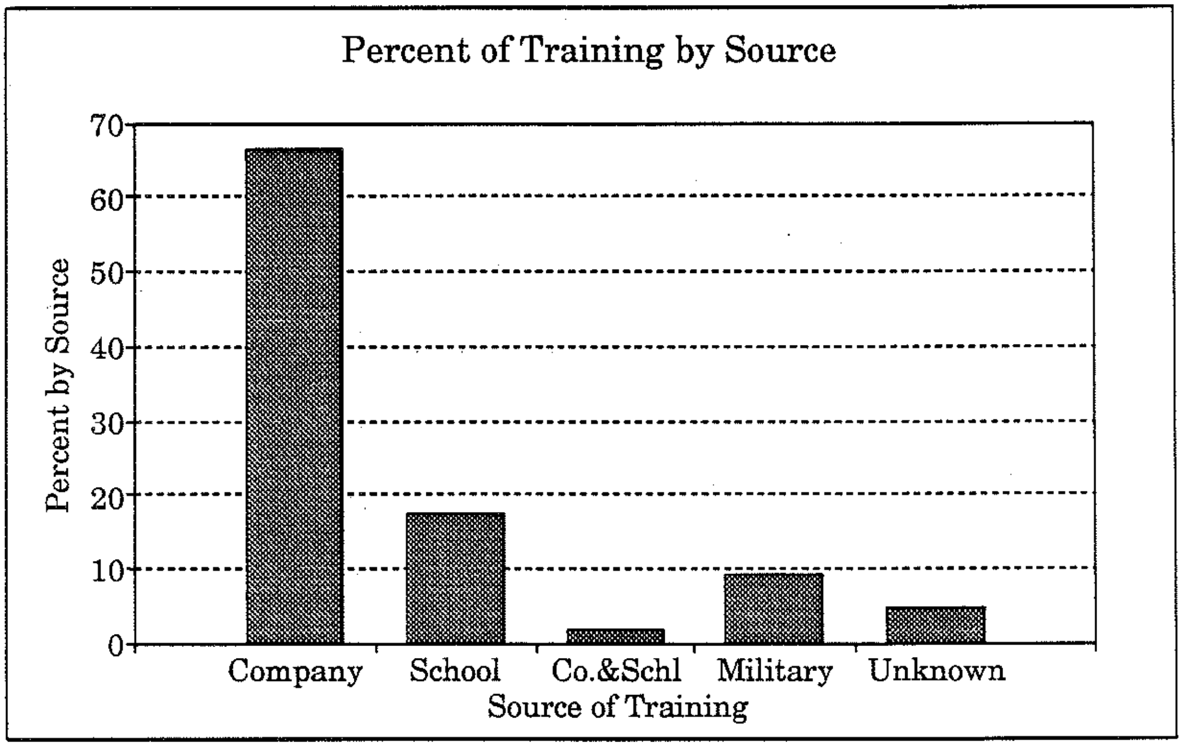

Figure 2-12

The type of training was also surveyed among the group of drivers who had been trained. The possibilities were either classroom work exclusively or a combination of classwork and road work. The survey showed that most of the training involved both classwork and hands-on experience in driving a truck. Of the drivers who had training, only 16.1% said that it consisted exclusively of classroom work, while for 77.2% it involved both classwork and actual driving. This mix of training techniques was roughly the same for all age groups. Figure 2-13 illustrates the breakdown of training methods for each age group. There appear to be few significant differences between the groups. Table C-10 in the appendix supplies a detailed breakdown.

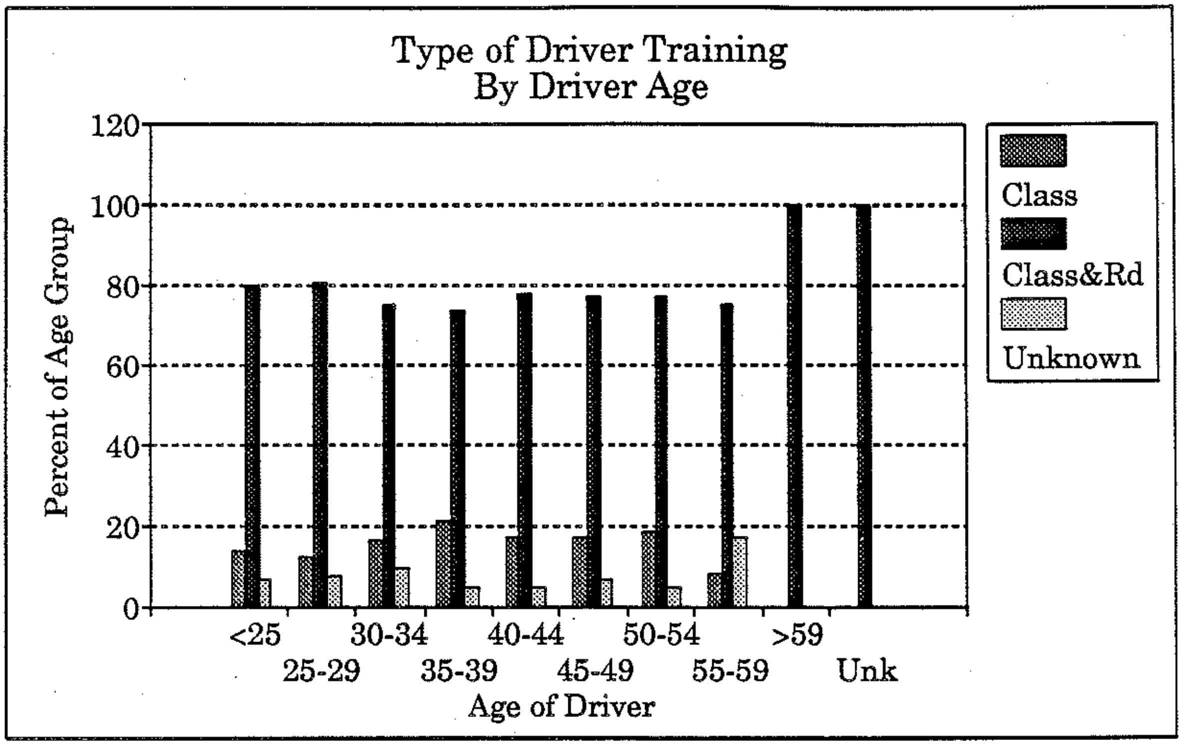

Figure 2-13

2.4.4 Driver Training and Company Type

One might expect the frequency of driver training to be related to the type of company operating the vehicle or, more marginally, to whether or not the truck operates in interstate commerce. For-hire trucking companies may put more emphasis on training their drivers than private firms, resulting in a higher fraction of trained drivers. Similarly, companies that operate across state lines, in interstate commerce, may be more likely to have trained drivers. In both cases, the survey does not show that pattern, though the large amount of missing data may bias the results. (There was a third category of company type, "daily rental," which covers vehicles rented on only a short-term basis. There were only 11 such cases, which can safely be neglected.) Figure 2-14 below charts the percent of drivers with training by company type. The bars sum to 100 percent for each company type. A for-hire company is defined here as any company whose business is the transport of freight. Moving companies, package delivery services, and freight haulers all qualify as for-hire under this definition. All other companies, including those who may use trucks extensively to move their own freight, are classified as private.

Figure 2-14 shows a 27% increase in the proportion of trained drivers for the for-hire carriers over private carriers. (See also table C-11 in the appendix.) Of the for-hire carriers' drivers, 17.4% were coded as trained, while 13.7% of private carrier drivers had been trained. It is difficult to draw any firm conclusions about the effect of company type on driver training, since training is unknown in about 30% of the cases.

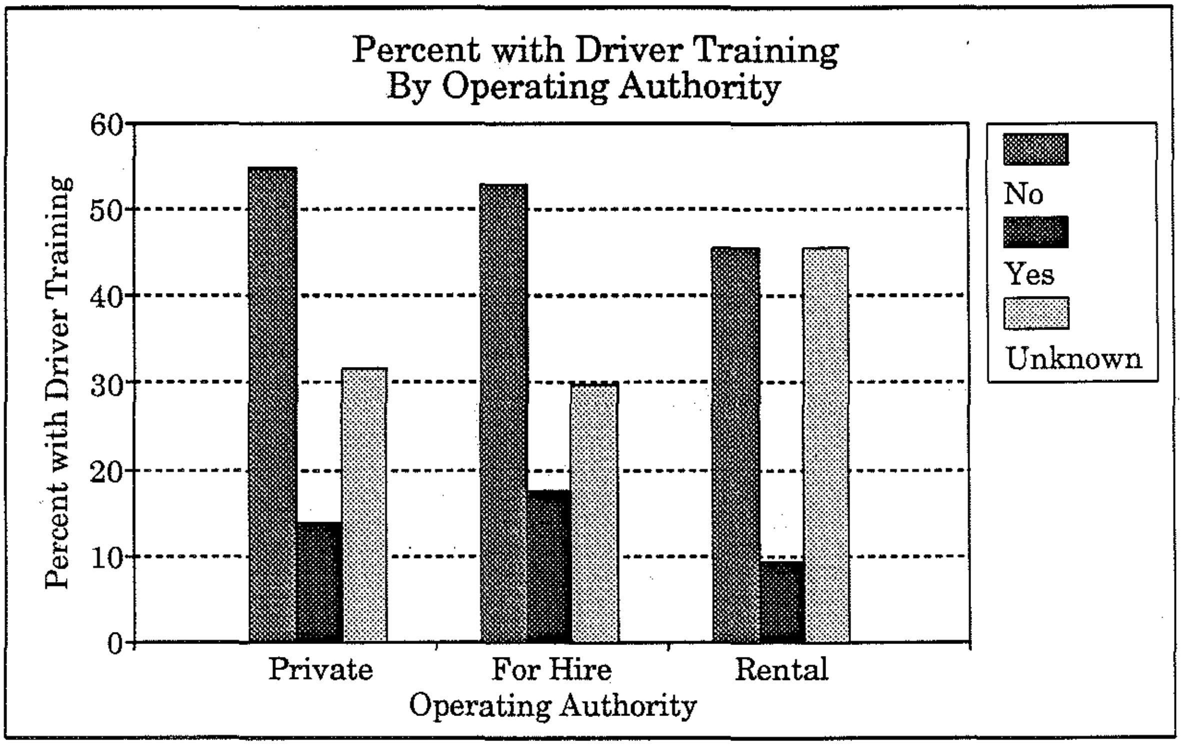

Figure 2-14

There may also be an effect from involvement in interstate commerce. For the purposes of this question, a company is considered to operate in interstate commerce if any of their trucks ever crosses state lines. Figure 2-15 displays these results. Again, the percents shown in the figure sum to 100 for each category. About 12% of the drivers whose companies were coded as intrastate had driver training, while 16.6% of the drivers of trucks from companies whose operations crossed state lines were trained. In both cases, a much higher proportion of the drivers had never had any truck driver training. And in both cases, the number of unknowns is substantial, about 30%. While there might be some effect, because of the large number of unknowns it is difficult to be confident of its magnitude and possibly even of its direction. This is an area which requires further work to draw firm conclusions. Table C-12 in the appendix shows the results in tabular form.

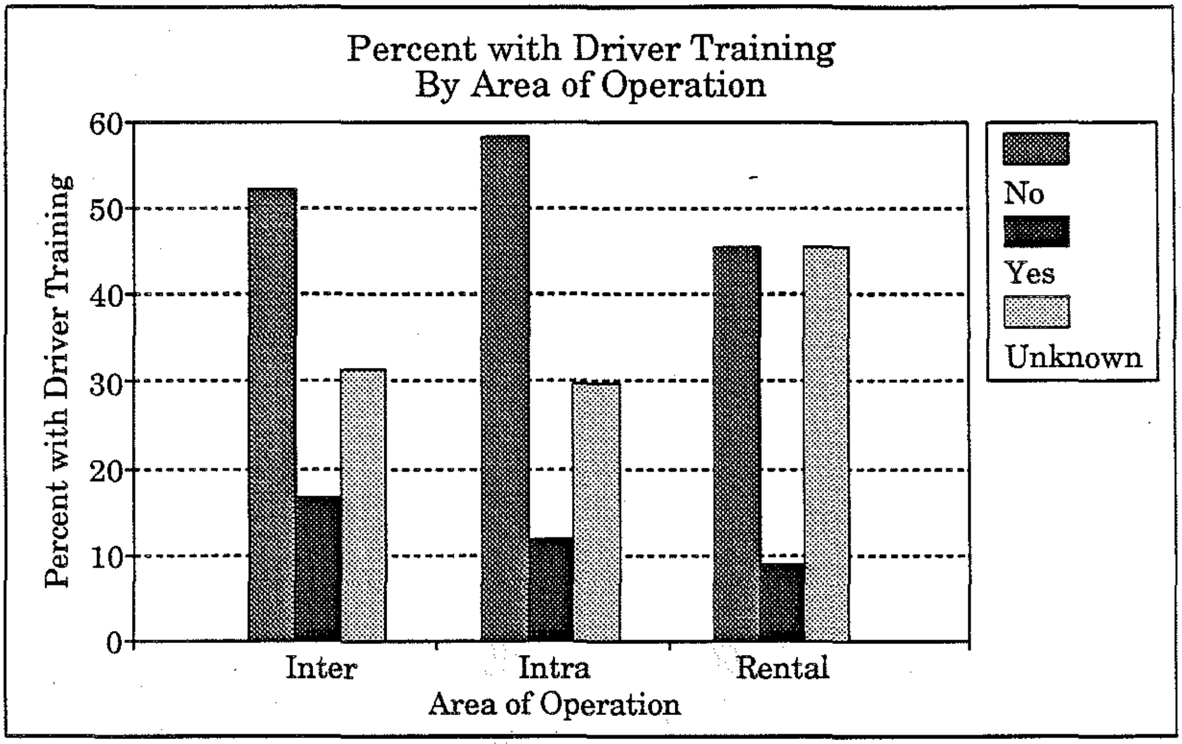

Figure 2-15

2.5 Summary

The Michigan Truck Travel Information Survey (MTTIS) is a source of information on the population and travel of trucks registered and operating in Michigan. Roughly 1,300 trucks were drawn from Michigan registration files with registration dates as of February, 1987. Their owners were contacted, and information about the truck and its usage was collected. A follow-up survey gathered data on the actual day-to-day operations of the vehicle. On four randomly selected days, information was collected about the loading, type of trailers, route covered, and other details of the truck's operations. The route descriptions were traced on specially prepared maps, and the mileage broken down by road type, time of day, and area type. With this survey technique, travel estimates were generated for several truck configurations of interest for different combinations of road type, time of day, and area.

The MTTIS data indicate that there were almost 35,000 tractors registered in Michigan as of February, 1987, the date the sample was drawn. Almost 10,000 of the tractors had taken advantage of Michigan's weight laws and were registered to gross over 80,000 pounds. About 55% of all tractors were owned by private businesses, 44% by for-hire trucking firms, and 1% were daily rentals. The whole group of Michigan tractors traveled about 880 million miles in Michigan over the course of a year. Over 88% of this travel was accumulated by tractors pulling one semitrailer. Tractors with two trailers put on 10.4% of the travel and bobtails 1.2%. Most of the total travel of all tractors was on interstates or interstate-quality roads. When pulling a single trailer, 59.4% of the travel of tractors was on limited access roads. With two trailers, the proportion rose to 64%.

Michigan's weight laws permit much heavier combination weights than other states. About 30% of the tractors registered in Michigan were licensed to gross over 80,000 pounds. Almost 63% of those were owned by private companies. Although the percentage of the tractor population licensed for over 80,000 pounds was high, only about 14% of the total tractor travel was at weights over 80,000 pounds. For tractors licensed for over 80,000 pounds pulling just one trailer, 22% of the travel was at weights over 80,000. Tractors licensed to gross over 80,000 pulling two trailers put on almost 52% of their miles at weights over 80,000 pounds. Such tractors put on 88% of the doubles travel. On the other hand, much of the travel was while empty or only very lightly loaded. Tractor singles, whatever their licensed weight, operated 44% of the time close to empty. The proportion was very similar for doubles.

The MTTIS data can also be used to study the driver population in Michigan. The age structure of Michigan drivers in the MTTIS survey was quite similar to the national population. About 3.6% of the miles were accumulated by drivers younger than 25. Less than a half of a percent of the travel was accounted for by drivers over 64. The data also show that driver training does not appear to have made much of an impact on Michigan drivers. Only 15.2% of the drivers have had any formal truck driving training at all. While there was considerable missing data on this part of the survey, it appears that no age group was significantly better trained than any other. For-hire haulers and companies that operate in interstate commerce may have a higher proportion of trained drivers, but the large amount of missing data makes firm conclusions on that score impossible.

SECTION 3

TRUCK CRASHES IN MICHIGAN

3.1 Introduction

The fundamental source for highway accident data in Michigan is the file maintained by the Michigan Department of State Police (MSP). This file is based on the accident form, the UD-10, Traffic Accident Report (see Appendix A), which is filled out for each traffic accident that occurs in the state. This standard form is used by all enforcement agencies in the state and is generally coded at the crash site by the investigating officer. The data from the UD-10 are combined with other interpretive data by the MSP and converted to a computerized record. The accident files are maintained and distributed by the MSP. The Michigan Department of Transportation (MDOT) modifies these files by taking only the first two vehicles in a crash and by adding roadway segment identifiers which permit roadway geometric information to be merged in from other files. MDOT makes the resulting files available to researchers and other users—the MDOT version of the file provided the base data which were used in this study.

In this section of the report, truck crash frequencies and trends in Michigan are discussed. This discussion is separated into several parts:

The existing crash data and the manipulations necessary to provide accurate truck crash data are described;

Background information is provided which describes the general truck crash "picture" in Michigan;

Comparisons between the study period and other years are discussed; and

Truck crashes are discussed in the context of the stratifications of the survey-based exposure data, and the crash data which match the exposure data are presented.

The truck exposure data discussed in the previous section was limited to tractors registered in Michigan. This section will cover all truck crashes in Michigan, including all trucks larger than a pickup or panel van, straight trucks (which have cargo bodies attached to their chassis) as well as tractors, Michigan-registered trucks as well as those registered in other states. Subsection 3.5.1 below returns the focus to Michigan-registered tractors and Section 4 will present crash rates for Michigan-registered tractors.

3.2 Michigan Truck Crash Data

At the present time, truck crash data are not collected or treated differently from other crash data in Michigan. In order to extract truck crashes from the general accident files, searches must be made which are keyed to, for example, vehicle classification data recorded on the UD-10. Data in the computerized accident report file that are used directly in determining the number of truck crashes include vehicle make code, vehicle type, and trailer type which are coded directly from the UD-10. Other UD-10 fields that can provide information concern truck cargo spillage (which is coded), the license plate legend, and the written/drawn description of a crash. The license plate legend and the description are not currently coded in any useful way for capturing truck data.

3.2.1 General Data Problems

Early in the project it was noted that there appeared to be a disproportionately large number of bobtails (tractors operating without a trailer attached) involved in crashes. This led to a general review of coding for trucks. It was discovered that the vehicle-type and trailer codes were often incorrectly coded in the field by investigating officers. The principal problem involved the use of the word "semi" in the vehicle-type description on the UD-10 instructions provided to investigating officers—apparently this was often interpreted in the field as adequate coding for both the tractor and the trailer since the trailer code was often left blank when crashes clearly involved a tractor-semitrailer combination (e.g., the collision diagram showed such a combination).

The results of these coding errors were historic under-reporting (e.g., in Michigan State Police reports such as the annual *Michigan Traffic Accident Facts*) of the frequency of crash involvement of singles (tractor-semitrailer) and an over-reporting of straight truck (a truck with the cargo body attached to the power unit chassis, such as a dump truck or delivery van) crash involvement, since bobtails were typically aggregated with straight trucks as "single-unit" trucks. This coding error was corrected beginning in 1987. This is reflected in table 1-2 (note, for example, the dramatic reduction in the number of bobtail-involved crashes between 1986 and 1987).

Another limitation of the crash data came in identifying the state of registration for each truck. The design of the MTTIS necessarily focused on trucks that were registered in Michigan. That is, the exposure data would be for Michigan-registered trucks on the Michigan highway system. In order to obtain crash data that would match the exposure data, it was necessary to separate trucks by their state of registration. This involved manually reviewing the UD-10s for all truck crashes and coding this additional information from 1986 through the end of the study period.

3.2.2 Other Data Limitations

There are other minor limitations introduced in determining the frequencies of crashes of the various types of trucks. For example, only truck-involved crashes where the truck was considered to be the first or second vehicle in a crash were considered. The limitation here is one of undercounting—e.g., crashes where the only truck was the third vehicle are not included. The magnitude of this limitation is, however, quite small. In 1988, for example, only 118 singles were involved as the third vehicle in a crash, compared with an estimated 8,971 crashes which involved singles as the first or second vehicle in a crash. Excluding the trucks involved as the third vehicle reduces the total by just over 1%.

Other limitations were related to trailer coding errors. For example, while reviewing hard copies of crash reports from previous years, a case was found of a tractor pulling a flatbed trailer with a bulldozer on it that was coded as a tractor and a towed vehicle. Since the case was incorrectly coded, it would have been excluded from the analysis had it occurred during the study year (when it should have been included). Such errors were not prevalent in the data and are considered to add no more than an additional 1% error—indeed they are probably largely compensating. It should also be noted that the trailer code provides no information regarding the type of trailer (e.g., box, flatbed, tank). There are also "odd" truck combinations such as some auto-carriers which are really straight trucks with a trailer instead of a tractor and semitrailer combination (which is what it visually appears to be).

Another type of "error" comes about in coding so-called "gravel trains." A straight truck pulling a full trailer is a fairly common "gravel train" configuration (e.g., a five-axle dump truck with a three- or four-axle trailer). This might be mis-coded in a number of ways—as a tractor with a semitrailer (in which case it was erroneously included as a single) or as a tractor with a utility trailer (in which case it was excluded). In general, however, there were no exposure data for this sort of vehicle and they would be typically excluded from the crash frequencies reported here. No estimation of the error was made for this problem although it is thought to be small.

In summary, while there are a number of types of errors (or purposeful exclusions) that were detected in the data, the major errors were corrected. Other errors are likely to be compensating. In any event, the estimate of error in the numbers of vehicles reported in various categories is expected to be within about 2%.

3.3 Michigan Truck Crash History and Description

Truck crash trends have been tracked in a number of ways for the overall period from 1982 to 1988. The general trends over the period were reported in figure 1-1. Data represented in that figure reveal that truck crashes have increased by 64% between 1982 and 1988 while the total number of all vehicle crashes has increased by 39%. However, since 1986 the number of truck crashes has actually decreased from 23,412 to 21,233. Currently, about 50% of all truck crashes involve straight trucks. Straight trucks without a trailer and bobtails are sometimes combined as "single unit" trucks, as noted above. While the year-to-year trend in this category is not obvious (because of the "bobtail error" discussed earlier), it seems reasonably clear that the number of "single unit" involvements has been increasing over the period. In 1988 there were almost 9,000 crashes involving singles (tractor-semitrailer) which is just over 2% of all crashes and about 42% of all truck crashes. Further, the number of double-involvements has more than doubled over the seven-year period. However, even in 1988 doubles accounted for only about 0.2% of all crashes and less than 4% of all truck crashes. Indeed, in 1988 there were only 741 crashes involving doubles.

In short, the year-to-year variation in the types of trucks involved in crashes is somewhat erratic—sharp increases over some periods with slight decreases or no change over others. This comment notwithstanding, over the past several years, the frequency of crashes for major truck types (straight trucks, singles, and doubles) has been increasing in Michigan and at a rate that is far greater than the overall crash trend.

The following discussion is directed to a general characterization of truck crashes in Michigan. First, truck crashes are described in terms which are reasonably compatible with stratifications based directly on the Michigan UD-10 accident reporting form. Then, the crashes are re-examined in terms of the MTTIS data that were collected. The latter culminates in a presentation of those data which will be used directly with the survey-based exposure data in calculating crash rates.

In some of the following discussion, only two years of data are discussed, 1987 and 1988. This is due to the fact that only 1987 and later data were corrected for the "bobtail error." General trends and findings are given in the text and detailed documentation is contained in Appendix D.

3.3.1 Types of Crashes

In addition to the numbers and rates of truck-involved crashes, the types of crashes are also of interest. A comparison of crash type distributions for general vehicle classes (all vehicles, non-trucks, trucks) was undertaken (see table D-1) for types identified and coded by MSP. The variation between 1987 and 1988 for any of the three classifications is quite small—there is generally less than a one percentage point shift. The differences between vehicle classifications are much more marked. The comparison of non-truck-involved and truck-involved crashes showed the following differences (where differences of about a 2% or more are noted):

> Compared to non-trucks, trucks have proportionately <u>more</u> one-vehicle miscellaneous, two-vehicle backing, and two-vehicle rear-end (all types) crashes; and
>
> Compared to non-trucks, trucks have proportionately <u>fewer</u> one-vehicle with parked vehicle, one-vehicle with fixed object, one-vehicle with animal, two-vehicle angle/straight, and two-vehicle head-on (with one turning left) crashes.

One of the largest differences is in the two-vehicle rear-end category which accounts for over one-third of all truck-involved crashes but only about one-quarter of all non-truck-involved crashes. On the other hand, trucks are (proportionately) much less likely to be involved in one-vehicle animal crashes. More importantly, if one-vehicle crashes are taken collectively, it is seen that trucks are far less likely to be involved in such crashes—the averages for the two years show that about 21% of all truck-involved crashes involved only one vehicle compared with about 43% of all non-truck-involved crashes. This would seem to indicate that trucks have "problems" in interactions with other vehicles as opposed to when there are no such interactions.

A similar comparison was made (table D-2 in the appendix) for different types of trucks—specifically straight trucks, bobtails, singles, and doubles. The table shows the following:

> **Doubles** have proportionately <u>more</u> one-vehicle miscellaneous, overturning, two-vehicle head-on, and two-vehicle rear-end crashes than all other truck types;
>
> **Doubles** have proportionately <u>fewer</u> one-vehicle with fixed object (except relative to straight trucks), two-vehicle angle/straight, and driveway (except relative to singles) crashes;
>
> **Singles** have proportionately <u>more</u> one-vehicle miscellaneous (except relative to doubles) and two-vehicle turning crashes;
>
> **Singles** have proportionately <u>fewer</u> driveway crashes;

Straight trucks have proportionately more one-vehicle with parked vehicle, two-vehicle angle/straight, two-vehicle backing, and driveway crashes;

Straight trucks have proportionately fewer one-vehicle with fixed object, and two-vehicle rear-end and turning-related crashes; and

Bobtail crashes are hard to characterize as neatly as the others—in some instances they appear to be similar to combinations while in others they are similar to straight trucks.

In general, the crashes that the different types of trucks are involved in appear to be related to the kind of service they typically provide. Straights are more likely to be shorter-haul, within urban area trips, while combinations are more likely to be used for longer hauls in both urban and rural areas, and the crashes that they are involved in are of the type that would be expected. It should be noted that some of the over-involvements in certain crash types may be due to "quirks" in the coding of crashes. For example, if a truck spilled some gravel which broke the windshield of a vehicle going the opposite direction, the crash would be coded as a two-vehicle head-on. Likewise, gravel which struck following vehicles might be coded as two-vehicle rear-end. Indeed, if there was a problem with a single truck spilling gravel over the length of a trip, several separate crashes might be reported. (It should be noted that there was, indeed, one such incident pointed out by MSP coders—one truck was involved in more than six separate "crashes.")

Crashes where the truck involved was coded as "vehicle 1" (the assumed at-fault vehicle in the crash) were also examined (table D-3 in the appendix). Note that both one-vehicle truck crashes and multi-vehicle crashes where the truck is the first vehicle are considered. For the most part the same types of trends noted above were observed, only the differences are somewhat more dramatic. For example, the tendency for doubles to be in one-vehicle, roll-over (overturn) crashes is highlighted.

Examination of one-vehicle versus multi-vehicle crashes shows that all truck types are less likely to be involved in one-vehicle crashes than other vehicle types. For example, in 1988, 19% of the bobtail involvements, 23% of the singles involvements, and 21% of the doubles involvements were single-vehicle crashes versus 39% of all non-truck crashes.

The distribution of single-vehicle truck crashes also differed from single-vehicle non-truck crashes by time of day. Approximately one-quarter of the truck-involved, single-vehicle crashes occurred between 7:00 P.M. and 5:00 A.M., while almost half of the non-truck-involved, single-vehicle crashes occurred during these hours. Conversely, 46% of truck-involved, multi-vehicle crashes occurred between 9:00 A.M. and 3:00 P.M. versus only 32% of the non-truck, multi-vehicle crashes. This trend is consistent over the 1982-1988 period for truck involvements although there has been some shift of the trends for non-trucks—particularly a proportional decrease in one-vehicle, non-truck involvements from midnight to 5:00 A.M. (from 23.7% in 1982 to 18.4% in 1988 with most of the decrease between 1982 and 1985).

3.3.2 Severity of Crashes

While truck-involved crash frequencies and rates are of significant interest, another perceived problem concerns the seriousness, or severity, of such crashes. The conventional wisdom is that, even if truck crash rates are lower than those for other vehicles, the severity of truck crashes is likely to be much higher. Indeed, it could be argued that it is the severity of these crashes that make them so prone to extensive media coverage.

For this portion of the analysis, a crash was categorized according to the most serious injury that resulted from the crash—e.g., if at least one person was killed, the crash was considered to be fatal; if anyone was injured, the accident was classified as an injury accident; if no one was injured or killed, the crash was considered to be "property damage only" (PDO).

The number of fatal crashes involving trucks in Michigan is relatively small. In 1982, there was a total of 101 fatal crashes involving straight trucks, bobtails, singles, and doubles, which increased to fatal 179 in 1988—a 77% increase in fatal crashes compared to the 68% increase in all crashes in those same categories. The 179 fatal crashes were distributed among vehicle types as follows: doubles, 10; singles, 101; bobtails, 6; and straight trucks, 52. Because of the bobtail error, it is difficult to say whether there has been shifting among the categories over the period, but in 1982 doubles accounted for about 3% of the fatal crashes attributed to the four different truck groups compared to almost 6% in 1988. Such percentages are, however, relatively volatile as one or two crashes can change the percentages dramatically. Indeed, in 1987 doubles accounted for almost 11% of the fatalities for these four groups.

Table 3-1 shows the summary of crashes for 1982 through 1988 for all crashes, all non-truck-involved crashes, and all truck-involved crashes. The entries in the table are the percentages of crashes that fell into the appropriate category—e.g., in 1982, 0.4% of all crashes resulted in fatalities while 69.9% were PDOs.

Table 3-1
General Comparison of Crash Severity (1982–1988)

Crash Severity	1982	1983	1984	1985	1986	1987	1988
ALL CRASHES							
Fatal	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
A-injury	5.0	5.1	5.0	4.7	4.4	4.5	4.2
B-injury	10.2	10.1	10.1	8.7	8.2	8.1	7.6
C-injury	14.4	15.2	15.5	14.4	14.2	14.0	13.9
PDO	69.9	69.2	68.9	71.9	72.8	73.0	74.0
NON-TRUCK CRASHES							
Fatal	0.4%	0.3%	0.4%	0.3%	0.3%	0.3%	0.3%
A-injury	5.3	5.3	5.4	4.8	4.6	4.5	4.2
B-injury	10.9	10.6	10.6	9.1	8.6	8.3	7.9
C-injury	15.0	15.8	16.0	14.9	14.6	14.1	14.3
PDO	68.4	68.0	67.6	70.8	72.0	72.8	73.2
ALL-TRUCK CRASHES							
Fatal	0.8%	0.9%	0.8%	0.7%	0.6%	0.7%	0.8%
A-injury	4.8	4.9	4.8	4.4	4.4	4.9	4.4
B-injury	7.3	7.3	7.1	6.9	6.4	6.4	6.0
C-injury	11.4	11.7	12.3	12.2	12.2	11.8	11.3
PDO	75.7	75.2	75.0	75.9	76.3	76.2	77.5

NOTE: For this analysis a crash was "classed" according to the most serious injury reported—e.g., a crash resulting in a fatality and an A-injury is classed as a fatal, and the number of fatalities or injuries in a single accident is not considered. A=incapacitating injury, B=non-incapacitating injury, C=possible injury, PDO=no injury, and/or property damage only.

The statistics in table 3-1 indicate that for all crashes there have been proportional decreases in injury crashes and an increase in PDOs while the proportion of fatal crashes has remained relatively constant. This same trend is noted for all non-truck crashes although there is some variation in the fatality proportion. The fatality proportion for truck-involved crashes has shown some variation over the period but is roughly the same in 1988 as it was in 1982. The injury categories for truck crashes have all decreased over the entire period while the PDO proportions have increased.

The comparison between all crashes and all truck crashes is interesting in that it shows that trucks appear to be involved in both a higher proportion of fatal crashes as well as a higher proportion of PDOs. While the fatal proportion for trucks is low, it is, nonetheless, more than twice that for non-trucks. The differences in the PDO proportions are far greater in an absolute sense. While the explanation of why a higher proportion of truck-involved crashes result in fatalities is found in simple physics, the explanation of the higher

PDO proportion is not as obvious. It is possible that there is a high number of "crashes" that involve things like gravel damaging automobile windshields which would be counted as a two-vehicle PDO crash. It does not seem appropriate that such crashes be "counted" with the same weight even as "fender-benders," let alone with fatals. Indeed, counting such incidences as crashes tends to upwardly bias the number of truck crashes while "undervaluing" the percentage of truck crashes that result in serious injuries or fatalities. That is, if the number of "real" crashes is artificially raised, the percentage of crashes that result in fatalities is, conversely, artificially lowered. Such incidents, if prevalent, would also tend to bias the relative proportions of one- and two-vehicle crashes.

Severity can also be examined in the context of type of truck and whether the truck was "vehicle 1" (the assumed "at-fault" vehicle) or "vehicle 2" (the vehicle which is assumed to be less at fault). Table D-4 in the appendix displays this analysis. Note that in this table when vehicle 1 is not a truck, vehicle 2 is a truck, and that single-vehicle and multi-vehicle crashes are combined. For example, of the 5,910 crashes in 1987 where a single was vehicle 1, 26 (0.4%) resulted in fatalities, 218 (3.7%) resulted in an A-injury, and so forth.

When vehicle 1 is a double, crashes are somewhat more likely to be more serious than when a single is vehicle 1. However, the magnitude of the difference is not very large and seems prone to considerable variation (the fatality proportion for doubles as vehicle 1 in 1987 is 1.4% but only 0.4% in 1988). Similar year-to-year variations were noted for 1982-1986 due to the small absolute numbers of fatal crashes with doubles as vehicle 1.

General examination of such data shows that crashes tend to be more serious when the crash involves the truck as vehicle 2 than as vehicle 1 (notwithstanding the fact that one- and two-vehicle crashes are combined), and that this is true for all truck types shown.

3.3.3 Truck Driver Age

Another question of identified interest in truck crashes concerns the age of the driver. Thus, the age of the driver of vehicle 1 for all crashes, non-truck-involved crashes, and truck-involved crashes for 1982-1988 was examined (table D-5). The age distributions show remarkable year-to-year consistency with a slight trend towards older driver 1's in all crashes and non-truck-involved crashes.

The ages of the truck drivers themselves as driver 1 were also examined (table D-6). Of interest here is the finding that the age profile of truck drivers who are assumed to cause crashes (since they are identified as driver 1) is considerably higher than the profile of all drivers who cause crashes. Over one-quarter of all drivers who cause crashes are 21 or less (table D-5) while driver 1's in that same age category account for only around 2% of the singles and doubles crashes (table D-6). Similarly, between about 6% of driver 1's in all accidents are older than 64, while in 1988 only 0.8% of singles driver 1's and 0.2% of doubles driver 1's were in that age category. These findings are not unexpected given that "all drivers" includes many younger (school-age) drivers whereas far more of the truck drivers would naturally be beyond high-school age but younger than retirement age.

The comparisons by type of truck are also revealing—straight trucks are driven by the youngest drivers (by far), while doubles drivers are somewhat older than those who drive singles (although there are proportionately more crash-involved drivers over 65 who drive singles than doubles). Truck driver age is also addressed later in this section using the age stratifications which were used for the survey.

3.3.4 Truck Crash Locations

It was suggested in an earlier section that truck crash types were related to where trucks were used—straight truck crashes appeared to be associated with more local service while combination truck crashes appeared to be more "over the road" type crashes. Thus, truck crashes were also examined according to the part of the highway system on which they occurred. In general, a review of the 1982-1988 data showed that between 60 and 70% of the non-truck crashes occurred on the "local" highway system (streets and roads without a Michigan or US number, such as city streets and county roads) while truck-involved crashes were considerably more likely to occur on interstates and Michigan and US-numbered highways. For non-trucks, this observation is fairly consistent regardless of the level of severity. However, when examining the proportions of crashes on the "non-local" system by severity, fatals were somewhat more likely to occur on this part of the system than other types of crashes (e.g., almost 40% of the fatals occurred on the non-local system versus 33% of the B-injury crashes).

Truck-involved crashes, however, showed the reverse of the above. From 50% to more than 70% of the crashes occurred on the non-local system with the proportion of fatal truck-involvements being the most dramatic. The proportion of fatals on the non-local system was always the highest of all severity types. In 1988, non-local roads accounted for almost three-quarters of all truck-involved fatal crashes.

The severity by road type analysis was taken even further (table D-7) through examination of the distributions of severity of crashes by road type for truck-involved and non-truck-involved crashes on non-local roads. More than half of all non-truck-involved crashes that occur on the non-local system occur on Michigan-numbered roads; US-numbered routes account for another one-quarter; and the interstate system accounts for less than one-quarter. This is consistent for all severity levels and (generally) for both 1987 and 1988.

On the other hand, truck-involved crashes are more evenly distributed by road type than non-truck crashes. While Michigan-numbered routes still generally account for the greatest proportion of, for example, fatal crashes, the proportion is much lower (nearer 40%, versus 50% for non-trucks). Further, with the exception of fatal crashes, interstates account for a considerably higher proportion of crashes than US-numbered routes.

Roadway classifications used during the calculation of the exposure estimates are somewhat grosser than those discussed above. The stratification of truck crashes according to those is discussed in the next section.

3.3.5 Summary of Michigan Crash History

In general then, the review of Michigan truck crash characteristics shows that trucks are more likely to be involved in two-vehicle crashes than non-trucks, truck crashes are more likely to be on interstates and Michigan- and U.S.-numbered routes, trucks are more likely to be involved in both fatal and PDO crashes but severity has decreased slightly over time, trucks are more likely to be driven by older drivers, and truck crashes are more likely to occur during the daytime hours. Differences between truck types were also noted: for example, doubles have more overturning and two-vehicle rear-end crashes while singles have more two-vehicle turning crashes.

What remains to be determined is whether the trends noted in the frequencies of crashes are similar to those when crash rates are considered.

3.4 Comparison of Study Period with Other Years

As described in an earlier section of this report, the study year was not congruent with a calendar year; it spanned the period from May, 1987 through April, 1988. Thus, it was necessary to draw the appropriate crashes from the two years. In this section, a brief review of the study year data is provided and the study year is compared with data from calendar years 1987 and 1988, in order to demonstrate that the study year data are representative.

There was a total of 408,066 crashes in the study year, compared to approximately 397,400 in 1987 and 410,600 in 1988. This appears to be a reasonable number given that the trend has been year-to-year increases in the number of crashes (with the exception of 1986 which represented a "spike" in the trend—see figure 1-1).

The number of truck crashes increased steadily between 1982 and 1986, then decreased in 1987 and again (very slightly) in 1988. However, the number of truck-involved crashes in the study year is greater than either 1987 or 1988: 21,427 in 1987, 21,827 in the study year, and 21,233 in 1988. The higher number in the study year is driven, in part, by the pattern of crashes for straight trucks and (to a far lesser extent) bobtails—that is, there are higher numbers of straight trucks and bobtails in the study period than in either year per se. Within the two-year period there appears to be a "spike" of crashes occurring during the study period within the context of a net decrease in truck crashes between the two years. Single and double involvements increased between 1987 and 1988 (despite the overall decline in truck involvements), and the single and double involvements in the study year are consistent with that trend, although the number of doubles is lower than would have been expected. These findings are illustrated in table 3-2.

Table 3-2
General Comparison of 1987, Study Year, and 1988 Data

Crash Category	1987	Study Year	1988
Total Crashes	397,388	408,066	410,587
All Trucks	21,427	21,827	21,233
Straights	10,774	10,993	10,289
Bobtails	450	458	454
Singles	8,726	8,883	8,971
Doubles	668	678	741

In general terms then, the numbers of crashes involving bobtails and straight trucks in the study year are somewhat higher than would be expected (although the variation in the number of bobtails is very small). On the other hand, the numbers of single and double involvements in the study year seem consistent with the 1987-1988 differences and with the longer trend over time, notwithstanding the note (above) that the number of doubles might be somewhat lower than expected.

Qualitative comparisons between 1987, the study year, and 1988 were made along the same lines as discussed in the last section (e.g., crash type, crash location) with the following results:

> There were no differences in the crash type distributions for all vehicles, non-trucks, and trucks, <u>or</u> for specific types of trucks (straight trucks, bobtails, singles, doubles);
>
> There were no differences in the distributions of crashes by severity for all vehicles, non-trucks, and trucks, <u>or</u> for specific types of trucks (straight trucks, bobtails, singles, doubles);
>
> Although the year-to-year variations in the percentage of truck crashes that result in fatalities for different truck types is quite volatile, the statistics for the study year were within the range defined by the 1987 and 1988 figures (e.g., for doubles, the study year figure was 0.103% with 1987 at 0.108% and 1988 at 0.056%;
>
> There were no differences in the distributions of the age of the driver of vehicle 1 in truck-involved crashes, regardless of type of vehicle driven;
>
> There were no differences in the distributions of the age of the driver of vehicle 2 in truck-involved crashes, regardless of type of vehicle driven;
>
> In general, there were no differences in the distribution of crashes by severity and roadway type for all, non-truck, and truck-involved crashes (notwithstanding the fact that there was some year-to-year variation noted earlier);
>
> There were no differences in the distributions of one- and multi-vehicle crashes by time of day for either truck or non-truck crashes;
>
> There were no differences in the distributions of crash severity by time of day for either truck-involved or non-truck involved crashes;

As is obvious from the above, with the exception that there seemed to be somewhat more truck-involved crashes in general during the study year, there were no notable differences in their distributions by severity, location, or any of the other parameters of concern. It should also be remembered that the single- and double-involved crashes during the study year appeared to be more consistent with the 1987-1988 differences than were all truck involvements. In short, while any "all truck" crash rates derived for the study year may be somewhat higher than for either all of 1987 or all of 1988 (assuming that truck use increases or decreases with the number of crashes over the short term), their relative variations are expected to be characteristic for Michigan. Further, the single- and double-involvement rates are not be expected to be "too high" relative to the crash frequency differences between the two years.

3.5 Truck Crashes in the Study Period

In this section, the stratifications of truck crashes according to the "cells" defined during the development of the exposure estimates are discussed. As indicated earlier, there were four variables used to define the exposure estimates: vehicle type, time of day, road type, and an urban/rural notation. In addition, the crashes had to be sorted according to the state of vehicle registration (Michigan or non-Michigan). It was also necessary to consider whether the crash involved the truck as the "first" or "second" vehicle.

Of the 21,827 total truck crashes in the study year, there were 21,445 that were usable—the truck was either the first or second vehicle and complete data records were available. The following paragraphs serve to characterize these crashes according to the stratifications noted above. Reference is also made to comparisons between different years for the study variables.

There is a shift in how truck crashes are defined, and counted, from this point on—a distinction is made between a crash that involves one or more trucks, a ***truck-involved crash*** or ***truck crash***, and the number of ***truck-involvements***, or ***involvements***, (each truck that is in a crash is counted separately). For the rates to be developed later, the appropriate unit is a truck involvement rather than a truck-involved crash per se. Operationally, this means that a crash involving two trucks, for example, will be counted as two involvements, while a crash that involves only one truck is one involvement. In essence, truck-involved crashes are counted more than once if they involved more than one truck. The number of truck involvements will be the numerator in the rates that are developed. The denominator will be the vehicle-miles-traveled (VMT) in millions of miles for the appropriate truck type. Rates will not be presented until Section 4.

3.5.1 Stratifications According to Study Variables

There is a total of 21,445 usable truck crashes in the study period—this includes any crash which involved any type of truck in either the first or the second position in the crash (as per the UD-10 and accident record). These 21,445 crashes resulted in 14,967 truck involvements as vehicle 1 and 8,169 truck involvements as vehicle 2 for a total of 23,136 truck involvements.

Truck involvements by one- vs. two-vehicle crashes and road class.

The total involvements are categorized by truck type, one- and two-vehicle crashes, and road class in table 3-3. The distribution of total involvements (regardless of the number of vehicles involved) by road class is about as expected—straight truck involvements, for example, are much more likely to occur on the more local part of the system while doubles are more likely on limited access highways. Note that the higher frequency of singles-involvements on the more local system may also be indicative of a far higher rate of involvement.

The comparison of involvements in one-vehicle crashes with involvements as vehicle 1 in two-vehicle crashes indicates that straight trucks and bobtails are proportionately more prone to be involved in the latter than either singles or doubles. Straight trucks, however, have far more involvements on the local system—this is presumably related to usage patterns. The patterns for singles and doubles indicate that both are more likely to be involved in one-vehicle crashes on limited access highways than on other roads, while singles are more likely to be vehicle 1 in two-vehicle crashes on other roads than on limited access highways. This is presumably due to the fact that vehicle-vehicle interactions are more "limited" on the former. While a similar, if somewhat more pronounced, pattern is noted for doubles, straight trucks do not show the same shift between road systems.

Comparison of involvements in two-vehicle crashes as vehicle 1 versus vehicle 2 shows that while all truck types have more involvements as vehicle 1 than vehicle 2, the ratios (involvements as vehicle 1 [in two-vehicle crashes] divided by total involvements as vehicle 2) show that bobtails (1.6) appear to be more prevalent as vehicle 1 than straight trucks (1.3), singles (1.3), and doubles (1.2). However, while the ratio for straight trucks is fairly consistent across road classes and doubles decrease from 1.3 for limited to 1.1 for both major and local, the ratio for singles increases from 1.16 for limited to 1.23 for major and 1.48 for other road classes. This would seem to indicate that singles have an increasing probability of a crash under, generally speaking, more restrictive operating geometry and where vehicle-vehicle interactions are more prevalent.

Table 3-3
Truck Crash and Involvement Characteristics
By Road Class, Truck Type, and One- vs. Multi-Vehicle Crashes

Road Class	Straight Truck	Str. Truck + Trailer	Bobtail	Single	Double	Other
TRUCK-INVOLVEMENTS IN ONE-VEHICLE CRASHES						
Limited	248	42	29	803	80	0
Major	451	46	23	603	47	1
Other	1,418	113	33	687	39	0
Totals	2,117	201	85	2,093	166	1
TRUCK INVOLVEMENTS AS VEHICLE 1 IN MULTI-VEHICLE CRASHES						
Limited	581	75	49	1,247	108	100
Major	1,452	114	72	1,139	89	113
Other	3,041	190	105	1,507	76	246
Totals	5,074	379	226	3,893	273	459
ALL TRUCK INVOLVEMENTS AS VEHICLE 1						
Limited	829	117	78	2,050	188	100
Major	1,903	160	95	1,742	136	114
Other	4,459	303	138	2,194	115	246
Totals	7,191	580	311	5,986	439	460
ALL TRUCK INVOLVEMENTS AS VEHICLE 2						
Limited	456	41	38	1,079	83	119
Major	1,091	71	36	921	81	166
Other	2,357	139	67	1,013	69	342
Totals	3,904	251	141	3,013	233	627
ALL TRUCK INVOLVEMENTS AS VEHICLE 1 AND VEHICLE 2						
Limited	1,285	158	116	3,129	271	219
Major	2,994	231	131	2,663	217	280
Other	6,816	442	205	3,207	184	588
Totals	11,095	831	452	8,999	672	1,087

Michigan-registered truck involvements by type and road class.

As indicated, only Michigan-registered trucks are represented in the exposure data. Thus, variations in the mix of trucks by registration are of interest, and are presented in table 3-4. The entries in this table are the ratio of Michigan trucks to all trucks and the percentage of Michigan trucks. The ratio is shown since it was not possible to categorize all involvements shown in table 3-3 by registration (i.e., there are fewer involvements summarized in table 3-4 than in 3-3).

Table 3-4
Truck Crash and Involvement Characteristics
By Road Class and Registration

Road Class	Straight Truck	Str. Truck + Trailer	Bobtail	Single	Double	Other
MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 1						
Limited	721/801 (90.0)	101/116 (87.1)	45/73 (61.6)	975/1,971 (49.5)	129/182 (70.9)	47/54 (87.0)
Major	1,711/1,866 (91.7)	141/159 (88.7)	64/93 (68.8)	1,063/1,695 (62.7)	108/135 (80.0)	68/72 (94.4)
Other	4,162/4,369 (95.3)	283/301 (94.0)	108/137 (78.8)	1,370/2,119 (64.7)	91/111 (82.0)	136/145 (93.8)
MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 2						
Limited	401/440 (91.1)	35/40 (87.5)	25/37 (67.6)	512/1,025 (50.0)	52/80 (65.0)	55/62 (88.7)
Major	1,005/1,083 (92.8)	63/69 (91.3)	21/33 (63.6)	600/900 (66.7)	67/79 (84.8)	100/107 (93.5)
Other	2,262/2,338 (96.7)	127/136 (93.4)	52/67 (77.6)	668/994 (67.2)	62/68 (91.1)	221/225 (98.2)
ALL MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 1 AND VEHICLE 2						
Limited	1,122/1,241 (90.4)	136/156 (87.2)	70/110 (63.6)	1,487/2,996 (49.6)	181/262 (69.1)	102/116 (87.9)
Major	2,716/2,949 (92.1)	204/228 (89.5)	85/126 (67.5)	1,663/2,595 (64.1)	175/214 (81.8)	168/179 (93.9)
Other	6,424/6,707 (95.8)	410/437 (93.8)	160/204 (78.4)	2,038/3,113 (65.5)	153/179 (85.5)	357/370 (96.5)
TOTAL	10,262/10,897 (94.2)	750/821 (91.4)	315/440 (71.6)	5,188/8,704 (59.6)	509/655 (77.7)	627/665 (94.3)

Table entries: [# Michigan-registered / total # trucks]
(percentage of Michigan-registered trucks)

The data in table 3-4 do not reveal any unexpected trends. For example, a far higher percentage of straight trucks (versus singles or doubles) involved in crashes are registered in

Michigan. The data also indicate that Michigan-registered trucks (regardless of type) are more likely to be involved in crashes on the more local parts of the system. Although the vehicle 1 (the presumed at-fault vehicle) data are not broken down by one- vs. multi-vehicle crashes, there appear to be similar trends for vehicle 1 and vehicle 2 involvements (with the exception of doubles which may be more a function of sample size)—that is, Michigan trucks do not seem to be more likely to be involved as vehicle 1 than vehicle 2. Conversely non-Michigan trucks do not seem to be over-represented in causing or simply being involved in crashes.

Truck involvements by type, road class, and time of day.

The involvements were also categorized by a basic time-of-day differentiation: day and night (as defined earlier). The involvement data are summarized according to this dichotomy in table D-8 in the appendix. In general, the large majority of truck-involved crashes occurs during the daytime hours although there are some interesting variations by truck type, road class, and whether the crash involved one or more vehicles.

For one-vehicle truck crashes, straight trucks had proportionately more daytime involvements on limited access roads than combination vehicles although only a small fraction of straight truck-one-vehicle crashes is on that type of highway. Conversely, higher percentages of one-vehicle combination truck crashes occur on "lower" classes of highways during the daytime. This is most likely due to their relative exposure on those kinds of roads during the day. That is, there are probably more singles on limited access roads during the night than on other types of roads.

Truck involvements by type, road class, and urban/rural designation.

The last stratification to be addressed is the urban/rural designation (table D-9). Examination of these data showed that more of the crashes involving any type of truck tend to occur in rural areas—although crashes involving combinations are considerably more likely in rural areas than are those involving straight trucks and bobtails. Within the context of a higher proportion of truck involvements being in rural areas, it is interesting to note that involvements as vehicle 2 in multi-vehicle crashes are more likely in rural areas than involvements as vehicle 1. In general, this seems to support the notion that trucks "cause" more of a problem in urban areas than they do in rural areas.

3.5.2 Study Year Crash Frequencies

Detailed breakdowns are shown in the appendix for the numbers of crashes for each "cell" of the frequency matrices formed by the combinations of the study variables for the study year: (truck type) by (day/night) by (rural/urban) by (state of registration) by (road class). Frequencies for one-vehicle crash involvements (table D-10), multi-vehicle crash involvements (table D-11), and total involvements (table D-12) are shown. Similar tabulations are also provided (tables D-13 through D-15) for casualty crashes.

3.5.3 Crash Frequencies on "Green Routes"

The so-called "green routes" refer to a designation of truck routes on the truck operator maps provided by the Michigan Department of Transportation to all truckers. The routes on these maps are color-coded as follows: green and black roads are generally US and M-numbered routes and are open to legal axle loads for year-around service; and red routes are generally M-numbered routes which have seasonal load limitations. Local streets and roads are not shown on these maps. In addition, the green routes have more liberal length and width regulations and are generally somewhat "better" roads than those designated in black (e.g., all interstates are green).

UMTRI-collected data on exposure did not permit a breakdown of the total estimated exposure by truck route designations per se. However, it was possible to determine what type of route (from the truck route map) each crash occurred on. Hence, a cross-tabulation of the crash data was done considering the two route classification variables—i.e., UMTRI-defined routes (limited access, major artery, and other) and truck-operator-map-defined (TOM) routes. Overall, there were approximately 11,600 crashes which received both a TOM and an UMTRI code.

Crashes occurring on TOM-green routes are split about evenly between the UMTRI classifications of limited and major (approximately 4,800 crashes each) with only about 2% of the crashes identified as occurring on TOM-green routes being coded as occurring on UMTRI-other roads. Just over 85% of the crashes occurring on TOM-black routes were on the UMTRI-major designation (1,270 crashes). Finally, about 95% of the crashes occurring on TOM-red routes were on UMTRI-major roads—although the total number of crashes was not large (just over 100). Almost half of the total crashes did not receive a TOM code. These crashes occurred on the local system and were defined a default value for the UMTRI coding (other) and were not coded in the TOM system. There was also a small number of crashes that appeared to be mismatched between the two coding systems.

The TOM vs. UMTRI designation was also examined for urban vs. rural conditions. Approximately 60% of the crashes in question occurred in rural areas, although the matching between the two systems remained about the same. For the rural situations, the crashes occurring on TOM-green routes were somewhat less likely to be on the UMTRI-limited system—this is due to the distribution of rural crashes between interstates and US- or state-numbered routes. The UMTRI designation picks up the difference between interstates (and other limited access highways) and other major roads while the TOM designations do not (or at least as clearly). The comparison of the UMTRI and TOM codes has shown the following:

For both urban and rural situations, the TOM-green routes are basically split between the UMTRI-limited and UMTRI-major designations—thus conclusions about over- or under-representation in terms of casualty crashes would be an "average" of those made in 3.5.1.

For both urban and rural situations, the crashes on TOM-black routes were matched with those from the UMTRI-major designation—thus conclusions in regard to casualty crashes would be similar.

There were very few crashes on TOM-red routes, but almost all of them had an UMTRI-major designation. It is not clear whether there are any substantial differences in, for example, geometry between the TOM-red and TOM-black designations although the preponderance of TOM-red routes are in rural areas. Conclusions about the crashes (casualty or otherwise) on TOM-red routes cannot be reasonably drawn from the available data.

3.6 Summary

The source of crash data in Michigan is the computerized file coded from the UD-10, Traffic Accident Report, which is filled out by enforcement agencies for all reportable traffic accidents. The accident files are maintained and distributed by the Michigan State Police. For the purpose of this report, truck crashes were identified and extracted from the accident file maintained by the Michigan Department of Transportation. Some problems were identified in the coding of truck variables in the UD-10, most notably the mis-identifications of bobtails as tractor-semitrailers, but this problem was corrected beginning in 1987. To produce the analysis file, each case was manually reviewed and information indicating whether the truck was registered in the state of Michigan was added to the file. For the purpose of calculating rates, a one-year file running from May 1987 to April 1988 was formed. These dates match the period covered by the MTTIS travel data. Comparison of the study year with the two years from which it was drawn showed remarkable agreement.

The distribution of truck and all crashes from 1982 to 1988 was reviewed. In that period, truck crashes increased by 64%, while crashes involving any vehicle type increased by only 39%. But that overall increase masks year-to-year variations. Truck crashes increased to a peak in 1986, and declined in each of the two years following. Overall, truck crashes amount to about 5% of all traffic crashes. In the study year, there were 21,827 trucks involved in crashes. Of that total, 10,993 were straight trucks, 8,883 were singles, 678 were doubles, and 458 were bobtails.

Some intriguing differences were noted when crash severity was compared for trucks and non-trucks. Overall, the percentage of fatalities for truck crashes was about twice as high as for non-truck crashes. This seems reasonable, since trucks have a much greater mass than non-trucks, and consequently deliver much higher energies in collisions. But the data also indicated that a higher proportion of truck crashes were property-damage-only than non-truck crashes, which means that truck crashes have a lower probability of non-fatal injuries than non-truck crashes. The PDO proportion of truck crashes rose fairly consistently from 1982 to 1988. One explanation for this pattern is an artificial inflation of truck PDO crashes through multiple reports of vehicle damage from a single gravel train (for example) spilling some of its cargo in transit.

It was also found that trucks are more likely to be involved in a multi-vehicle crash as vehicle 1, the presumed at-fault vehicle, than as vehicle 2. When split out by truck type, bobtails had the highest ratio of vehicle 1 identifications to vehicle 2 identifications, followed in order by straight trucks, singles, and doubles. However, crashes tended to be more serious when the involved truck was identified as vehicle 2 than as vehicle 1.

It was also found that trucks were less likely to be involved in single-vehicle crashes than non-trucks, indicating that vehicle-vehicle interactions are more of a problem for trucks than other vehicles. Truck crashes are also more likely to occur on interstates and Michigan- and U.S.-numbered routes than on local roads. This primarily reflects the fact that trucks more often use those roads. Similarly, truck crashes occur more often in rural areas than non-truck crashes. The proportion of rural crashes is even greater if the only singles and doubles are considered. Finally, the proportion of "at-fault" drivers who are under 21 or over 64 is much smaller for trucks than for all other vehicles.

The crash frequencies reported here are used as the numerators in various rate calculations discussed in the following section. The exposure measures (the rate denominators) were discussed in Section 2. Calculating rates permit the identification of truck configurations and operating conditions that carry a higher probability of a crash. These rates allow us to separate situations in which there are many truck crashes simply because that is how trucks are used, from those situations where the truck truly is at greater risk.

SECTION 4

CRASH RATES OF MICHIGAN TRUCKS ON MICHIGAN ROADS

4.1 Introduction

Combining the UD-10 accident data supplemented by MSU with the MTTIS exposure data collected by UMTRI allows the calculation of crash involvement rates for different tractor configurations in different operating environments. In evaluating the safety of tractors, rates represent a significant extension of an analysis based on frequencies alone. Frequency counts of crashes classified by various factors are important in identifying where the crashes are, in a sense. Clearly, for example, the tractor-semitrailer combination suffers the greatest number of involvements. But singles are the most common tractor combination on the road, so one would expect them to have the greatest number of crashes. Rates combine frequency data with exposure data to produce estimates of crashes per mile traveled. Thus, the exposure to crashes of a given tractor combination can be taken into account and the relative risk of different tractor combinations under different operating conditions can be fairly compared. Thus, despite the fact that singles have so many more crashes than doubles, the safety experience of the two combinations can be legitimately compared. The rate computed to make these comparisons is the number of trucks involved in crashes per million miles of truck travel.

The rates calculated are based on the actual crash frequencies for the survey year as determined by MSU from MSP UD-10 reports and on the travel estimates generated by UMTRI from the MTTIS exposure study. Even though the rates are based on actual crash frequencies, they are estimates. The denominator in the calculation, miles traveled, is the product of a sample survey and thus subject to sampling error. And even though the crash frequencies are, barring some error in identifying or counting crashes, census numbers for the survey year, the survey year is itself a sample of the current crash experience of large trucks. Consequently, since the rates are estimates, the reader should keep in mind that the reliability of those estimates is sensitive to the number of instances on which they are based. Those based on relatively frequent occurrences-more miles, more crashes-are more reliable. Those based on infrequent occurrences-fewer crashes, less travel-are less reliable. In comparing particular rates, as a rule of thumb, those based on over 50 crashes and over a few million miles of travel are probably reasonably accurate. For those based on fewer crashes and travel, the rate should be regarded as a best estimate from a range of values.

Truck crash rates (and those for other types of vehicles as well) where the numerator is expressed in terms of truck involvements and the denominator in terms of (truck) vehicle miles of travel have been criticized because there is no consideration of the "exposure" of the other vehicles involved in the crash. From this point of view, the one-vehicle rates are arguably the purest form since they are unencumbered (biased) by consideration of other vehicles in the traffic stream. This point notwithstanding, rates based on the miles traveled of the vehicle type of interest are still widely used. In this study, rates will be expressed in various terms of truck involvements: one-vehicle involvements only, multi-vehicle involvements (where a truck is vehicle 1 or vehicle 2) only, and total crash involvements. In each case, the measure of exposure will be the miles traveled by the tractor configuration of interest in the particular analysis.

While frequency data for Michigan and non-Michigan straight trucks, bobtails, singles, and doubles were discussed in the last section and provided in tabular form in Appendix D, rates are developed for only Michigan bobtails, singles, and doubles. In each table that shows crash rates, the number of crash involvements is also shown—the data are shown in this way so that a qualitative assessment can be made as to the reliability of the rates since some are based on very few involvements. The last line in each table shows an overall rate (aggregated over all roadway types and so forth) by vehicle type which is probably the most reliable set of rates for each table.

Both the crash data organized (and sometimes coded) by MSU and the travel data collected by UMTRI has been cross-classified by the same factors:

• three configurations:	Bobtail, tractor-semitrailer, double trailer
• two area types:	Urban or rural
• two times of day:	Day or night
• three road types:	Limited access, major artery, other

In addition, the crash data were split into three different groups: all crashes; crashes which involved injury or death; and property-damage-only crashes.

Calculating rates which take into account all of these factors produces 108 different rates: 3 configurations x 2 area types x 2 times of day x 3 road types x 3 crash types. (3 x 2 x 2 x 3 x 3 = 108) These calculations are displayed in tables E-1 through E-3 in Appendix E. But discussing each of the 108 rates here would be unwieldy and tedious. Instead, each separate classification—rural/urban, day/night, road type, configuration type—will be taken up in turn, with the relevant subsets noted as appropriate.

4.1.1 Crash Rates by Area Type

Figure 4-1 below displays crash rates for all Michigan-registered tractors on Michigan roads. The rates are shown separately for urban and rural areas for three different crash severities. The pair of bars in the figure labeled "All" shows the rates for all police-reported crashes. The next two sets of bars represent the rates for "casualty" crashes (those involving a death or "A," "B," or "C" injuries), and for PDO (property damage only) crashes. The "all" crash category is simply the sum of casualty crashes and property damage crashes. As mentioned above, all the rates shown are crashes per million miles of travel. Table 4-1 presents the same results in tabular form. The three sections of the table display the three different crash groups, with subtotals for each crash severity. The first column gives the raw number of crashes falling into the respective categories. The second column shows estimated vehicle miles. The travel numbers are the same within each crash category since the exposed travel is the same. The last column shows the crash rate per million miles of travel. The rates are calculated simply by dividing the crash column by the travel column.

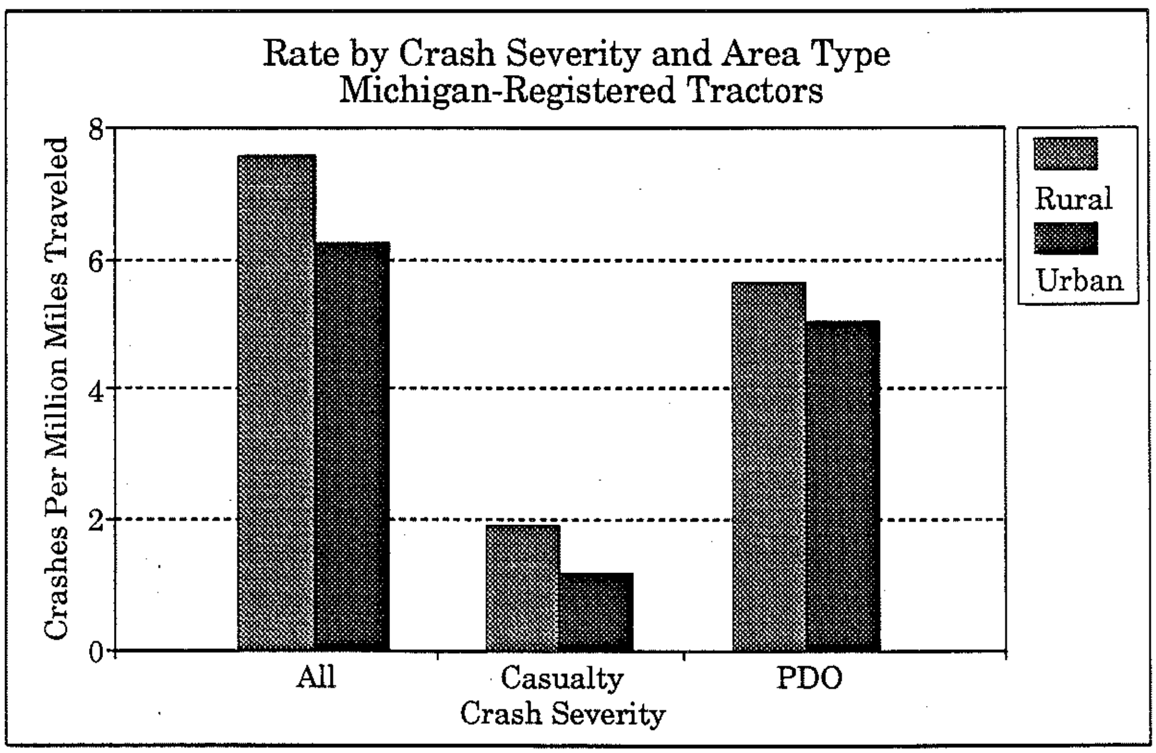

Figure 4-1

Looking at the first set of bars, the figure shows that for all crashes, the rate is higher in rural areas than in urban. This is the pattern one would expect. In general, speeds are higher in rural areas, and higher speeds are often, though not always, associated with higher crash rates. Road class is also associated with variations in crash rates, as will be shown below, and, other than the interstates, the quality of roads varies more widely in rural areas. On the other hand, traffic densities are often lower in rural areas, which should lead to a lower rate, but apparently that effect is not enough to overcome the effect of higher speeds or roadway quality.

The two sets of bars on the right of the figure show crash rates for Michigan-registered tractors separately for casualty and PDO (property damage only) crashes. Once again, the rate in rural areas is higher than that in urban areas for both levels of crash severity. Closer examination, however, indicates that the rate is proportionally higher in rural areas for the more severe crashes than for the less severe. In rural areas, the casualty crash rate is 1.90 per million miles, which is almost 60% higher than the corresponding rate, 1.19 per million miles, in urban areas. The PDO rate is more nearly the same in both urban and rural areas, though the rural rate is 12% higher. Looking at the raw numbers in table 4-1, there are more than twice as many casualty crashes in rural areas as in urban, while among PDO crashes, there are only 43% more rural crashes. Given a crash, a casualty is more likely to be a result in a rural area than in an urban area. This is again probably a function of the generally higher travel speeds in rural areas and the varying road quality. With a higher speed, a crash is more likely to involve death or injury to the occupants of the involved vehicles.

Table 4-1
Crashes, Travel, and Crash Rates
By Area Type and Crash Severity
Michigan-Registered Tractors

Area Type	Crashes	Travel (millions)	Rate
	ALL CRASHES		
Rural	3,648	484.06	7.54
Urban	2,354	378.74	6.22
Total	6,002	862.80	6.96
	CASUALTY CRASHES		
Rural	921	484.06	1.90
Urban	450	378.74	1.19
Total	1,371	862.80	1.59
	PROPERTY DAMAGE ONLY CRASHES		
Rural	2,727	484.06	5.63
Urban	1,904	378.74	5.03
Total	4,631	862.80	5.37

4.1.2 Crash Rates by Road Type

For this study, roads were divided into three types: limited access, major artery, and "other." Limited access roads consist primarily of the interstate system, but include other divided highways which are similar to interstates in that access is controlled. U.S. routes, numbered state routes, and other primary roads form the major artery category. All other roads are consigned to the "other" road category.

Table 4-2 presents the crash experience of tractors in Michigan for the three different road types. Figure 4-2 shows them graphically. The formats of the figure and table are similar to the previous figure and table. Table 4-2 shows the raw number of crashes and travel along with the calculated crash rate. In the figure, the first set of three bars graphs the crash rate per million miles of travel for all crashes. The next two sets of bars show those rates separately for casualty and property damage crashes.

Table 4-2
Crashes, Travel, and Crash Rates
By Road Type and Crash Severity
Michigan-Registered Tractors

Road Type	Crashes	Travel (millions)	Rate
	ALL CRASHES		
Limited Access	1,737	516.11	3.37
Major Artery	1,922	239.55	8.02
Other	2,343	107.14	21.87
Total	6,002	862.80	6.96
	CASUALTY CRASHES		
Limited Access	445	516.11	0.86
Major Artery	476	239.55	1.99
Other	450	107.14	4.20
Total	1,371	862.80	1.59
	PROPERTY DAMAGE ONLY CRASHES		
Limited Access	1,292	516.11	2.50
Major Artery	1,446	239.55	6.04
Other	1,893	107.14	17.67
Total	4,631	862.80	5.37

Table 4-2 illustrates the importance of calculating crash rates, as opposed to simply counting crashes. In the "all" crash group, the raw numbers of crashes are not all that different from road type to road type. About 29% of the crashes occurred on limited access roads, 32% on major arteries, and 39% on "other" roads. It is clear that "other" roads account for a large share of the crashes, but the difference is not dramatic. Among the most serious crashes, those involving a death or injury, the distribution of crashes by road class is very even. Each road class experienced about 450 casualty crashes during the survey year. (The distribution of property damage crashes accounts for the preponderance of the "other" road category among "all" crashes.)

However, the distribution of miles traveled by road class should be noted in the "Travel" column of table 4-2. About 60% of the travel by Michigan-registered tractors on Michigan roads is on limited access roads. Twenty-eight percent is on major arteries and only 12% is on the remaining "other" road class. While the differences in the raw numbers of crashes are not extraordinary, taking travel into account reveals the large differences in the risk of crash involvement between road types. For all crashes, the rate is 3.37 on limited access roads, 8.02 on major arteries, and 21.87 on other roads. Thus, overall, the crash rate on limited access roads is about six times lower than "other" roads. Looking at the casualty crashes, the ratio is about the same. The casualty crash rate for tractors is 0.86 on limited access roads, 1.99 on the major arteries, and 4.20 on the remaining roads. It is clear that for the most serious crashes, those involving a death or injury, the crash rate on limited access roads is about 2.3 times lower than major arteries and about 5 times lower than other roads. The rates for PDO crashes are higher on each road type, but in roughly the same proportion. The PDO rate on limited access roads is 2.5 crashes per million miles of travel, 6.04 on major arteries, and 17.67 on other roads.

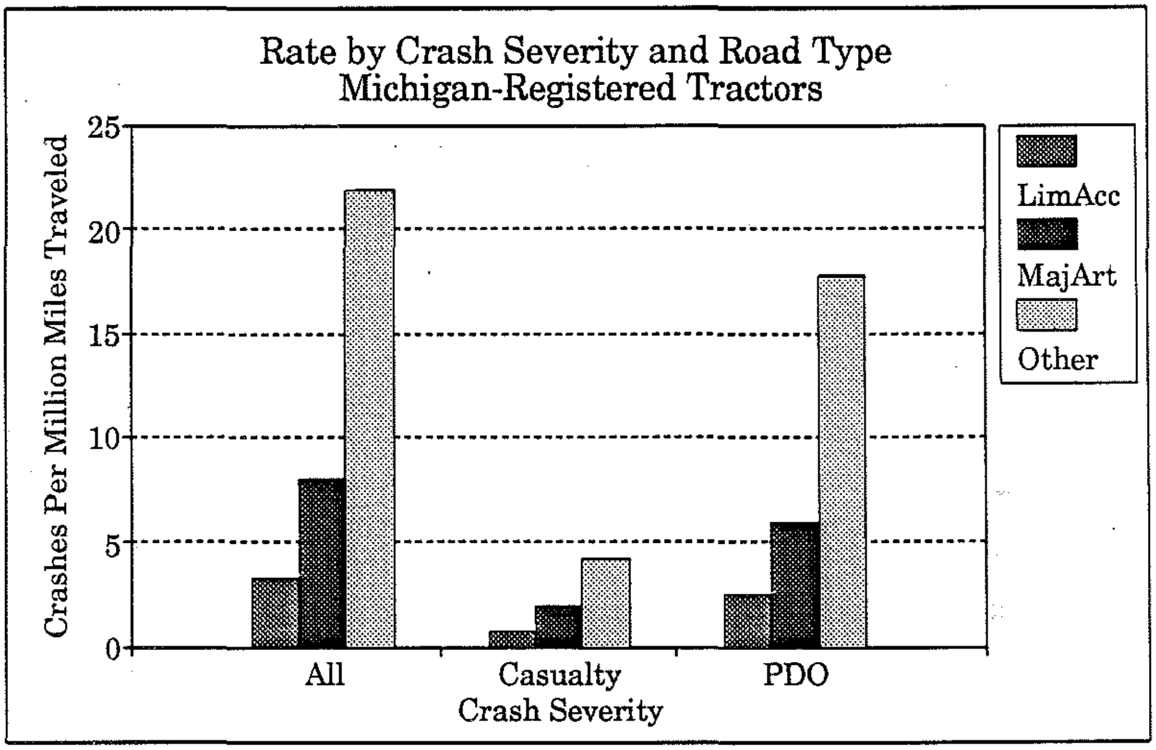

Figure 4-2

Figure 4-2 graphically illustrates the differences in crash rate by road class. It is apparent that the crash rate on "other" roads is much higher than on major arteries or limited access roads. This is the case for each crash severity level. It is also apparent that limited access roads are by far the safest, with a rate less than half that of the major arteries for all crashes.

It might be thought that, since interstates and highways like them typically see the highest speeds, their crash rates would be correspondingly high. But limited access roads are the safest roads in the traffic system. It is likely that the controlled access to the road, separated one-way traffic streams, roadway design, and other factors contribute to the relatively low tractor crash rate on such roads.

4.1.3 Crash Rates by Time of Day

Both the travel and the accident files included information which categorized travel and crashes by whether they occurred in the day or in the night. Day was defined as the period between 6 A.M. and 9 P.M.; the remaining hours were assigned to night. The purpose of this categorization was to examine the difference between the crash experience during daylight and darkness. Any choice of a fixed time period for that purpose could not perfectly capture the distinction. With daylight savings and the daily progression of changes in the time of sunrise and sunset, the periods of daylight and darkness change every day. Nevertheless, for practical reasons, particularly in mapping the mileage of the exposure population, it was necessary to settle on a fixed period. A 6 A.M./9 P.M. split seemed the best.

Several factors lead to the expectation of a higher crash rate at night. Most obviously, drivers are not able to see as well at night as they can during the day. Crash situations which a driver might otherwise see in time to avoid are less apparent at night. In addition, fatigue is presumably more of a problem at night, both in cases where the driver is approaching the end of a normal day and in cases where the driver is operating outside his normal sleep/waking cycles. Finally, both the frequency and proportion of drinking drivers, which typically does not include the truck driver, is higher at night.

Figure 4-3 below graphs the involvement rate by time of day for all crashes, casualty crashes, and property damage only crashes. Table 4-3 presents the crash, travel, and rate estimates on which the figure is based. The formats of both are the same as those of previous figures and tables.

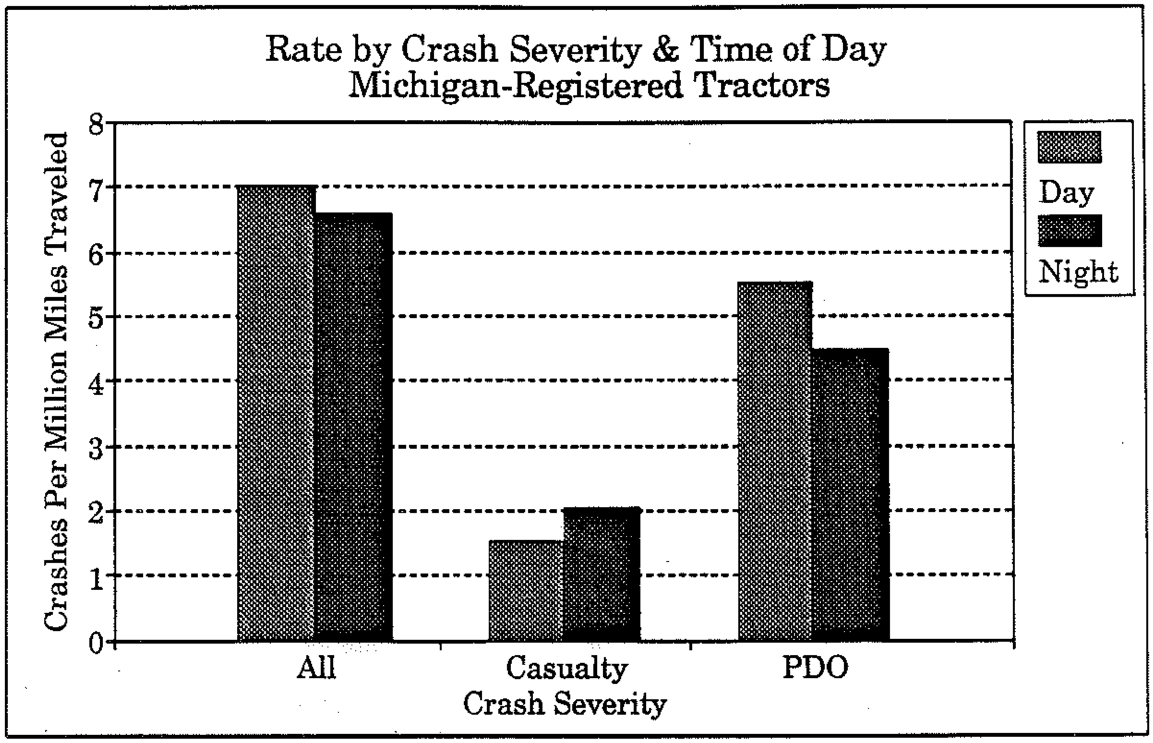

Figure 4-3

Figure 4-3 shows that, unexpectedly, for all crashes, the crash rate for tractors in Michigan is actually higher during the day than the night. By far the majority of the crashes occur during the day, 5,225 to 777, (see table 4-3) as would be expected. But most of the travel is also in the day, and it would be expected that there would be enough such travel that the daytime rate would be lower than for the night. In fact, though the overwhelming majority of travel is during the day, almost 750 million day miles to 118 million at night, that preponderance is not enough to result in a lower day rate. As it is, the day rate is only slightly higher than the night rate. During the day, the crash rate is 7.02, while during the night, the rate falls to 6.55. This difference is not great, but the expectation, based on the factors mentioned above, is that the rate should be higher at night. That this is not so constitutes a problem that warrants further exploration.

Table 4-3
Crashes, Travel, and Crash Rates
By Time of Day and Crash Severity
Michigan-Registered Tractors

Time of Day	Crashes	Travel (millions)	Rate
	ALL CRASHES		
Day	5,225	744.16	7.02
Night	777	118.64	6.55
Total	6,002	862.80	6.96
	CASUALTY CRASHES		
Day	1,126	744.16	1.51
Night	245	118.64	2.07
Total	1,371	862.80	1.59
	PROPERTY DAMAGE ONLY		
Day	4,099	744.16	5.51
Night	532	118.64	4.48
Total	4,631	862.80	5.37

Looking at the rate by crash severity (table 4-3) and the type of area (table 4-4) in which the crash occurred helps to explain this anomaly. When the rates are calculated separately by the two levels of crash severity, the casualty crash rate is in the anticipated direction, while the PDO rate is even more strongly in the opposite direction. For daytime casualty crashes, the rate is 1.51, while at night, the rate rises to 2.07. But for crashes which involved only property damage, the day rate of 5.51 compares to a nighttime rate of 4.48. Because there are so many more PDO crashes than casualty crashes, when an aggregate rate is calculated, the lower nighttime rate for PDO crashes overwhelms the higher casualty nighttime rate. As a result, overall the nighttime rate is slightly lower. So the explanation appears to be related to the differences between PDO and casualty crashes, either directly or through some other factor correlated with crash severity. Clearly, the factors mentioned above as leading to a higher nighttime rate-darkness, fatigue, alcohol use-are not the only things going on here. There must be other factors, correlated with crash severity, which cut across the day-night split and independently affect those rates.

Crash rates in urban and rural areas by time of day and crash severity are presented in table 4-4. These figures show that for all crashes, the day rate is virtually identical to the night rate in rural crashes. But in urban areas, the day rate is substantially higher than the night rate. The next two sections of the table show the same cross-classification of rates, for casualty crashes and property damage only crashes. Among casualty crashes, the rates are higher at night in both rural and urban areas. But among the property damage only crashes, the rates are higher during the day for both area types and the difference is more dramatic in urban areas.

Table 4-4
Crash Rates by Time of Day and Area Type
And Crash Severity
Michigan-Registered Tractors

Area Type	Day	Night
	ALL CRASHES	
Rural	7.54	7.51
Urban	6.38	5.01
	CASUALTY CRASHES	
Rural	1.82	2.36
Urban	1.13	1.59
	PROPERTY DAMAGE ONLY CRASHES	
Rural	5.72	5.14
Urban	5.25	3.42

One explanation for these observations is that PDO crashes are much more a function of traffic density than casualty crashes. The typical PDO crash is a fender-bender which, in order to occur, requires the presence of other vehicles. Traffic density is much higher during the day, i.e., exposure to the "other vehicle" is greater during the day, which may lead to more PDOs, but not necessarily more serious crashes. The factors mentioned above as contributing to a higher night rate—fatigue, darkness, drinking drivers—are not as important in PDO crashes. It is more likely that they would contribute to a casualty crash. The data presented here are consistent with that explanation. The night rate is higher in both urban and rural areas for casualty crashes.

4.1.4 Crash Rates by Configuration

Tractors in Michigan are used primarily in three different configurations: without a trailer in the bobtail configuration; pulling one trailer, commonly called a "single;" and pulling two trailers, referred to as a "double" in this report. Since the real use of a tractor is in pulling a trailer, tractors run bobtail as little as possible, typically only when it is necessary to go from one location to another to pick up a trailer. Possibly because of their relatively small size, the bobtail configuration has not been discussed much as a safety problem. The major focus, from the point of view of regulation and the popular press, has been on singles and especially doubles. Doubles in particular can be enormous vehicles, ranging up to 160,000 pounds, and are usually considered to pose a significant safety problem. But in the past, data to directly evaluate the safety of the various tractor configurations has been lacking. Using the accident file prepared by MSU with the UMTRI exposure file for the first time allows those vehicles to be compared for non-fatal crashes.

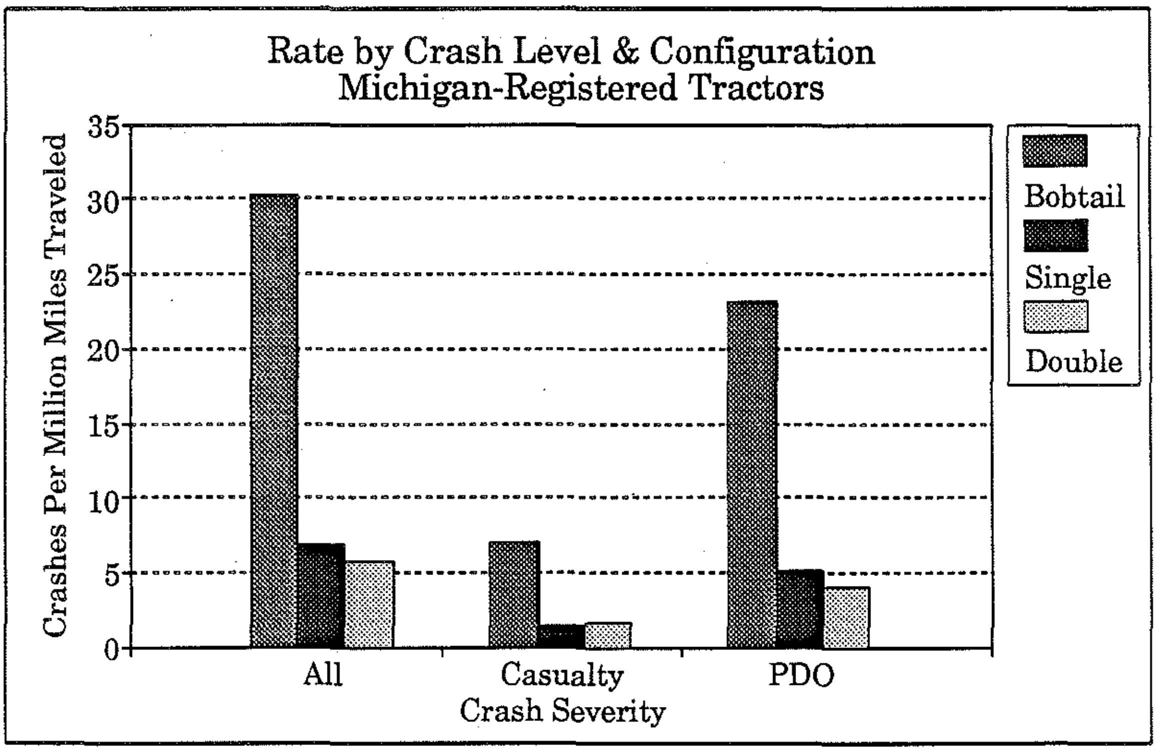

Figure 4-4

Figure 4-4 shows the crash rates of the three tractor combinations by crash severity. As the reader can see, bobtails have much higher crash rates for each level of crash severity. This is particularly marked for the "all" crash group, but is also true for casualty and PDO crashes. In fact, throughout this section, bobtails will be shown to have the highest involvement rates, regardless of road type, time of day, or area type. The rates for singles and doubles are, in contrast, quite similar to each other. In the casualty crash group, singles and doubles are practically indistinguishable. Singles are slightly higher for PDOs, and thus slightly higher in the "all" crash group.

Table 4-5
Crashes, Travel, and Crash Rates
For Three Tractor Configurations
For All, Casualty, and PDO Crashes
Michigan-Registered Tractors

Configuration	Crashes	Travel (millions)	Rate
	ALL CRASHES		
Bobtail	314	10.35	30.30
Single	5,179	763.03	6.79
Double	509	89.43	5.69
Total	6,002	862.80	6.96
	CASUALTY CRASHES		
Bobtail	74	10.35	7.15
Single	1,153	763.03	1.51
Double	144	89.43	1.61
Total	1,371	862.80	1.59
	PROPERTY DAMAGE ONLY CRASHES		
Bobtail	240	10.10	23.19
Single	4,026	763.03	5.28
Double	365	89.41	4.08
Total	4,631	862.80	5.37

Table 4-5 presents the raw numbers on which the chart is based. This table gives an idea of the relative magnitude of the numbers of crashes for each configuration type. Overall, the singles dominate. But this is a reflection of the dominance of that configuration in trucking, as the figures in the travel column indicate. There are many more tractor semitrailers on the road and they put on many more miles. The numbers of bobtail and doubles crashes are much more nearly comparable. In the "all" crash category, there are about 62% more doubles than bobtails, but the number of singles crashes differs by an order of magnitude. Yet while the crash frequencies of bobtails and doubles are not dissimilar, their respective crash *rates* are very different. A look at the travel column will show why.

The UMTRI exposure survey estimated that tractors in the doubles configuration accumulated over 89 million miles on Michigan roads, while bobtails traveled only one-ninth that amount. Even though the number of doubles crashes was roughly comparable to the bobtails, doubles travel, and therefore their exposure to crashes, is so much greater that their crash rate per million miles of travel is much less.

Singles and doubles together account for almost 99% of the travel and 95% of the crashes of tractors. Overall, their crash rates are reasonably close, though the singles rate is somewhat higher, 6.79 to 5.69. For casualty crashes, their rates are virtually identical, while for property damage crashes, doubles are actually slightly underinvolved. The difference between 1.61 and 1.51 for casualty crashes is probably not statistically significant, which means that, at this level of detail, the crash experience of the two configurations cannot be distinguished. But the difference between the 5.28 rate for singles and 4.08 rate for doubles in PDOs is doubtless real. Thus, looking at all crashes, doubles are slightly underinvolved compared to singles. The casualty crash involvement rates for two configurations are very close. The underinvolvement of doubles with respect to PDOs is probably a reflection of the fact that doubles have a higher probability of injury, given a crash.

Next, the effect of each of the three variables discussed above—time of day, area type, and road class—will be examined for each of the three configurations. It was decided to use casualty crashes, those which involved death or injury, for this analysis, since that group includes the most serious crashes and the crashes of the greatest interest. The "all" crash category consists preponderantly of property damage only crashes, whose effects tend to come through most strongly and overwhelm the casualty crashes. Many PDO crashes are relatively minor. Casualty crashes, on the other hand, are the more serious and command more attention, regulatory and otherwise.

Figure 4-5 below shows the casualty crash rates of Michigan tractors by configuration in rural and urban areas. The high involvement rates of bobtails are striking. They are much higher in both urban and rural areas than the rates for singles or doubles. For each category of vehicle, the rural rate is higher than the urban rate, which follows the pattern found for all tractors. In urban areas, the casualty crash rate for doubles is somewhat higher than that of singles, while in rural areas their rates are virtually identical. Table 4-6 shows the rates and the raw numbers from which the rates are computed.

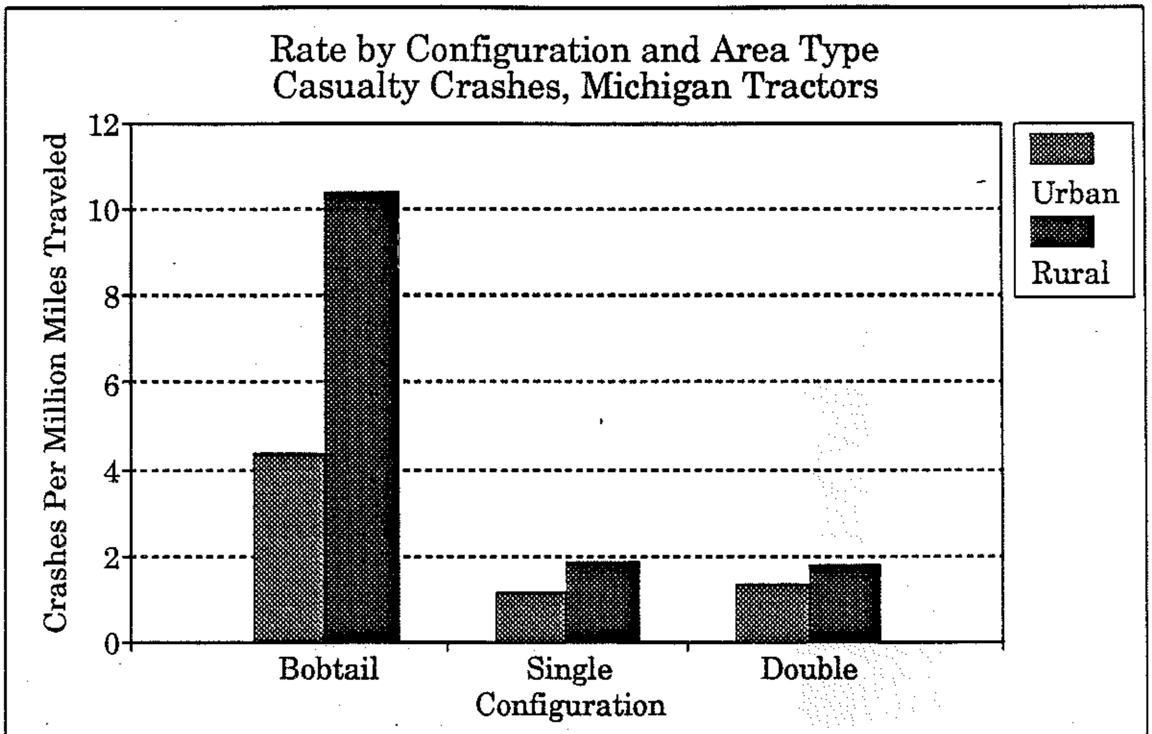

Figure 4-5

Table 4-6
Crashes, Travel, and Crash Rates
For Three Tractor Configurations by Area Type
Casualty Crashes
Michigan-Registered Tractors

Configuration	Crashes	Travel (millions)	Rate
	URBAN AREAS		
Bobtail	24	5.53	4.34
Single	378	337.30	1.12
Double	48	35.91	1.34
Total	450	378.74	1.19
	RURAL AREAS		
Bobtail	50	4.83	10.35
Single	775	425.73	1.82
Double	96	53.50	1.79
Total	921	483.06	1.90

Figure 4-6 shows the rates for each tractor configuration by time of day. Bobtails show both the highest rates and the most dramatic difference between day and night, though the estimate for the night rate is based on only 13 crashes. For doubles, there is essentially no difference between the night rate and the day rate, while for singles, the night rate is 43% higher than the day rate, 2.04 to 1.43.

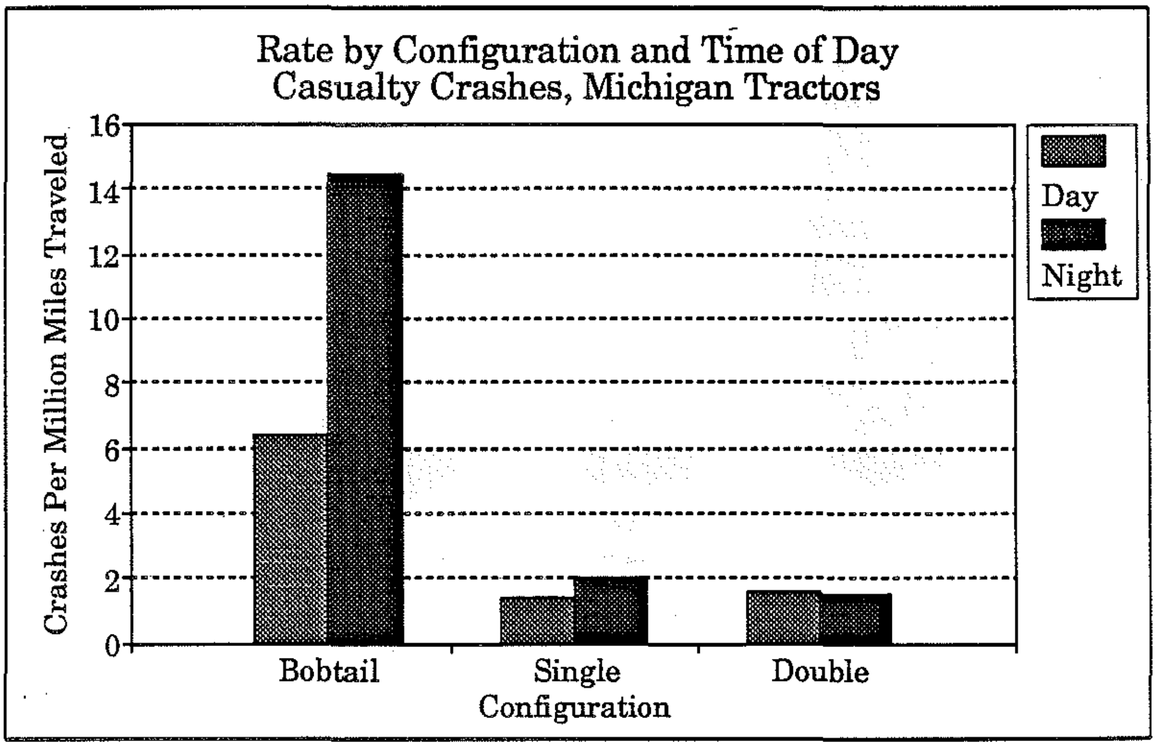

Figure 4-6

Table 4-7 below displays the crash frequencies, travel estimates, and rates for Figure 4-6. During the day, the rates of singles and doubles are quite comparable, with doubles having a rate slightly above that of singles. At night, the rate for doubles is markedly lower than that of singles, 1.53 to 2.04. In general, the doubles rate would be expected to be about the same as or somewhat higher than that of singles. But that doubles have a lower rate than singles is not entirely surprising, when the way doubles are operated is taken into account. Doubles put on more of their miles on limited access roads than singles do, and at night, this disparity is even greater. Since limited access roads are safer than non-limited access roads, regardless of time of day, the higher proportion of limited access travel at night by doubles results in a rate lower than that of singles at night.

Table 4-7
Crashes, Travel, and Crash Rates
For Three Tractor Configurations by Time of Day
Casualty Crashes
Michigan-Registered Tractors

Configuration	Crashes	Travel (millions)	Rate
	DAYTIME		
Bobtail	61	9.46	6.45
Single	946	661.65	1.43
Double	119	73.05	1.63
Total	1,126	744.16	1.51
	NIGHTTIME		
Bobtail	13	0.90	14.44
Single	207	101.38	2.04
Double	25	16.36	1.53
Total	245	118.64	2.07

As indicated above, road type has a strong influence on crash rates. This holds true for each tractor configuration. Figure 4-7 graphs the crash rates for limited access, major artery, and "other" roads for each configuration. As usual, the rates for bobtails are higher than for singles or doubles for every type of road. But it is also important to note that the crash rate on each road type is different and ascends like stair steps within each tractor configuration. Limited access roads consistently have the lowest rates. The rates for major arteries are clearly higher, and the "other" roads are quite a bit higher.

Table 4-8 shows the crash frequencies and travel estimates from which the rates were computed. The frequencies in some of the bobtails cells are rather small, which reduces confidence in the resulting rate. Rates estimated from the small cells are less reliable than the others. Thus, the true rate for bobtails on limited access roads, which is based on 18 crashes, may vary somewhat more widely than the rate for singles, which is based on 381 crashes. Even so, the bobtail rate is so high that it is clear that their crash rates are significantly higher than singles and doubles. The rates for singles and doubles are based on more data, more crashes and more travel, so confidence in those rates is greater.

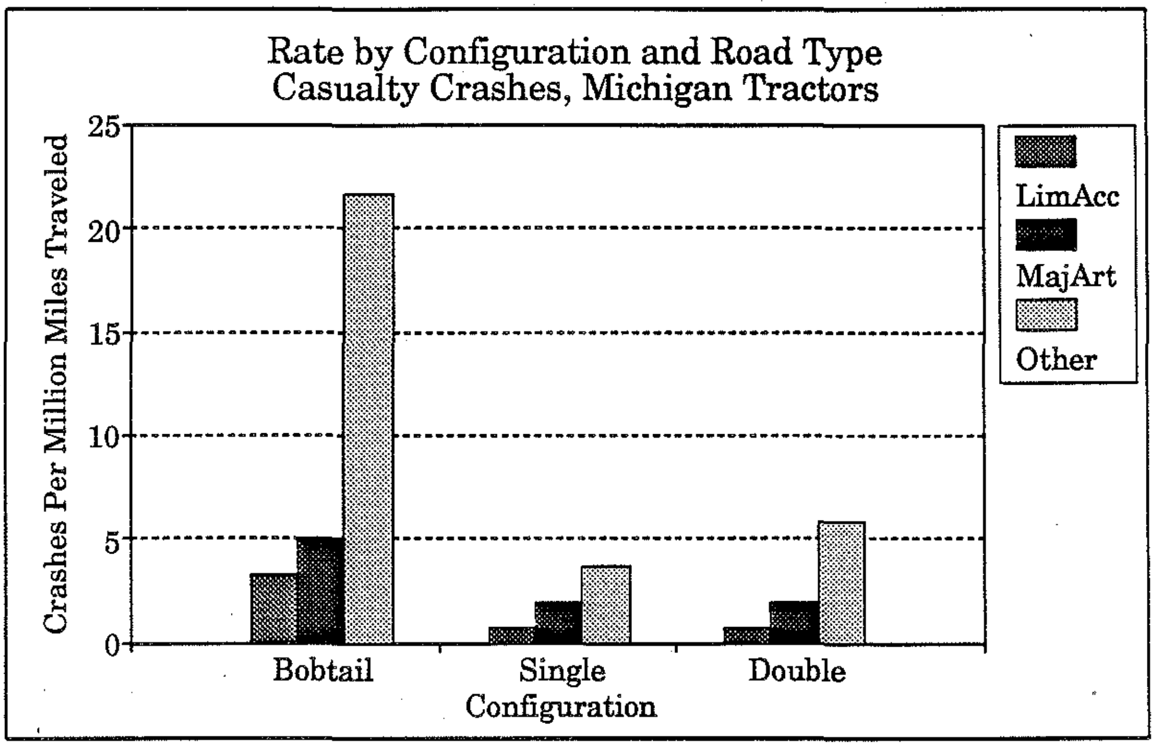

Figure 4-7

Casualty crash rates are by far the lowest on limited access roads. For both singles and doubles, the rate is under 1 crash per million miles of travel. Both singles and doubles do about equally well, indicating that there are no real differences in the performance of one and two trailer combinations on limited access roads with respect to casualty crashes. The rates on major arteries for each configuration are a little more than double those on limited access roads. Again, the crash experience of singles and doubles is about the same. The rate for singles is 1.94 and that for doubles is 2.01. That difference is probably not significant statistically. On "other" roads, however, doubles do quite a bit more poorly than singles. Doubles experience over two more casualty crashes per million miles of travel than singles, 5.85 to 3.72. "Other" roads include all roads that cannot be classified as either limited access or major artery, so they range from the less important city streets to county roads in the countryside. Doubles use such roads much less than limited access roads or major arteries. They also put on many fewer "other" miles than singles. So despite their higher rate on such roads, the total number of doubles crashes on "other" roads is about the same as the number of crashes on limited access roads and major arteries.

Table 4-8
Crashes, Travel, and Crash Rates
For Three Tractor Configurations by Road Type
For Casualty Crashes

Configuration	Crashes	Travel (millions)	Rate
	LIMITED ACCESS		
Bobtail	18	5.34	3.37
Single	381	453.51	0.84
Double	46	57.26	0.80
Total	445	516.11	0.86
	MAJOR ARTERY		
Bobtail	16	3.17	5.05
Single	413	212.95	1.94
Double	47	23.43	2.01
Total	476	239.55	1.99
	OTHER ROADS		
Bobtail	40	1.85	21.62
Single	359	96.57	3.72
Double	51	8.72	5.85
Total	450	107.14	4.20

4.2 One-Vehicle Crash Rates

Crash rates were also developed using only one-vehicle truck crashes. As demonstrated in Section 3, single-vehicle crashes account for a smaller percentage of truck crashes than non-truck crashes. They have been separated from the multi-vehicle crashes since it is the latter which are primarily at issue. The rates presented here are based on the same exposure data as the all-involvement rates, and, as would be expected, are far lower than those reported above. They are shown in table 4-9. It should be noted that the rates for bobtails and doubles are based on very few involvements and should be used with great caution. Comparison of the overall rates (over all road classes, light conditions, and so forth) indicates that bobtails have the highest rate (5.2) with singles (1.6) and doubles (1.2) considerably lower and quite similar to each other. It is interesting to note that the relative involvement (in one-vehicle crashes) of the different truck types is similar to that reported for all crash involvements. That is, the all-involvement rate noted for bobtails (30.3) is approximately 4.5

times as great as the single rate (6.8) which, in turn, is about 1.2 times greater than the double rate (5.7)—for single-vehicle crash involvements, these same ratios are 3.3 and 1.3. The single/double ratios are obviously quite similar.

Table 4-9
Crash Rates for Tractors in One-Vehicle Crashes
By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental Condition	Bobtail Crashes	Bobtail Rates	Single Crashes	Single Rates	Double Crashes	Double Rates
Rural/Day/Limited	4	1.9	194	0.9	27	1.2
Rural/Day/Major	9	4.3	236	1.8	19	1.3
Rural/Day/Other	13	50.0	224	7.1	16	5.0
Rural/Night/Limited	6	25.0	99	2.4	13	1.4
Rural/Night/Major	5	71.4	76	4.3	7	2.9
Rural/Night/Other	5	83.3	32	24.8	2	9.1
Urban/Day/Limited	5	1.9	65	0.4	5	0.2
Urban/Day/Major	1	1.1	56	0.9	7	1.3
Urban/Day/Other	5	3.5	172	2.9	10	2.0
Urban/Night/Limited	1	2.7	18	0.6	1	0.3
Urban/Night/Major	0	0.0	8	1.2	1	2.2
Urban/Night/Other	0	0.0	16	4.2	1	2.9
Overall	54	5.2	1,196	1.6	109	1.2

Examination of the patterns for singles involved in one-vehicle crashes reveals that the worst condition occurs for the combination of rural, night, and other (local) road class where the rate is 24.8. The difference between the rural night rates by road class, however, is proportionately less than the similar difference when all involvements are considered. Within the limits of the accuracy of the rates, it is clear that the safety of singles decreases at night and as the road becomes more restrictive. Interestingly, the one-vehicle rates are relatively low for urban situations. It could be argued that this is more a function of vehicle-vehicle interactions than safe truck operations *per se*—an issue that is addressed in the next sub-section.

The one-vehicle crashes involving doubles result in generally lower rates than the singles for most situations—although sample sizes are very small, and there is at least one notable exception. The exception is for rural, day conditions on limited access highways where the doubles rate is somewhat higher than the singles rate. (When all involvements were considered, the doubles rate was lower.) This may be due to the low rollover thresholds for doubles and the inclusion of interchange (ramp) crashes in the limited access road category.

Investigation of one-vehicle crashes for doubles showed that of 109 total crashes, 29 were rollovers (overturn) and eight (8) appear to have occurred in a ramp situation. This number of crashes has a dramatic impact on the rural, day, limited access one-vehicle crash frequency—and accounts for the double rate being higher in this situation.

While it is unreasonable to attach a great deal of significance to the trends for doubles rates given the small sample sizes, it appears that the crash rate degrades at night relative to day and with lower roadway type. Further, the rural rates are higher than urban rates.

4.2.1 One-Vehicle Casualty Crash Rates

Another aspect of the "conventional wisdom" regarding truck crashes is that they are more likely to be serious crashes—i.e., fatal and personal injury crashes. It has already been noted that trucks, in general, seem to account for a greater proportion of fatal crashes (the proportion of crashes that result in fatalities) as well as for property-damage-only (PDO) crashes. To further examine the relationship between trucks and crash severity, one-vehicle "casualty crash" rates were calculated for all of the same stratifications as discussed in the previous section—a casualty crash was defined as one which involved an injury or a fatality (or, conversely, was not a PDO).

As was noted in the discussion of the overall casualty crash involvement rates, sample sizes are significantly reduced when only casualty crashes are considered (the number of singles, for example, dropped from 5,179 to 1,153). Table 4-10 shows the distributions and rates of one-vehicle casualty crashes for the study period. The ratios between bobtail and single rates (3.3) and single and double rates (1.3) which were reported for all one-vehicle crashes were compared to similar ratios for one-vehicle casualty crashes: the bobtail to single ratio increased to 5.5 while the rates for singles and doubles were roughly the same (a ratio of 1.0). In general, this indicates that the bobtails were relatively more likely to be involved in serious crashes than combination trucks when one-vehicle crashes are considered.

Table 4-10
Casualty Crash Rates for Tractors in One-Vehicle Crashes
By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental	Bobtail		Single		Double	
Condition	Crashes	Rates	Crashes	Rates	Crashes	Rates
Rural/Day/Limited	0	0.0	42	0.2	5	0.2
Rural/Day/Major	2	1.0	39	0.3	3	0.2
Rural/Day/Other	4	15.4	29	0.9	4	1.2
Rural/Night/Limited	1	4.2	19	0.5	4	0.4
Rural/Night/Major	0	0.0	9	0.5	0	0.0
Rural/Night/Other	3	50.0	2	1.6	1	4.5
Urban/Day/Limited	0	0.0	22	0.1	2	0.1
Urban/Day/Major	0	0.0	7	0.1	0	0.0
Urban/Day/Other	1	0.7	9	0.2	1	0.2
Urban/Night/Limited	0	0.0	5	0.2	1	0.3
Urban/Night/Major	0	0.0	0	0.0	0	0.0
Urban/Night/Other	0	0.0	0	0.0	0	0.0
Overall	11	1.1	183	0.2	21	0.2

While the extremely low number of one-vehicle casualty crashes limits the realistic inferences that can be made about any trends, there is some evidence that supports the trend of an increasing crash rate being associated with lower classes of roadways. About the only one-vehicle casualty crash rates that can be compared with the all (one-vehicle) crash rates are for singles considering rural, day crashes. The ratio of the rates for all crashes on "other" roads to all crashes on limited access roads is 6.5, while the similar ratio for casualty crashes is 4.9, and a similar result is noted when major roads are added to the consideration. This would appear to indicate that the increasingly restrictive geometry has more effect on all crashes than on casualty crashes—the increase in non-casualty crashes is higher than in casualty crashes. While crashes are occurring at a higher rate on lower class roads, they are typically not more serious (assuming that casualty versus non-casualty is a valid measure of seriousness).

4.3 Multi-Vehicle (Only) Crash Rates

Crashes involving two or more vehicles (but only those where a truck was either vehicle 1 or vehicle 2) were also considered separately, with table 4-11 showing the rates for such involvements. Again, a examination of the overall rates shows that bobtails (25.1) have a far greater involvement rate than either singles (5.2) or doubles (4.4), and singles are observed to have a higher rate than the doubles. Overall, the involvement rates here are considerably higher than they were for one-vehicle involvements. The relative ratio of the bobtail to single rates and single to double rates here are 4.8 and 1.2, respectively—the first is somewhat higher than that for single-vehicle crashes while the latter is somewhat lower. These relative ratios are quite similar to those observed when all involvements were considered.

Table 4-11
Crash Rates for Tractors in Multi-Vehicle Crashes
By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental	Bobtail		Single		Double	
Condition	Crashes	Rates	Crashes	Rates	Crashes	Rates
Rural/Day/Limited	13	6.2	574	2.8	59	2.5
Rural/Day/Major	32	15.2	735	5.7	93	6.2
Rural/Day/Other	56	215.4	724	22.8	70	21.8
Rural/Night/Limited	3	12.5	101	2.4	12	1.3
Rural/Night/Major	3	42.9	106	6.0	10	4.2
Rural/Night/Other	9	150.0	57	44.2	4	18.2
Urban/Day/Limited	35	13.3	390	2.2	61	2.9
Urban/Day/Major	35	37.6	389	6.5	34	6.1
Urban/Day/Other	60	41.7	754	12.6	43	8.7
Urban/Night/Limited	3	8.1	45	1.5	3	0.9
Urban/Night/Major	0	0.0	56	8.2	4	8.7
Urban/Night/Other	11	122.2	52	13.8	7	20.6
Overall	260	25.1	3,983	5.2	400	4.5

Singles have their highest rate for rural, night conditions on other (local) roads (as was the case when one-vehicle crashes were considered). The rates clearly suggest that safety declines with more restrictive lighting and geometry conditions. Interestingly, the table also shows that the trend noted above that urban conditions yield generally lower rates than rural conditions for one-vehicle crashes is also true for multi-vehicle involvements. The only exception to this for multi-vehicle crashes is on major (versus both limited and local) streets where the multi-vehicle involvement rate is higher in urban situations than in rural situations for both day and night conditions. The expectation would be that urban areas would have higher multi-vehicle than single-vehicle crash rates, since urban areas have higher traffic densities. In fact, in general, the urban rates are lower for both crash types.

Multi-vehicle crash rates for doubles are generally similar or lower than the corresponding rates for singles. The exception is for urban, day conditions on limited access highways where the rate is somewhat higher. (Little credibility is given to the differences for urban night conditions as there are so few double crashes reported although it is noted that the trend is very similar to that for singles.) It is also interesting to note that, unlike singles, the rural night rates are generally lower than rural day rates (although the former are based on relatively few crashes).

4.3.1 Vehicle 1 (in Multi-Vehicle Crashes) Crash Rates

Rates were also calculated for the instances where a truck was vehicle 1 in multi-vehicle crashes (table 4-12). Comparison of these rates with those where only one-vehicle crashes were considered should give some insight into the effect of the "other" (non-truck) vehicles in the traffic stream (notwithstanding the potential problems with correctly identifying which vehicle is really vehicle 1, the "at-fault" vehicle). Overall, the involvement rates as vehicle 1 in multi-vehicle crashes are substantially higher than those for one-vehicle crashes—indicative, in part, of the problems that trucks have in interacting with other vehicles in the traffic stream. While bobtails have higher rates than singles, and singles are higher than doubles, the bobtail rate increased three-fold while the rates approximately doubled for singles and doubles.

For singles, the urban rates were still often lower than the rural rates although the differential was far less than noted for one-vehicle crash involvements. That is, while singles urban rates for involvements as vehicle 1 were generally lower than rural rates, the relative differences between urban and rural rates were not as pronounced for involvements as vehicle 1 (e.g., 12.7 for rural, day, other roads versus 7.9 for urban, day, other roads) as they had been for involvements in one-vehicle crashes (e.g., 7.1 for rural, day, other roads versus 2.9 for urban, day, other roads). The exception was for major roads where urban rates were higher than rural rates for both day and night conditions. Overall, the trend toward higher rates with more restrictive geometry was generally noted, while the rate increase noted at night for one-vehicle crashes was generally not present here.

Table 4-12
Crash Rates for Tractors as Vehicle 1 in Multi-Vehicle Crashes By Configuration and Environmental Condition Michigan-Registered Tractors

Environmental Condition	Bobtail Crashes	Bobtail Rates	Single Crashes	Single Rates	Double Crashes	Double Rates
Rural/Day/Limited	9	4.3	322	1.6	35	1.5
Rural/Day/Major	25	11.9	373	2.9	48	3.2
Rural/Day/Other	37	142.3	402	12.7	36	11.2
Rural/Night/Limited	0	0.0	36	0.9	4	0.4
Rural/Night/Major	0	0.0	46	2.6	1	0.4
Rural/Night/Other	2	33.3	29	22.5	2	9.1
Urban/Day/Limited	19	7.2	220	1.2	42	2.0
Urban/Day/Major	24	25.8	243	4.1	24	4.3
Urban/Day/Other	41	28.5	474	7.9	23	4.6
Urban/Night/Limited	1	2.7	20	0.7	2	0.6
Urban/Night/Major	0	0.0	25	3.7	1	2.2
Urban/Night/Other	4	44.4	17	4.5	1	2.9
Overall	162	15.7	2,207	2.9	219	2.4

The rates for doubles were also calculated although there were very few crashes at night (although the night rates seem to be reasonably consistent with some of the trends noted earlier). The rates considering involvement as vehicle 1 in multi-vehicle crashes are considerably higher than those reported for single-vehicle crashes (by a factor of about 2.0), and they are higher for rural than for urban areas except for limited access highways. Further, the doubles rates were generally lower than singles rates—the exceptions being for urban, day, major streets (doubles at 4.3 versus singles at 4.1), urban, day, limited highways (doubles at 2.0, singles at 1.2), and rural, day, major (doubles at 3.2, singles at 2.9). Finally, while the double rates increase with more restrictive geometry, they do not degrade at night (although the night rates are based on few crashes).

Consideration of the bobtail rates, generally limited to day conditions, showed that rural rates for limited and major roadways were lower than urban rates, but the reverse was true for other roadways. This was somewhat different than for one-vehicle involvements although there were even fewer of the latter crashes.

4.3.2 Vehicle 2 (in Multi-Vehicle Crashes) Crash Rates

Assuming that the designation of vehicle 1 and vehicle 2 is reasonably accurate, consideration of the involvement rates as vehicle 2 (table 4-13) gives an indication of whether the "truck crash involvement problem" is attributable to the trucks or to the "other" vehicles in the crashes. That is, if the truck involvement rate as vehicle 1 is higher than the involvement rate as vehicle 2, then the "problem" lies with the trucks (in terms of causation).

Overall, the general trend of bobtail rates being higher than singles and singles higher than doubles is again observed for involvements as vehicle 2. Regardless of truck type, however, overall truck involvement rates as vehicle 1 are typically higher than the rates as vehicle 2—there is more of a problem with trucks causing crashes with other vehicles than vice versa. Interestingly, examination of the night involvement rates show the reverse in several instances—singles and doubles in rural situations for limited and major roadways (and the rates are close for other roadways) and singles and doubles in urban areas regardless of roadway type (doubles, however, account for very few crashes). A possible explanation for the difference at night is that the "other" drivers may have more difficulty gauging the size and speed of trucks at night than during the day.

Table 4-13
Crash Rates for Tractors as Vehicle 2 in Multi-Vehicle Crashes By Configuration and Environmental Condition Michigan-Registered Tractors

Environmental Condition	Bobtail Crashes	Bobtail Rates	Single Crashes	Single Rates	Double Crashes	Double Rates
Rural/Day/Limited	4	1.9	252	1.2	24	1.0
Rural/Day/Major	7	3.3	362	2.8	45	3.0
Rural/Day/Other	19	73.1	322	10.1	34	10.6
Rural/Night/Limited	3	12.5	65	1.5	8	0.8
Rural/Night/Major	3	42.9	60	3.4	9	3.8
Rural/Night/Other	7	116.7	28	21.7	2	9.1
Urban/Day/Limited	16	6.1	170	1.0	19	0.9
Urban/Day/Major	11	11.8	146	2.4	10	1.8
Urban/Day/Other	19	13.2	280	4.7	20	4.0
Urban/Night/Limited	2	5.4	25	0.8	1	0.3
Urban/Night/Major	0	0.0	31	4.5	3	6.5
Urban/Night/Other	7	77.8	35	9.3	6	17.6
Overall	98	9.5	1,776	2.3	181	2.0

4.3.3 Multi-Vehicle (Only) Casualty Crash Rates

There are considerably more multi-vehicle casualty crashes and considerably more information is contained in table 4-14. First, it should be noted that of 260 multi-vehicle crash involvements where the truck was a bobtail, 63 (24%) resulted in a fatality or injury; while for singles the corresponding figures were 970 of 3,983 (24%); and for doubles, 123 of 400 (31%). So, from the outset, it is clear that double-involved crashes are somewhat more likely to result in casualties. This result notwithstanding, the overall bobtail casualty rate (6.1) is still far higher than that for singles (1.3) or doubles (1.4). The fact that the doubles casualty rate is higher than the singles rate is the reverse of the result for all crashes.

Table 4-14
Casualty Crash Rates for Tractors in Multi-Vehicle Crashes
By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental	Bobtail		Single		Double	
Condition	Crashes	Rates	Crashes	Rates	Crashes	Rates
Rural/Day/Limited	7	3.3	146	0.7	16	0.7
Rural/Day/Major	10	4.8	202	1.6	28	1.9
Rural/Day/Other	18	69.2	171	5.4	22	6.9
Rural/Night/Limited	1	4.2	44	1.0	7	0.7
Rural/Night/Major	0	0.0	52	2.9	5	2.1
Rural/Night/Other	4	66.7	20	15.5	1	4.5
Urban/Day/Limited	9	3.4	85	0.5	11	0.5
Urban/Day/Major	4	4.3	85	1.4	11	2.0
Urban/Day/Other	6	4.2	109	1.8	16	3.2
Urban/Night/Limited	0	0.0	18	0.6	0	0.0
Urban/Night/Major	0	0.0	19	2.8	0	0.0
Urban/Night/Other	4	44.4	19	5.0	6	17.6
Overall	63	6.1	970	1.3	123	1.4

The overall tendency for rates to increase with lower road class is still apparent although the difference in rates between limited access and other road classes, for example, is not as great as when all multi-vehicle crash involvements were considered (see table 4-11)—the ratio of the singles rates for rural, day, limited access to rural, day, other for all multi-vehicle crashes was 8.1 while for multi-vehicle casualty crashes the same ratio is 7.7. Thus, the general observation made for one-vehicle crashes—that while one-vehicle truck crashes are occurring at a higher rate on lower class roads, they are not generally more serious—is seen to be appropriate for multi-vehicle crashes as well.

Considering singles, the analysis of all multi-vehicle crashes indicated that urban rates tended to be lower than rural rates. This result is also apparent when only casualty crashes are examined. The all-crash rate (table 4-11) on limited-access roads during the day decreased by about 20% (from 2.8 to 2.4) between rural and urban conditions, while the casualty rate decreased about 29% (from 0.7 to 0.5). This same sort of decrease was also noted for "other" roads where the all-crash rates decreased from 22.8 to 12.6 (about 45%) and the comparable casualty rates decreased from 5.4 to 1.8 (about 67%). The decrease may well be largely attributable to the difference in vehicle operating speeds—"other" roads in rural situations are most likely to be two-lane rural roads with speed limits of 50-55 mph, while "other" roads in urban situations are far more likely to be city streets where speed limits are much lower.

Interestingly, the differential in rates between all multi-vehicle crashes (table 4-11) and casualty multi-vehicle crashes (table 4-14) involving singles on "major" roads in rural areas was lower than that for urban areas (an exception to what was otherwise indicated above). However, the casualty crash rate is higher in rural areas than in urban areas which is consistent with the differences for the other road classes and the speed-related hypothesis.

For singles, it was also seen that multi-vehicle crash rates (table 4-11) increased at night, except for limited-access highways in both urban and rural situations. The most dramatic shift (when all multi-vehicle crashes were considered) was for rural "other" roads where the rate almost doubled at night. In urban areas, the rate increases were more modest and, as noted, the rate on limited-access highways decreased. The nighttime increases in rural situations for multi-vehicle casualty crash rates (table 4-14) are more dramatic (the rate on "other" roads almost tripled) and occur for all roadway types. Similarly, the night casualty rates in urban situations all increase, and more precipitously than the rates for all multi-vehicle urban crashes. This suggests that the combination of speed and decreased visibility at night make trucks considerably more of a hazard.

There are very few double-involved casualty crashes at night, but the daytime frequencies allow for some discussion and comparison with the trends noted for all multi-vehicle crashes. The same general trend, as noted for singles, in increasing casualty rates with lower road classes is noted in both urban and rural situations—although the doubles casualty rates are higher than those for singles in almost all situations (the urban and rural day rates on limited highways are approximately same). The rural casualty rate increase is slightly more abrupt than the comparable increase for singles—but less than the increase in the all multi-vehicle crash rate increase. The urban pattern is somewhat different—the increase due to road type is more abrupt (although the absolute value of the rates are, obviously, much higher for all multi-vehicle crash involvements) and the doubles rates are increasingly higher than the singles rates for decreasing roadway class.

4.3.4 Vehicle 1 (in Multi-Vehicle Crashes) Casualty Crash Rates

As before, separate casualty rates were also calculated for vehicle 1 and vehicle 2 in multi-vehicle crashes. The former are shown in table 4-15. However, as seen in the table, there are only a few instances where there are adequate data to draw reliable conclusions.

Table 4-15
Casualty Crash Rates for Tractors as Vehicle 1 in Multi-Vehicle Crashes By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental	Bobtail		Single		Double	
Condition	Crashes	Rates	Crashes	Rates	Crashes	Rates
Rural/Day/Limited	5	2.4	84	0.4	7	0.3
Rural/Day/Major	8	3.8	94	0.7	9	0.6
Rural/Day/Other	12	46.2	80	2.5	9	2.8
Rural/Night/Limited	0	0.0	9	0.2	2	0.2
Rural/Night/Major	0	0.0	17	1.0	1	0.4
Rural/Night/Other	0	0.0	10	7.8	0	0.0
Urban/Day/Limited	6	2.3	40	0.2	6	0.3
Urban/Day/Major	3	3.2	53	0.9	6	1.1
Urban/Day/Other	4	2.8	59	1.0	7	1.4
Urban/Night/Limited	0	0.0	6	0.2	0	0.0
Urban/Night/Major	0	0.0	6	0.9	0	0.0
Urban/Night/Other	2	22.2	2	0.5	1	2.9
Overall	40	3.9	460	0.6	48	0.5

Overall, the bobtail rate (3.9) is substantially higher than those for singles (0.6) and doubles (0.5). The ratio of the bobtail rate to the single rate is about the same as it was for the corresponding rates considering all crashes (table 4-12).

Consideration of the singles shows that urban, day rates are lower than similar rural rates except for major roads where the urban rate is a little higher. The difference between the rates for vehicle 1 (the presumed at-fault vehicle) in all multi-vehicle crashes (table 4-12) and for vehicle 1 in multi-vehicle casualty crashes (table 4-15) indicates that the variation in rates is far less for casualty crashes. While this is also noted for the comparison of all multi-vehicle crashes (table 4-11) and all multi-vehicle casualty crashes (table 4-14), the rates when only vehicle 1 is considered are even closer.

Although very few doubles were involved in crashes as vehicle 1 in multi-vehicle casualty crashes, the rates were generally lower than singles. This is similar to what was observed when all crashes were considered, but counter to the observations thus far when considering only casualty crashes.

4.3.5 Vehicle 2 (in Multi-Vehicle Crashes) Casualty Crash Rates

Table 4-16 shows the casualty rates when trucks are involved in the crash as vehicle 2. Comparisons between tables 4-15 and 4-16 help to provide some further insight into the "truck safety problem" in terms of whether the trucks are the cause per se or whether "other" drivers are having problems interacting with the trucks.

Table 4-16
Casualty Crash Rates for Tractors as Vehicle 2 in Multi-Vehicle Crashes By Configuration and Environmental Condition
Michigan-Registered Tractors

Environmental	Bobtail		Single		Double	
Condition	Crashes	Rates	Crashes	Rates	Crashes	Rates
Rural/Day/Limited	2	1.0	62	0.3	9	0.4
Rural/Day/Major	2	1.0	108	0.8	19	1.3
Rural/Day/Other	6	23.1	91	2.9	13	4.0
Rural/Night/Limited	1	4.2	35	0.8	5	0.5
Rural/Night/Major	0	0.0	35	2.0	4	1.7
Rural/Night/Other	4	66.7	10	7.8	1	4.5
Urban/Day/Limited	3	1.1	45	0.3	5	0.2
Urban/Day/Major	1	1.1	32	0.5	5	0.9
Urban/Day/Other	2	1.4	50	0.8	9	1.8
Urban/Night/Limited	0	0.0	12	0.4	0	0.0
Urban/Night/Major	0	0.0	13	1.9	0	0.0
Urban/Night/Other	2	22.2	17	4.5	5	14.7
Overall	23	2.2	510	0.7	75	0.8

Overall, bobtails have a higher involvement rate as vehicle 1 (3.9) than they do as vehicle 2 (2.2) while singles and doubles have higher involvement rates as vehicle 2—0.7 vs. 0.6 for singles and 0.8 vs. 0.5 for doubles. For bobtails, these findings are consistent with those noted for involvements in all multi-vehicle crashes. However, for singles and doubles, it had been noted that both had higher rates as vehicle 1 than as vehicle 2 when all multi-vehicle crashes had been considered.

Restating the above, when all multi-vehicle crashes (where a tractor is vehicle 1 or 2) are considered, tractors cause the crashes at a higher rate regardless of tractor configuration. However, when only casualty crashes are considered, only bobtails are involved as vehicle 1 at a higher rate—singles and doubles have higher involvement rates as vehicle 2. There are, however, some variations in these results.

For singles, involvement rates as vehicle 1 are generally lower than as vehicle 2 for the same combinations of stratifying variables with the following exceptions: rural, day, limited access highways; urban, day, major and "other" highways; and they are the same for rural, night, "other" highways. In addition, the singles involvement rate as vehicle 1 is higher than the doubles involvement rate as vehicle 1.

For doubles, involvement rates as vehicle 1 are also generally lower than as vehicle 2 with the exception of urban, day, limited-access and major roads. It must be noted, however, that many of the doubles rates are based on very few crashes although the overall rate as vehicle 2 is lower than as vehicle 1.

4.4 Driver Age

The elevated risk of *fatal* crash involvement for younger drivers of both passenger cars and large trucks has been shown previously. Williams[2] examined nationwide fatal crash rates of passenger car drivers. The rate for male drivers aged 19-20 was 2-3 times the overall rate (approximately 10-15 fatal crashes per 100 million miles traveled versus 5). National estimates of fatal crash rates for large trucks by driver age were published recently by UMTRI.[3] Drivers under the age of 21 of large trucks were over-involved by more than a factor of 5 in comparison to the overall rate (about 50 fatal crash involvements per 100 million miles traveled versus 9.2).

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[2]Williams, Allan F., "Nighttime Driving and Fatal Crash Involvement of Teenagers." *Crash Analysis and Prevention*, Volume 17, Number 1, pp 1-5, 1985.

[3]Campbell, Kenneth L., "Fatal Crash Involvement Rates by Driver Age for Large Trucks." *33rd Annual Proceedings of the Association for the Advancement of Automotive Medicine.* pp 111-122, October 1989.

However, very little information has been available previously on non-fatal crash rates for large trucks. Police-reported crash rates for passenger cars were presented by driver age by Williams and Carsten.[4] Passenger car drivers (male and female) aged 19-20 were involved in about 18 police-reported crashes per million miles traveled as compared to an overall rate of about 5. These rates were developed from the National Crash Sampling System for the years 1982-1984 and the 1983 National Personal Transportation Survey.

Figure 4-8 presents rates for all police-reported crashes for tractors registered in Michigan by driver age. Drivers aged 19-20 are over-involved by about a factor of 5 in comparison to all truck drivers (37 involvements per million miles versus 7). The police-reported crash rate for 19-20 year old tractor drivers in Michigan is about double the national rate for passenger car drivers of the same age calculated by Williams and Carsten. The overall police-reported crash rate reported by Williams and Carsten for passenger cars is about 5 involvements per million miles traveled as compared to about 7 involvements per million miles for tractors in Michigan.

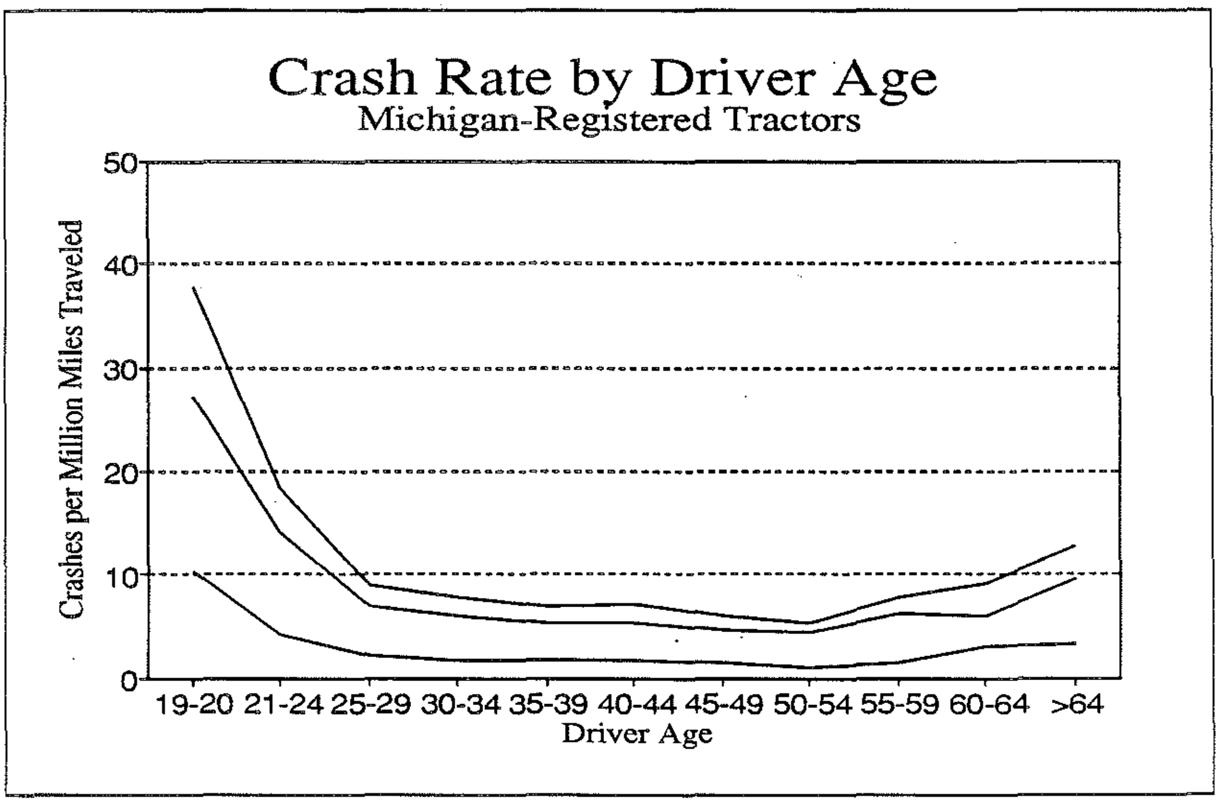

FIGURE 4-8

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[4]Williams, Allan F. and Carsten, Oliver, "Driver Age and Crash Involvement." *American Journal of Public Health*. Volume 79, Number 3, pp 326-327, March 1989.

Crash rates for tractors registered in Michigan are shown separately for casualty and property-damage-only crashes by driver age in Figure 4-8. This figure shows that the relationship with driver age is essentially the same for casualty and property-damage-only crashes. The data supporting these figures are shown in table E-4.

Older drivers are also of interest. Both the fatal and the police-reported crash rates for passenger car drivers published by Williams increased substantially for both the younger and the older drivers. Younger drivers were over-involved up until about age 25 and older drivers were over-involved starting at about age 60. Surprisingly, the fatal crash rates for drivers of large trucks developed by UMTRI did not show appreciable over-involvement for the older drivers.

The Michigan data, shown in figure 4-8, do show an over-involvement of older drivers of tractors starting at age 60. The over-involvement shown for older drivers is substantially less than that shown for the younger drivers. Whereas drivers aged 19-20 are over-involved by about a factor of 5, drivers over the age of 64 are over-involved by a factor of about 1.5.

In summary, police-reported crash rates for tractor drivers in Michigan show a strong association with driver age. Drivers under the age of 25 and over the age of 60 were over-involved. The highest risk was shown for drivers aged 19-20. This age group was over-involved by about a factor of 5. Drivers over the age of 64 were over-involved by about a factor of 1.5. These associations of police-reported crash rates with driver age for tractor drivers in Michigan are similar to the findings by Williams for drivers of passenger cars nationwide.

4.5 Summary

The crash data prepared by MSU and the travel data produced by UMTRI permit the calculation of crash rates by tractor configuration, time of day, road class, area of operation and any combination of those variables. These rates can then be used to evaluate the relative safety of the Michigan tractor population on Michigan roads, in order to identify those configurations and operations that present higher safety hazards. Some of the results were unexpected, but even where the results accord with common expectations, this analysis has produced more precise, quantitative estimates.

Overall, rural areas had higher involvement rates than urban areas. This held true for each level of crash severity, although the differences were slight for PDO crashes. Road type appeared to have a much stronger association with the probability of a crash. Limited access roads were clearly the safest regardless of the severity level considered. Rates on major arteries were generally two or three times higher, and those on the other road type were greater by an order of magnitude. Road type clearly must be a factor in any analysis of traffic safety.

The association of crash rates with day and night was less simple. Casualty crash rates were higher at night, but PDO rates were higher during the day. The effect of combining the two crash severities was to wash out the casualty rate, so that overall, the day rate was somewhat higher. The explanation for this appears to be that the PDO rate is higher during the day than at night in both urban and rural areas, but particularly in urban. PDOs are in large part a function of traffic density, and that density is higher in the day, and particularly in urban areas. The strength of this effect is sufficient to drag up the overall PDO rate.

Bobtails consistently had the highest casualty crash rate for all the operating conditions examined and for all crash types considered. The magnitude of the over-involvement varied from condition to condition. Bobtails seem to have an even worse time at night relative to the other configurations than they do during the day. But the excess of bobtail crashes over what one would expect from their travel is consistent across all the operating environments examined. It seems apparent that the bobtail configuration itself is associated with a higher crash rate. Of course, tractors are designed to pull trailers. So their handling, braking, and other systems are all designed for the situation in which the tractor is pulling a semitrailer. Without the trailer, the handling properties of the vehicle are less than optimum, and it appears that this results in a higher crash rate. Drivers may be aware of the greater instability of the bobtail configuration and compensate in their driving, but any such compensation is apparently not enough to produce a crash rate similar to the other tractor configurations.

Doubles are generally regarded as posing the most important traffic safety hazard for tractor combinations. They command this attention because of their size and the spectacular nature of some of their crashes. But in terms of crashes per mile, bobtails far outpace both singles and doubles. And in terms of the sheer number of crashes, bobtails are certainly in the same range as doubles. Overall, during the survey year, there were 509 doubles crashes and 314 bobtails, surprisingly close given the amount of attention paid to doubles.

The tractor-single-trailer combination by far accounts for the greatest number of tractor crashes, but that is simply because singles are the most common tractor configuration, with the overwhelming majority of tractor miles. In looking at the safety experience of singles and doubles, it may be surprising to find that they are fairly similar. In all crashes, singles have a somewhat higher crash rate than doubles. In the most serious crashes, involving death or injury, their rates are virtually identical. It is only when the rates are broken down into finer groups, when the effects of road class, time of day, and area type are taken into account, that the handling and performance differences between singles and doubles manifest themselves. For example, the rates for singles and doubles are very similar for casualty crashes, with the doubles actually slightly better for property-damage-only crashes (4.1 to 5.3). When casualty crash rates are calculated by road type, doubles and singles have virtually the same rate on limited access roads. But on the lower road classes, doubles have more problems. The doubles rate is slightly higher on major arteries, and significantly higher on the "other" roads.

Overall, similar patterns were found when the cases were broken down into single-vehicle and multiple-vehicle crashes. In single-vehicle crashes, bobtails still had by far the worst performance, while the rates of singles and doubles were much lower and reasonably close to each other. Single-vehicle crash rates also indicated an association between higher crash rates and lower road classes; that is, the presumably more-restrictive geometries of the lower road classes, major arteries and other roads, had progressively higher rates than limited access roads. Rural rates were also generally higher than urban rates, and night rates were typically higher than day rates.

Bobtails again had strikingly higher involvement rates when multi-vehicle crashes were considered, while the rates for singles and doubles were much lower and similar to each other. Crash rates in urban areas were somewhat lower than those in rural areas, for both singles and doubles. This runs contrary to expectations, since traffic densities are higher in urban areas.

The crashes were also broken down into those in which the tractor was involved as vehicle 1, the presumed at-fault vehicle, and those as vehicle 2. This analysis gives some general insight into the relative responsibility of trucks in crash causation. When rates were calculated, they showed that bobtails had higher crash rates as vehicle 1 in multi-vehicle casualty crashes than as vehicle 2. For singles and doubles, the situation was reversed. Their rates were generally higher as vehicle 2, the presumed "less-at-fault" vehicle in the crash. The singles casualty rate as vehicle 2 was slightly lower than the doubles casualty rate. For all multi-vehicle crashes, which include PDOs, generally involvement rates as vehicle 1 were higher than those as vehicle 2.

The association of driver age with the safety experience of tractors on Michigan roads was also examined. Overall, the analysis reinforced previous work done on passenger car drivers. Crash rates showed a strong association with driver age. Drivers under the age of 25 or over 60 tended to have higher involvement rates than other drivers. Drivers aged 19 to 20 had the highest rates, with a crash rate about 5 time higher than the average. This relationship held for both casualty and property-damage-only involvements. The older group was over-involved by a factor of about 1.5 overall, but they surprisingly did not show an over-involvement in casualty crashes.

SECTION 5

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This section summarizes the results of the Michigan Heavy Truck Study. The Michigan Office of Highway Safety Planning initiated the project to address concerns about the safety of heavy trucks on Michigan's highways. Major changes in the trucking industry have taken place in recent years. The changes include deregulation at the federal level, the 1982 Surface Transportation Assistance Act allowing an expanded role for doubles, and the implementation of the Commercial Driver's License. At the same time, there has been growing concern about truck safety in Michigan. From 1982 to 1988, truck crashes grew by 64%, while all crashes grew by only 40%.

Despite the increasing interest in truck safety, there are still significant gaps in current knowledge about truck crash rates and the causal factors involved. In this context, the present research project was undertaken jointly by the University of Michigan Transportation Research Institute and the Michigan State University Department of Civil and Environmental Engineering. The goal of the project was to develop statistical information on crashes, travel, and the risk of crash involvement. Operationally, the objectives of the study can be defined as calculating disaggregate truck crash rates for combinations of the following variables: truck types; roadway types; rural and urban areas; and day and night.

In general, Michigan State University (MSU) was responsible for the crash data while the University of Michigan's Transportation Research Institute (UMTRI) was responsible for exposure data. The study period was the twelve-month period beginning in May, 1987, and ending in April, 1988.

5.2 Truck Crashes in Michigan

In Michigan, all traffic crashes that occur on public roads are reported on a common form (UD-10, Traffic Accident Report) by the investigating officer. The data from the forms are then further interpreted (e.g., road classification codes) and entered in a computerized file which is maintained by the Michigan Department of State Police (MSP). These files are made available by both MSP and the Michigan Department of Transportation (MDOT). The MDOT has several versions of the file (e.g., one has physical location data) which are then available for researchers and others.

MSU was basically responsible for assembling and preparing the crash data for the study year. The preparation included a considerable manual effort because of significant coding errors which occurred when trucks were classified by type—involvement of singles was under-reported by approximately 20%. Manual review was also required to separate trucks registered in Michigan from those registered elsewhere, since this information is not included in the computerized files.

During the twelve-month study period there were approximately 21,900 crashes which involved a truck larger than a pickup or panel truck. Of these, just over 10,000 involved bobtails, singles, or doubles. Some of the findings regarding truck crashes in Michigan are summarized below. The findings noted here are based on crash frequencies and are not adjusted for exposure, as are crash rates. These frequencies indicate the sizes of different aspects of the truck crash problem, and how they compare with all traffic crashes. Findings based on crash rates, which identify configurations and operations with higher associated risks, are discussed later.

Overall

About 5% of all crashes in Michigan involve a truck larger than a pickup or panel truck. These accidents can be classified by the type of truck as follows.

Table 5-1
Distribution of Truck and All Crashes in Michigan

Truck Type	Crashes	Percent
Straight	10,993	2.7%
Bobtail	458	0.1%
Single	8,883	2.2%
Double	678	0.2%
All Trucks	21,827	5.3%
All Crashes	408,066	100%

Straight trucks (trucks with a cargo body mounted on the power unit chassis) are involved in about half of the truck crashes in Michigan. The other half are tractor configurations (bobtail, single, and double).

Types of Crashes

About 57% of non-truck-involved crashes involved two or more vehicles compared to 79% of all truck-involved crashes.

Other prevalent crash types appear to be most related to the type of service that the different truck types tend to provide: straights have turning, driveway, and angle-straight type crashes; singles have one-vehicle miscellaneous, two-vehicle turning, and (overall) two-vehicle crashes; and doubles have more overturning and other two-vehicle crashes (e.g., rear-end).

A far greater percentage of single-vehicle non-truck crashes occurred at night (about 50%) than did single-vehicle truck crashes (about 25%). Conversely, a higher percentage of truck-involved multi-vehicle crashes (46%) occurred during non-rush-hour daytime hours (9:00-3:00) than did non-truck-involved multi-vehicle crashes (32%).

Severity of Crashes

Trucks appear to be overrepresented in both fatal and property-damage-only crashes. While the absolute number of fatal crashes involving trucks is quite low (a total of 179 in 1988 for all types of trucks), the proportion of crashes that result in fatalities is about twice as high for trucks as it is for non-trucks. Crashes involving trucks appear to be more serious when the truck is vehicle-2 (the less at-fault vehicle) versus when it is vehicle-1 (the more at-fault vehicle).

Driver Age

In general, drivers of doubles are older than singles drivers, who are in turn older than the drivers of straights. (Note that this finding is based only on the ages of drivers who are involved in crashes.)

Roadway Type

In general, non-truck crashes were more likely to occur on the local road portions of the highway network (city streets and county roads) than were truck-involved crashes. For non-truck crashes, this is consistent regardless of severity level. For truck-involved crashes, however, fatals were somewhat more likely to occur on the non-local system (e.g., 40% of the fatals were on Interstate, and U.S.- and Michigan-numbered routes versus 33% of "B-injury" crashes).

5.3 Truck Travel in Michigan

In order to develop crash involvement rates, accurate exposure data (e.g., vehicle-miles of travel) as well as accurate crash frequencies are needed. Although MDOT collects vehicle count data at numerous counting stations, it is impossible to accurately disaggregate these data according to the variables cited above. Thus, new exposure data were collected by UMTRI in the Michigan Truck Trip Information Survey (MTTIS). The basic data came from telephone interviews of tractor owners (or their representatives) conducted during the study period. It should be noted that while the ultimate goal of the survey was to be able to estimate differential travel by truck type (i.e., bobtails, singles, and doubles), the unit of observation for the survey was the truck tractor (i.e., the power unit of a tractor-trailer combination). The travel estimate was then based on how that tractor was used; i.e., how much mileage, if any, was logged by the tractor without a trailer (as a bobtail), by the tractor pulling a single trailer (as a single), and finally by the tractor pulling two trailers (as a double).

The sample of owners for the MTTIS was drawn from the vehicle registration file maintained by the Michigan Department of State as of February, 1987. The target group consisted of the owners of truck tractors with an empty weight over 6,000 pounds—basically all medium- and heavy-duty truck tractors registered and operating in Michigan. The survey data were collected during four telephone interviews over the course of the study period: basic descriptive information on the company and the vehicle was obtained on the first interview, as well as actual travel information. The travel data consisted of information about loading, type of trailers, route covered, and other operational details. In all, travel information was collected on four randomly selected days spaced over the 12 month period for each of the sampled tractors. The route descriptions allowed mileage to be broken down by road type, time of day, and area type. Using this technique, travel estimates were generated for the three tractor configurations of interest for different combinations of road type, time of day, and area (urban-rural). In addition to travel characteristics, data were also obtained about the drivers (e.g., age and training). This methodology has been used successfully in the past in the context of the analysis of nationwide truck-involved fatal crashes.

The registration file indicated that there was a total of approximately 34,600 truck tractors registered in Michigan at the beginning of the study period, and detailed travel data were collected on a random sample of 1,085 of these. Findings concerning the travel patterns of trucks in Michigan are summarized below:

<u>Travel Characteristics</u>

It is estimated that Michigan-registered tractors traveled approximately 883 million miles within the state during the study period—an average of approximately 25,500 miles annually in Michigan.

It is estimated that 10,000 tractors in Michigan (just under 30%) are registered to gross over 80,000 pounds.

Tractors with semitrailers (singles) account for over 88% of the total travel with doubles accounting for 10.4% and bobtails just 1.2%.

Approximately one-half of the travel by singles is on limited access highways during the day (27% rural, 23% urban) and almost another 25% is on major highways during the day (17% rural, 8% urban). The highest percentage of night travel (by highway and area type) is on limited access highways in rural areas (5.5%). Overall, about 59% of the singles travel was on limited access roadways.

The distribution of travel by doubles is very similar to that of singles, with the principal exception that about 11% of doubles travel is on limited access highways in rural areas at night. Overall, doubles traveled on limited access highways about 64% of the time—about 5% more than the comparable figure for singles.

A consideration of the travel of all tractors broken down by the approximate gross combination weight of the vehicle indicates that the 20-40,000 pound group (virtually all empty, or nearly empty, singles) accounts for about 39% of all travel, the 40-80,000 pound group accounts for about 43%, and about 14% of all travel is at weights in excess of 80,000 pounds.

For singles, nearly 44% of the travel is while empty or very lightly loaded while about 20% is in the 40-60,000 and 60-80,000 ranges (each) and about 10% occurs at weights over 80,000 pounds.

For doubles, the distribution of travel by weight is somewhat different. About 43% of the travel is while empty. The percentages are lower for intermediate weights, rising gradually to 26% in the 140-160,000 pound range. This indicates that doubles are very likely to be running fully loaded in one direction and returning empty—a typical pattern for the commodities carried by the very heavy trucks (e.g., gravel).

Driver Characteristics

The distribution of driver age shows that only 3.5% of the drivers are 24 or younger, while about 14% are 25-29, and 18% are 30-34. The percentages then drop gradually until 50-54 which accounts for 10.5%, and then more abruptly as only 6% are 55-59, about 2% are 60-64 and less than 0.5% are over 64.

With driver "training" defined as a combination of classroom and on-the-road training, approximately 54% of the drivers had no such training. Only about 15% had such training—the remainder, about 31%, were unknown. (The drivers themselves could not always be interviewed, and this information was often unknown to the actual interviewees.)

Of the drivers who had training (15%), about two-thirds received it from the employer (either current or previous), truck-driving schools accounted for about 18%, and the military for less than 10%. In other words, less than 3% of all drivers surveyed had received training at a truck driving school. For-hire haulers and companies that operate in interstate commerce may have a higher proportion of trained drivers, but the large amount of missing data makes firm conclusions on that score impossible.

5.4 Truck Crash Rates Michigan

The crash involvement and exposure data were combined to produce differential truck crash rates for various combinations of the stratifying variables described above. Remember that the exposure survey covered only travel in Michigan by tractors registered in Michigan. Thus, only crash involvements of Michigan-registered tractors were used for the rate calculations. About 62% of the tractors involved in crashes in Michigan were registered in Michigan.

In addition to the rates based on all combinations of these variables, rates based on only casualty crash involvements, or property-damage-only crash involvements were also calculated. The calculated rates for all police-reported, Michigan-registered tractor crash involvements, in their most disaggregate form, are shown in table 5-2 (this is a repeat of table E-1 in Appendix E). The rates are presented as crash involvements per million miles traveled.

Table 5-2
Overall Tractor Crash Rates
(all involvements)
Michigan-Registered Tractors on Michigan Roads

Travel Category			Bobtail		Single		Double	
			Crashes	Rate	Crashes	Rate	Crashes	Rate
Rural	Day	Limited	17	8.1	768	3.8	86	3.7
Rural	Day	Major	41	19.5	971	7.5	112	7.4
Rural	Day	Other	69	265.4	948	29.8	86	26.8
Rural	Night	Limited	9	37.5	200	4.8	25	2.6
Rural	Night	Major	8	114.3	182	10.3	17	7.1
Rural	Night	Other	14	233.3	89	69.0	6	27.3
Urban	Day	Limited	40	15.2	455	2.6	66	3.1
Urban	Day	Major	36	38.7	445	7.4	41	7.4
Urban	Day	Other	65	45.1	926	15.5	53	10.7
Urban	Night	Limited	4	10.8	63	2.1	4	1.2
Urban	Night	Major	0	0.0	64	9.4	5	10.9
Urban	Night	Other	11	122.2	68	18.0	8	23.5
Total			314	30.3	5,179	6.8	509	5.7

While some of the rates in this table should be interpreted with care given that the sample sizes are small, the results from table 5-2 (and related analysis not shown here) can be summarized:

In virtually all instances, bobtail crash involvement rates are far higher than those for singles and doubles.

Rates for doubles are generally somewhat lower than those for singles. It should be noted that this is the case regardless of whether all, one-vehicle, or multi-vehicle crashes are considered although the breakdown by number of vehicles involved is not shown in table 5-2. The same differential holds regardless of whether the truck in the crash was noted as vehicle-1 (the more-at-fault vehicle in the crash) or vehicle-2 (the less-, or not-at-fault vehicle) in the crash.

Although there are just over 300 bobtail involvements, the highest rates tend to be at night, generally in rural areas, and, most clearly, on the lowest class of roadway.

Singles involvement rates are always higher for lower classes of roadways—rates for major highways are typically two to three times higher than for limited access highways; and rates for other highways are typically seven to ten times higher than for limited access highways.

Singles involvement rates for night conditions are, at worst, about twice as high as for daytime conditions—typically for rural, other roads. The difference between night and day is not as distinct for urban areas. Generally, urban rates are lower than rural rates regardless of roadway class.

The results noted for singles are reasonably consistent regardless of whether the involvement is as vehicle-1 or vehicle-2.

Although limited by sample size considerations, doubles rates are lower than singles in most instances—the principal exception (from table 5-2) is on urban, limited access roads during the day.

Further analysis indicated that doubles rates were higher than singles in some specific situations such as: for one-vehicle involvements, rural limited access highways during the day; and for multi-vehicle involvements, rural major roadways during the day and urban limited access roadways during the day. It is interesting to note that the higher one-vehicle crash rate is primarily due to rollover crashes, a crash type for which doubles are well-known.

Table 5-3
Overall Tractor Casualty Crash Rates
(all involvements)
Michigan Tractors on Michigan Roads

Travel Category			Bobtail		Single		Double	
			Crashes	Rate	Crashes	Rate	Crashes	Rate
Rural	Day	Limited	7	3.3	188	0.9	21	0.9
Rural	Day	Major	12	5.7	241	1.9	31	2.1
Rural	Day	Other	22	84.6	200	6.3	26	8.1
Rural	Night	Limited	2	8.3	63	1.5	11	1.2
Rural	Night	Major	0	0.0	61	3.5	5	2.1
Rural	Night	Other	7	116.7	22	17.1	2	9.1
Urban	Day	Limited	9	3.4	107	0.6	13	0.6
Urban	Day	Major	4	4.3	92	1.5	11	2.0
Urban	Day	Other	7	4.9	118	2.0	17	3.4
Urban	Night	Limited	0	0.0	23	0.8	1	0.3
Urban	Night	Major	0	0.0	19	2.8	0	0.0
Urban	Night	Other	4	44.4	19	5.0	6	17.6
Total			74	7.1	1,153	1.5	144	1.6

Rates considering only casualty crashes are shown in table 5-3. The results shown in this table (which repeats table E-2 in the Appendix E) and from related analysis (not shown here) can also be summarized:

> Although there is an even greater scarcity of bobtail data, bobtail rates are higher than those for either singles or doubles. The ratio of the rates is about the same as it was when all (casualty and non-casualty) crashes were considered. In contrast to the set of all crashes, when only casualty crashes are examined, the overall doubles rate is higher than the singles rate. More specifically, it appears that doubles rates are higher than singles for day conditions in both rural and urban situations, and regardless of roadway class. Sample sizes for the disaggregated rates are, however, very small.
>
> When a differentiation between involvement as vehicle-1 and vehicle-2 was made, both singles and doubles have higher rates as vehicle-2 (vs. involvement as vehicle-1) in casualty crashes than they did for all crashes; and doubles have a lower involvement rate as vehicle-1 than singles (in casualty crashes).

While the disaggregated casualty crash rates shown in table 5-3 are of considerable interest, the sample sizes are, as noted, quite small in some instances. However, the crash and travel data can also be aggregated by the key variables and yield rates such as daytime rates for different truck types regardless of roadway class and urban/rural classification. The results of calculating such aggregated rates are given below in summary form. All rates are given in crashes per million vehicle-miles.

Table 5-4
All and Casualty Crash Rates
by Truck Configuration

	all crashes	casualty crashes
bobtails:	30.30	7.15
singles:	6.79	1.51
doubles:	5.69	1.61
total:	6.96	1.59

The above rates serve to highlight the fundamental differences between the different types of trucks and the impact of including property-damage-only (PDO) crashes in the rate calculation. The bobtail rates are clearly far higher than those for combination trucks, and inclusion of the PDO crashes tends to "wash out" some of the differences between truck types. When PDOs are included, the singles rate is considerably higher than the doubles rate—however, when only casualty crashes are considered, the differences between singles and doubles are very small.

Table 5-5
All and Casualty Crash Rates
by Truck Configuration and Urban/Rural Area

	all crashes		casualty crashes	
	urban	rural	urban	rural
bobtails:	28.21	32.71	4.34	10.35
singles:	5.99	7.42	1.12	1.82
doubles:	4.93	6.21	1.34	1.79
total:	6.22	7.54	1.19	1.90

The aggregation of urban and rural rates (regardless of roadway type and time of day) shows that, in general, rural rates are higher than those in urban areas (regardless of truck type and whether PDOs are considered). Furthermore, in both urban and rural areas the bobtails rates are still far higher than combination trucks. The rates for singles and doubles are very similar to each other although both have higher rural rates. The ratio of rural to urban rates is greater when only casualty crashes are considered (for both singles and doubles). It should also be noted that as PDO crashes tend to "drive" the overall rates, singles crashes also tend to dominate when, for example, the total rate is considered.

Table 5-6
All and Casualty Crash Rates
by Truck Configuration and Time of Day

	all crashes		casualty crashes	
	day	night	day	night
bobtails:	28.33	51.11	6.45	14.44
singles:	6.82	6.57	1.43	2.04
doubles:	6.08	3.97	1.63	1.53
total:	7.02	6.55	1.51	2.07

The differences between day and night rates are somewhat less clear than the other aggregated rates considered to this point. Overall, when all crashes are considered, the night rates are lower than the day rates, although this is not the case for bobtails. For combination trucks, there is more of a difference for doubles than for singles—i.e., the night doubles rate is much lower than the day rate. However, when only casualty crashes are considered, the night rates are higher for both bobtails and singles. The doubles rate is still somewhat lower at night than during the day. The "total" rate shows that when only casualty crashes are considered, combination trucks tend to have higher night rates—this is, however, driven by bobtails and singles.

Table 5-7
All and Casualty Crash Rates
by Truck Configuration and Road Type

	all crashes			casualty crashes		
	limited	major	other	limited	major	other
bobtails:	13.11	26.81	85.95	3.37	5.05	21.62
singles:	3.28	7.80	21.03	0.84	1.94	3.72
doubles:	3.16	7.47	17.55	0.80	2.01	5.85
total:	3.37	8.02	21.87	0.86	1.99	4.20

The aggregated rates by roadway type show a clear and consistent trend: the lower the road class, the higher the crash rate, regardless of truck type or whether all crashes or only casualty crashes are considered. The similarity between the rates for singles and doubles should also be noted although there is some divergence between the two when the lowest road class is considered.

5.5 Principal Findings and General Conclusions

As with any study of this magnitude, there is a host of sometimes confusing and/or contradictory results. However, it may be argued that there are several dominant findings that resulted from the project, notwithstanding some relatively minor variations. With regard to the three truck types that were considered,

- the bobtail configuration clearly has the most serious problem safely negotiating the highway system; and
- the performance of single and double truck configurations are generally quite similar to one another in terms of overall safety on the highway system.

In addition to the differences (or lack of them) that are attributable to truck type, there are also effects that are due to differences in the truck operating environment. In this study, environmental effects were limited to the type of roadway, the time of day, and whether the trucks were operating in rural or urban areas. The principal effects that were attributed to variation in these parameters are:

- the most significant and consistent effect appeared to be due to the type of roadway since crash rates for all types of trucks were highest on other roadways and lowest on limited access highways (generally regardless of variation of other variables);

- crash rates were generally lower in urban areas than they were in rural areas, regardless of truck type;

- at more aggregated levels, nighttime crash rates were lower than daytime rates for combination trucks (although the differential was greater for doubles) but higher for bobtails; overall, casualty rates were higher at night;

- there was some evidence of interaction among environmental variables, especially when the day and night rates were considered, that affected singles rates (i.e., several singles rates were higher at night).

- drivers under age 25 or over 60 were over-involved in crashes; the highest risk was shown for drivers aged 19-20, who were over-involved by a factor of 5.

Some of the findings reported above confirm earlier work. Of greater importance, however, is the general finding that the crash rates for singles and doubles are not radically different from one another, though part of the reason that doubles have relatively low crash rates is that most of their travel is on limited access roads, the safest in the highway system. It was also found that the other factors that appear to affect the relative safety of one type of truck have similar effects on the others as well. This is especially interesting since Michigan has liberal truck weight regulations and considerable experience with doubles on the highways. This is not to say that there are not specific instances when doubles do not perform as well as singles, but that in general they appear to present a similar degree of risk.

Perhaps the most significant and somewhat unexpected finding was the degree of degradation of relative truck safety when lower classes of roadway were considered: the crash rates on the lowest class of roadway were five to seven times higher than those on the limited access system. This far overshadows the effects of truck type or any of the other environmental factors.

5.6 Implications for Truck Crash Countermeasures, Highway Safety Policy, and Future Work in Michigan

The implications for truck crash countermeasures, highway safety policy, and future work in Michigan are varied. Given that the work just completed provides an accurate overview of the truck safety problem in Michigan, the most important implications for the future are the need for more specificity in future work and the need to move forward in developing, implementing, and evaluating countermeasures.

Improvements in Crash Data

In order to move forward with work in truck safety in Michigan, one of the key areas needing attention is data collection. Although the crash data available in Michigan are among the best in the nation, there are some shortcomings which were highlighted during this study. Specifically in regard to trucks, the data are inadequate in terms of describing the vehicle itself—truck tractor and trailer descriptions lack specificity (e.g., trailer type, tractor description, length and width, number of axles). Perhaps even more importantly (and of concern beyond just trucks) is the need to be able to effectively and efficiently merge data from the various files that are maintained by the state—e.g., crash data, vehicle registration data, and driver information.

The proposed Michigan Supplemental Truck and Bus Traffic Accident Report promises to remedy some of these problems by providing additional information on operating authority, gross vehicle weight rating, vehicle configuration, and cargo body type. Vehicle combination weight, length, width, and number of axles are not included on the form. The amount of detail on the physical characteristics of the truck that the supplemental report will provide is minimal, but it is an important first step toward capturing more complete information.

This study uncovered some evidence that suggests very few of the truckers on Michigan roads have had any driver training. Currently, there is no accident data on the driver training of truckers involved in crashes, though with the Commercial Driver License program and the growing emphasis on driver training, there will be a need to evaluate the safety impact of driver training schools.

As it stands at this point, the current data cannot be used to evaluate other key issues that have come up in the last several years—for example, it is virtually impossible to assess the impact of longer and/or wider trucks on Michigan's highways. Issues related to carrier type, e.g., examining the safety experience of inter- versus intrastate carriers, cannot be undertaken using currently available data. Further, it would be difficult, if not impossible, to differentiate the effect of increased numbers of doubles operating on Michigan roadways as a result of the 1982 Surface Transportation Assistance Act (STAA) from the pre-STAA doubles that were already allowed in Michigan.

Improvements in Truck Exposure Data

The exposure data gathered by UMTRI for this study are unique for the state and for a specific time period. Beyond these data, currently there are no viable truck exposure data being collected in Michigan that can be used for anything more than the grossest statewide analysis. If further rate-based work is to be done on truck safety in Michigan, particularly given the dynamic nature of the trucking industry, a methodical data collection plan needs to be implemented which will permit the calculation of vehicle miles of truck travel differentiated by truck type, roadway class, and selected other environmental variables. These data should include all trucks using Michigan roads.

Further Work on the Relationship between Truck Crashes and Geometry

One of the original objectives for the current project had been exploration of the relationship between roadway geometry and truck type. As noted earlier, as the project progressed, problems with data reduction acted to curtail the scope of what was studied. This project has, however, confirmed that restrictive geometry (as measured by which class of road is being considered) is a serious problem in truck safety. In fact, examination of some crashes showed that even the low crash rates for limited access highways may be overstated. For example, it was shown that a sizable number of one-vehicle crashes involving doubles resulted from overturns on ramps.

More work is required which is addressed to identifying those geometric characteristics which are specifically related to truck crashes. This should include not only consideration of the characteristics of the crashes and the roadways but also truck loading and travel characteristics. For example, the crash potential on ramps is related not only to the interaction between truck type per se and ramp geometry but also to the specifics of the truck configurations and their loads.

5.7 Conclusion

The work on the travel and safety of Michigan trucks presented in this report has covered considerable ground. The survey has determined the number of Michigan trucks and how they are distributed by licensed weight and the type of company which operates them. Travel information at a level of detail unavailable elsewhere has been collected and analyzed. The work also included a survey of the men and women who drive the trucks included in the study, to determine their level of training. Moreover, the Michigan crash experience of trucks spanning nearly a decade has been examined and compared to the rest of the motor vehicle population. Some problems in the collection and coding of that data have been identified. The study also presented data which speak to the role of the truck in motor vehicle crashes, and the size and seriousness of the truck safety problem, compared to other vehicles on the road.

But the main product of this study, the focus of the work, has been on the factors which affect the probability of crash involvement for Michigan tractors. For this, a substantial framework which can support future work has been constructed. By calculating and comparing crash rates in different circumstances, the role of the different tractor configurations has been clearly delineated. The bobtail configuration, a tractor without a trailer, has the highest crash rate of any configuration, sometimes several times higher. Overall, singles are similar to doubles, though there are differences between road types. Road type itself has been shown to have a large impact on crash rates. Some types of roads are much safer to operate on than others. The interstate highway system and other roads built to that standard are clearly the safest, while the U.S.- and State-numbered routes have crash rates about twice as high, and the remainder of the road system has rates nearly seven times as high. The more complicated impact of nighttime operations has also been explored. Casualty crash rates were higher at night, but PDO rates were higher during the day, when traffic densities are higher. And despite the fact that urban areas typically have higher traffic densities, rural areas generally had higher involvement rates than urban areas.

While this study has been comprehensive, by no means has it been exhaustive. Many questions remain. The analysis can be extended in several productive directions. The impact of carrier type, gross vehicle weight, and trailer cargo body are all opportunities for further research. Limitations in the information available from the UD-10, Traffic Accident Report, prevented this study from investigating carrier type, particular types of cargo bodies, or the impact of gross vehicle weight on the probability and seriousness of a crash. In an era of deregulation, differences in the safety record of various categories of truck operators will be of increasing interest, as well as an evaluation of any safety benefit from driver training schools. There is also considerable interest state wide in such combinations as Michigan gravel trains, not only in terms of load spillage, but also given the great weights at which these vehicles operate. The crash rates of tank trailers, particularly doubles, should also be examined—for example, the association between gross weight, road type, and rollover is an important safety issue.

Dealing with these issues requires additional data. Information on, for example, the cargo body, gross weight, and carrier type of trucks involved in crashes would have to be assembled. There may be some further work necessary as well to keep current with the changing trucking industry and to extend the analysis to all trucks operating on Michigan roads. But the necessary research techniques and methodologies have been established and demonstrated, in part by the present study. Moreover, by detailing the structure of trucking in Michigan and by identifying major factors affecting truck safety, the work represented by this report has laid a firm foundation that can support the exploration of future truck safety issues.

APPENDIX A
UD-10

AUTHORITY: Sec. 622, Act 300, P.A. of 1949
COMPLETION: Required
PENALTY: Misdemeanor

DO NOT USE

"X" IF CORRECTED COPY ☐

ORIGINAL

CIRCLE THE APPROPRIATE SELECTION

UD-10 (Rev. 9-85) State of Michigan

OFFICIAL TRAFFIC ACCIDENT REPORT

Department Name | LEIN Number | Department Complaint No. | DO NOT USE

ACCIDENT LOCATION

County No. | City No. | Twp. No. | Section No. | Day of Week S M T W T F S | Accident Date: Mo/Da/Yr | Time A.M. P.M.

ON Name | Route No. | Ft. Mi. N S E W | Intersection | Route Nos.

ACCIDENT COND.

WEATHER: 1 Clear or Cloudy 3 Rain 2 Fog 4 Snow

LIGHT: 1 Day 3 Street Lights 2 Dawn or Dusk 4 Dark

ROAD SURFACE: 1 Dry 3 Snowy or Icy 2 Wet 4 Other

TOTAL LANES: 1 Divided 2 Limited Access 3 Other

Y N Construction Zone
Y N Investigated at Scene

TOTAL NO. VEHICLES

VEHICLE DRIVER NO. 1

State | Driver's License | DOB: Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N

Driver's Name First M. Last | Address | City | State | Age | Sex | Inj.

Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN (Make Letters Larger Than Numbers) | Removed to/by

Y N Haz. Citation | *Y N Driver Re-exam | *Y N Vehicle Defect | *Y N Fuel Leakage | Impact | Severity | Truck Cargo: Y N Cargo Spillage | Class
Y N Other Citation | *Y N Vision Obstruct. | Y N Veh. Driveable | *Y N Vehicle Fire | Cargo Description

Restraints by occupants pos. | Name | Address | Pos. | Age | Sex | Inj. | Helmet Y N
1 2 3 | Y N
4 5 6 | Y N

Total Occupants | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 1

VEHICLE DRIVER NO. 2

State | Driver's License | DOB: Mo/Da/Yr | Hazardous Action No. | Citation Charge | HBD Y N | Test | Helmet Y N

Driver's Name First M. Last | Address | City | State | Age | Sex | Inj.

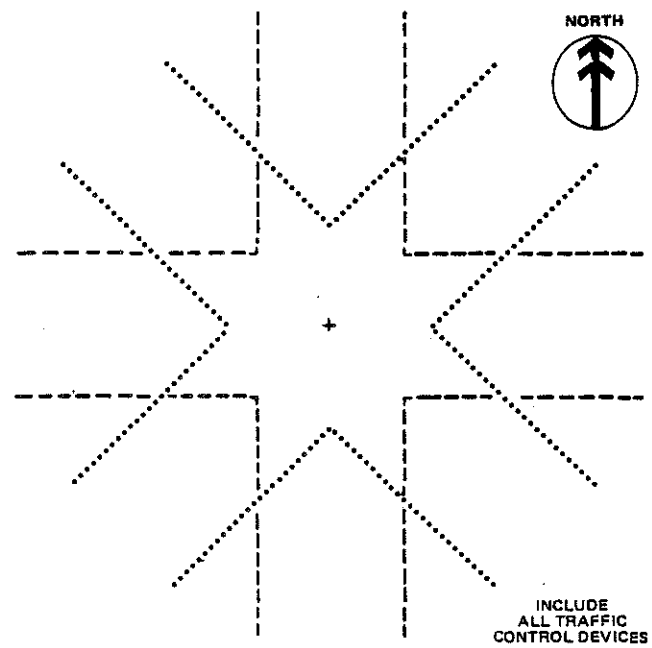
Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN (Make Letters Larger Than Numbers) | Removed to/by

Y N Haz. Citation | *Y N Driver Re-exam | *Y N Vehicle Defect | *Y N Fuel Leakage | Impact | Severity | Truck Cargo: Y N Cargo Spillage | Class
Y N Other Citation | *Y N Vision Obstruct. | Y N Veh. Driveable | *Y N Vehicle Fire | Cargo Description

Restraints by occupants pos. | Name | Address | Pos. | Age | Sex | Inj. | Helmet Y N
1 2 3 | Y N
4 5 6 | Y N

Total Occupants | Local Use/Owner, Phone (If Veh. Type 7 or 8, List Carrier) | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 2



ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Accid. Date - Mo/Da/Yr | File Class | Department Complaint No.

Reported: Mo/Da/Yr | Time A.M. P.M. | Investigators | Badge No. | Damaged Property Other Than Vehicle

Photos by | Comp. Disposition Open Closed | Reviewer | Person Advised of Damaged Traffic Control Device Name: Date: Time: | Owner | Address

* *Use Accident Description and Remarks area for explanation.*

FORWARD COPY TO: Michigan Department of State Police, Traffic Services Division, 7150 Harris Drive, Lansing, MI 48913

Area
Pseudo
Time
No. Units
No. Inj.
No. Killed
Residence
Test
Intent
Direction
Obj. Hit
Situation
Cont. Cir.
Residence
Test
Intent
Direction
Obj. Hit
Situation
Cont. Cir.
Road Align.
Traffic
Road Loc.
Acc. Type
Where
How
Tags
Road Def.
1Veh. Def.
1Vision Obs.
2Veh. Def.
2Vision Obs.
MALI
Coder
File

196479

APPENDIX B
Hypotheses

ADDENDUM TO ITEM 14. OBJECTIVES

The hypotheses developed by OHSP/MDOT and the other participants in the "advisory group" meetings are given below along with brief comments.

OHSP/MDOT Original Hypotheses (14 February 86)

(1) Trucks are under involved in respect to total accidents (need to define trucks). *COMMENTS: Currently being pursued in context of frequencies by MSU; rate–based will be done (jointly) in stages.*

(2) However, trucks are over involved in casualty accidents when compared to total accidents (i.e., they cause much more severity . . . casualty = F+I). *COMMENTS: As (1).*

(3) Privately–owned trucks are causing more of a problem than major fleet trucks. *COMMENTS: Although privately–owned trucks are identified in the UMTRI travel survey, they are not currently identified in the Michigan accident file.*

(4) Younger, inexperienced drivers are over represented in the accident picture (training versus time behind the wheel). *COMMENTS: As (1).*

(5) Casualty accidents are over represented on designated green routes. *COMMENTS: As (1); but green routes have to be identified in additional detail (e.g., MALI sections); there will be problems in explicit identification of interstate sections.*

(6) Super–heavy trucks (>80,000 GVW) are over represented in casualty accidents. *COMMENTS: As (1); in order to pursue further, need merging with SOS data.*

(7) Trucks are over involved in single–vehicle casualty accidents. *COMMENTS: As (1).*

(8) Trucks are over represented in night–time casualty accidents. *COMMENTS: As (1).*

(9) Most accidents happen at end of logged journey. *COMMENTS: Currently no substantial data are available which will give indications of this; this is quite hard to do even with exposure survey data; only accident follow–up survey will provide indication.*

(10) Accident data being collected for trucks needs to be improved. *COMMENTS: Will be pursued jointly over the course of the project.*

Additional Hypotheses (15 April 86)

(11) There are differential accident involvement rates for various truck/truck–trailer combination types based on roadway geometries. *COMMENTS: See (1).*

(12) There are differential accident involvement rates for various truck/truck–trailer combination types based on overall length and width of the combination.

Some concern was also expressed about "under–ride" accidents. This is a problem which really requires a more detailed description of accidents. Manually, some data could be retrieved by examining the original UD–10 reports for rear–end accidents. Beyond this, analysis will primarily be dependent on better forms and/or the accident follow–up survey.

APPENDIX C
Tables—Travel

TABLE C-1
Distribution of Miles by Company Type for Three Tractor Configurations
Michigan-Registered Tractors

All Tractors

Company Type	Bobtail Miles (millions)	Bobtail Column Percent	Single Miles (millions)	Single Column Percent	Double Miles (millions)	Double Column Percent	Total Miles (millions)	Total Column Percent
Interstate/Private	3.83	37.03%	285.63	37.43%	33.50	37.46%	322.96	37.43%
Interstate/Authorized	4.44	42.93	275.15	36.06	14.25	15.94	293.84	34.06
Interstate/Exempt	0.00	0.03	9.93	1.30	0.75	0.84	10.68	1.24
Intrastate/Private	1.66	16.02	141.86	18.59	25.55	28.57	169.06	19.59
Intrastate/Authorized	0.29	2.84	31.09	4.07	12.12	13.56	43.50	5.04
Intrastate/Exempt	0.00	0.00	14.67	1.92	3.26	3.64	17.93	2.08
Daily Rental	0.12	1.15	4.70	0.62	0.00	0.00	4.82	0.56
TOTAL	10.35	100.00%	763.03	100.00%	89.43	100.00%	862.81	100.00%

Tractors Licensed up to 80,000 Pounds

Company Type	Bobtail Miles (millions)	Bobtail Column Percent	Single Miles (millions)	Single Column Percent	Double Miles (millions)	Double Column Percent	Total Miles (millions)	Total Column Percent
Interstate/Private	2.87	35.43%	167.95	33.85%	9.08	93.46%	179.90	35.01%
Interstate/Authorized	3.56	43.94	222.73	44.90	0.60	6.21	226.89	44.15
Interstate/Exempt	0.00	0.04	6.74	1.36	0.00	0.00	6.74	1.31
Intrastate/Private	1.35	16.67	70.93	14.30	0.03	0.34	72.32	14.07
Intrastate/Authorized	0.20	2.45	17.30	3.49	0.00	0.00	17.50	3.41
Intrastate/Exempt	0.00	0.00	5.74	1.16	0.00	0.00	5.74	1.12
Daily Rental	0.12	1.46	4.70	0.95	0.00	0.00	4.82	0.94
TOTAL	8.11	100.00%	496.10	100.00%	9.72	100.00%	513.93	100.00%

Tractors Licensed over 80,000 Pounds

Company Type	Bobtail Miles (millions)	Bobtail Column Percent	Single Miles (millions)	Single Column Percent	Double Miles (millions)	Double Column Percent	Total Miles (millions)	Total Column Percent
Interstate/Private	0.96	42.81%	117.67	43.96%	24.42	30.93%	143.05	41.00%
Interstate/Authorized	0.88	39.29	52.42	19.58	13.65	17.28	66.94	19.19
Interstate/Exempt	0.00	0.00	3.94	1.47	0.00	0.00	3.94	1.13
Intrastate/Private	0.31	13.66	70.93	26.50	25.51	32.31	96.75	27.73
Intrastate/Authorized	0.09	4.24	13.78	5.15	12.12	15.35	26.00	7.45
Intrastate/Exempt	0.00	0.00	8.93	3.34	3.26	4.13	12.19	3.49
Daily Rental	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	2.24	100.00%	267.67	100.00%	78.96	100.00%	348.87	100.00%

TABLE C-2
Travel Distribution by Gross Combination Weight For All Tractors: Bobtails, Singles, and Doubles

Gross Combination Weight	Miles (10^6)	Percent
< 20K	19.1	2.22%
20–40K	334.6	38.78
40–60K	199.6	23.14
60–80K	169.1	19.60
80–100K	52.5	6.08
100–120K	22.2	2.57
120–140K	17.0	1.97
140–160K	25.7	2.98
160–180K	1.4	0.16
Unknown	21.6	2.51
Total	862.5	100.0%

TABLE C-3
Travel Distribution by Gross Combination Weight For Tractor-Semitrailer, and Tractor-Double-Trailer Combinations

Gross Combination Weight	Tractor Semitrailer		Tractor Two Trailers	
	Miles (10^6)	Percent	Miles (10^6)	Percent
< 20K	9.5	1.24%	0	0.00%
20–40K	331.7	43.47	2.3	2.58
40–60K	161.3	21.14	38.3	42.87
60–80K	166.3	21.80	2.8	3.09
80–100K	48.4	6.35	4.0	4.43
100–120K	16.8	2.20	5.4	6.02
120–140K	6.1	0.80	10.9	12.19
140–160K	2.5	0.32	23.3	26.03
160–180K	0	0.00	1.4	1.56
Unknown	20.5	2.69	1.1	1.22
Total	763.0	100.00%	89.4	100.00%

TABLE C-4
Travel Distribution by Gross Combination Weight For Tractor-Semitrailers Licensed for 80,000 Pounds or Less and for Over 80,000 Pounds

Gross Combination Weight	Licensed Under 80,001		Licensed Over 80,000	
	Miles (10^6)	Percent	Miles (10^6)	Percent
< 20K	9.5	1.91%	0	0.00%
20–40K	237.7	47.90	94.1	35.24
40–60K	105.0	21.17	56.3	21.08
60–80K	116.3	23.45	50.0	18.72
80–100K	12.2	2.46	36.2	13.56
100–120K	1.8	0.37	15.0	5.61
120–140K	0	0.00	6.1	2.28
140–160K	0	0.00	2.5	0.92
160–180K	0	0.00	0	0.00
Unknown	13.6	2.74	6.9	2.59
Total	496.1	100.00%	266.9	100.00%

TABLE C-5
Travel Distribution by Gross Combination Weight For Tractor-Doubles Licensed for 80,000 Pounds or Less and for Over 80,000 Pounds

Gross Combination Weight	Licensed Under 80,001		Licensed Over 80,000	
	Miles (10^6)	Percent	Miles (10^6)	Percent
< 20K	0	0.00%	0	0.00%
20–40K	1.3	13.16	1.0	1.29
40–60K	4.3	43.76	34.1	42.77
60–80K	0.6	6.49	2.1	2.68
80–100K	0	0.00	4.0	4.97
100–120K	0	0.00	5.4	6.75
120–140K	2.7	27.43	8.2	10.34
140–160K	0.9	9.14	22.4	28.09
160–180K	0	0.00	1.4	1.76
Unknown	0.002	0.02	1.1	1.36
Total	9.7	100.00%	79.7	100.00%

TABLE C-6
Travel Distribution by Road Type
For Different Categories of Gross Combination Weight
For Tractor-Semitrailers and Tractor-Double-Trailer Combinations

Gross Combination Weight	Miles (10^6)	Limited Access (Percent)	Major Artery (Percent)	Other (Percent)	Total (Percent)
Tractors with One Trailer					
< 20K	9.5	33.52%	40.05%	26.42%	100.00%
20–40K	331.7	55.18	29.65	15.18	100.00
40–60K	161.3	60.28	27.60	12.13	100.00
60–80K	166.3	69.75	24.24	6.01	100.00
80–100K	48.4	55.24	29.62	15.14	100.00
100–120K	16.8	54.65	31.15	14.20	100.00
120–140K	6.1	52.62	37.01	10.37	100.00
140–160K	2.5	79.76	9.39	10.86	100.00
160–180K	0	0.00	0.00	0.00	100.00
Unknown	20.5	63.44	19.27	17.29	100.00
All Singles	763.0	59.44%	27.91%	12.65%	100.00%
Tractors with Two Trailers					
20–40K	2.3	66.32%	20.83%	12.85%	100.00%
40–60K	38.3	61.68	28.21	10.11	100.00
60–80K	2.8	68.93	26.00	5.06	100.00
80–100K	4.0	89.83	6.41	3.76	100.00
100–120K	5.4	74.51	19.62	5.87	100.00
120–140K	10.9	68.92	28.50	2.58	100.00
140–160K	23.3	58.94	27.59	13.47	100.00
160–180K	1.4	56.30	28.51	15.19	100.00
Unknown	1.1	54.72	16.33	28.95	100.00
All Doubles	89.4	64.04%	26.20%	9.76%	100.00%
Singles & Doubles	852.4	59.92%	27.73%	12.35%	100.0%

TABLE C-7
Distribution of Travel by Driver Age For Tractor-Semitrailers

Driver Age	Miles (10^6)	Percent
19–20	1.8	0.24%
21–24	25.8	3.40
25–29	109.5	14.38
30–34	136.3	17.90
35–39	122.1	16.04
40–44	98.8	12.98
45–49	94.2	12.37
50–54	79.5	10.45
55–59	44.8	5.89
60–64	17.2	2.26
> 64	3.7	0.48
Unknown	27.4	3.61
Total	761.1	100.00%

TABLE C-8
Distribution of Drivers With Training for Truck Driving By Age

Driver Age	Received Truck Driver Training						Total	
	No		Yes		Unknown			
	N	Percent	N	Percent	N	Percent	N	Percent
< 25	51	68.0%	15	20.0%	9	12.0%	75	100.0%
25–29	147	65.0	41	18.1	38	16.8	226	100.0
30–34	194	68.1	56	19.6	35	12.3	285	100.0
35–39	158	55.6	61	21.5	65	22.9	284	100.0
40–44	133	61.0	41	18.8	44	20.2	218	100.0
45–49	113	62.1	30	16.5	39	21.4	182	100.0
50–54	93	64.1	22	15.2	30	20.7	145	100.0
55–59	60	65.2	12	13.0	20	21.7	92	100.0
> 59	49	81.7	3	5.0	8	13.3	60	100.0
Unknown	10	3.3	4	1.3	291	95.4	305	100.0
Total	1,008	53.8%	285	15.2%	579	30.9%	1,872	100.0%

TABLE C-9
Distribution of Source of Driver's Training
By Age

Driver Age	Source of Driver's Training										Total	
	Company		School		Company & School		Military		Unknown			
	N	%	N	%	N	%	N	%	N	%	N	%
< 25	7	46.7%	4	26.7%	0	0.0%	4	26.7%	0	0.0%	15	100.0%
25–29	26	63.4	12	29.3	1	2.4	1	2.4	1	2.4	41	100.0
30–34	37	66.1	15	26.8	1	1.8	0	0.0	3	5.4	56	100.0
35–39	43	70.5	11	18.0	0	0.0	6	9.8	1	1.6	61	100.0
40–44	32	78.0	3	7.3	1	2.4	3	7.3	2	4.9	41	100.0
45–49	21	70.0	3	10.0	1	3.3	5	16.7	0	0.0	30	100.0
50–54	16	72.7	1	4.5	1	4.5	3	13.6	1	4.5	22	100.0
55–59	4	33.3	1	8.3	0	0.0	4	33.3	3	25.0	12	100.0
> 59	2	66.7	0	0.0	0	0.0	1	33.3	0	0.0	3	100.0
Unk.	2	50.0	0	0.0	0	0.0	0	0.0	2	50.0	4	100.0
Total	190	66.7%	50	17.5%	5	1.8%	27	9.5%	13	4.6%	285	100.0%

TABLE C-10
Distribution of Type of Driver's Training
By Age

Driver Age	Type of Training						Total	
	Class		Class & Road		Unknown			
	N	Percent	N	Percent	N	Percent	N	Percent
< 25	2	13.3%	12	80.0%	1	6.7%	15	100.0%
25–29	5	12.2	33	80.5	3	7.3	41	100.0
30–34	9	16.1	42	75.0	5	8.9	56	100.0
35–39	13	21.3	45	73.8	3	4.9	61	100.0
40–44	7	17.1	32	78.0	2	4.9	41	100.0
45–49	5	16.7	23	76.7	2	6.7	30	100.0
50–54	4	18.2	17	77.3	1	4.5	22	100.0
55–59	1	8.3	9	75.0	2	16.7	12	100.0
> 59	0	0.0	3	100.0	0	0.0	3	100.0
Unknown	0	0.0	4	100.0	0	0.0	4	100.0
Total	46	16.1%	220	77.2%	19	6.7%	285	100.0%

TABLE C-11
Distribution of Drivers With Training for Truck Driving By Company Type

Driver Trained?	Private		For Hire		Daily Rental		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
No	590	54.6%	413	52.9%	5	45.5%	1,008	53.8%
Yes	148	13.7	136	17.4	1	9.1	285	15.2
Unknown	343	31.7	231	29.6	5	45.5	579	30.9
Total	1,081	100.0%	780	100.0%	11	100.0%	1,872	100.0%

TABLE C-12
Distribution of Drivers With Training for Truck Driving By Area of Operation

Driver Trained?	Interstate		Intrastate		Daily Rental		Total	
	N	Percent	N	Percent	N	Percent	N	Percent
No	693	52.1%	310	58.5%	5	45.5%	1,008	53.8%
Yes	221	16.6	63	11.9	1	9.1	285	15.2
Unknown	417	31.3	157	29.6	5	45.5	579	30.9
Total	1,331	100.0%	530	100.0%	11	100.0%	1,872	100.0%

APPENDIX D
Tables—Crashes

TABLE D-1
Comparison of Crash Type Distributions for Different Vehicle Types

Crash Type	All Vehicle Types		Non-Truck Vehicles		Trucks	
	1987	1988	1987	1988	1987	1988
0: 1-Veh Misc.	—	—	—	—	1.9%	1.7%
1: Overturn	3.2%	3.1%	3.2%	3.0%	2.7	2.5
2: 1-Veh w/ Train	—	—	—	—	—	—
3: 1-Veh w/ Pkd. Veh	7.4	7.2	7.6	8.2	4.4	4.5
4: 2-Veh Backing	1.1	1.0	—	—	4.0	4.2
5: 2-Veh Parking	—	—	—	—	—	—
6: 1-Veh w/ Ped.	1.1	1.1	1.1	1.2	—	—
7: 1-Veh w/ Fixed Obj.	13.1	13.6	13.4	14.7	8.4	8.5
8: 1-Veh w/ Other Obj.	—	—	—	—	—	—
9: 1-Veh w/ Animal	9.6	10.3	10.0	10.3	3.3	3.5
10: 1-Veh w/ Bike	1.1	1.1	1.1	1.1	—	—
11: 2-Veh Head-On	2.5	2.6	2.4	2.2	3.6	3.9
12: 2-Veh Angle/Str.	9.4	9.3	9.6	9.5	6.8	6.7
13: 2-Veh Rear-End	25.4	25.3	24.7	23.9	36.2	35.4
14: 2-Veh Angle/Turn	4.9	4.7	5.0	4.7	4.6	4.6
15: 2-Veh Sswipe/Same	—	—	—	—	—	—
16: 2-Veh Rear-End LT	2.1	2.0	2.1	2.0	2.7	2.5
17: 2-Veh Rear-End RT	1.1	1.1	1.0	—	3.5	3.6
18: 2-Veh Other DR	3.0	2.8	3.1	2.9	1.8	1.9
19: 2-Veh Angle DR	3.0	3.1	3.0	3.1	3.0	3.3
20: 2-Veh Rear-End DR	5.1	5.0	5.1	4.6	5.8	6.0
21: 2-Veh Sswipe/Opp.	—	—	—	—	—	1.1
22: 2-Veh Head-On LT	4.6	4.6	4.8	4.9	2.5	2.4
23: 2-Veh Both LT	—	—	—	—	—	—
24: 2-Veh Both RT	—	—	—	—	1.4	1.3
TOTAL	97.7%	97.9%	97.2%	96.3%	96.6%	97.6%

Entries are percentages of total crashes for each vehicle type (e.g., for 1988, 1.7% of all truck-involved crashes are in the 1-vehicle miscellaneous category). Percentages less than 1% not shown, so columns do not sum to 100%.

TABLE D-2
Comparison of Crash Type Distributions for Different Truck Types

Crash Type	Straight Trucks		Bobtails		Singles		Doubles	
	1987	1988	1987	1988	1987	1988	1987	1988
0: 1-Veh Misc.	—	—	—	—	3.3%	2.8%	4.0%	3.8%
1: Overturn	2.7%	2.2%	2.9%	1.4%	2.2	2.1	5.5	6.5
2: 1-Veh w/ Train	—	—	—	—	—	—	—	—
3: 1-Veh w/ Pkd. Veh	5.7	5.9	2.2	2.6	3.1	3.2	2.2	—
4: 2-Veh Backing	4.6	5.3	3.1	3.1	3.5	3.4	1.3	1.3
5: 2-Veh Parking	—	—	—	—	—	—	—	—
6: 1-Veh w/ Ped.	—	—	—	—	—	—	—	—
7: 1-Veh w/Fixed Obj.	6.2	5.9	11.3	10.6	10.6	11.3	9.4	7.4
8: 1-Veh w/Other Obj.	—	—	—	—	—	—	—	—
9: 1-Veh w/ Animal	3.5	3.6	3.6	4.0	3.2	3.6	2.4	2.7
10: 1-Veh w/ Bike	—	—	—	—	—	—	—	—
11: 2-Veh Head-On	3.8	4.0	2.2	2.4	3.0	3.4	5.7	6.3
12: 2-Veh Angle/Str.	8.5	8.6	7.3	6.2	4.5	4.5	4.8	5.8
13: 2-Veh Rear-End	34.8	33.9	42.9	43.8	37.1	36.4	45.1	45.2
14: 2-Veh Angle/Turn	5.1	4.9	3.1	2.0	4.1	4.5	3.0	3.8
15: 2-Veh Sswipe/Sm	—	—	—	—	1.0	—	1.0	—
16: 2-Veh R-End LT	2.8	2.4	1.6	2.4	2.6	2.5	1.8	2.4
17: 2-Veh R-End RT	2.1	2.2	4.2	5.7	5.5	5.4	2.5	2.7
18: 2-Veh Other DR	2.3	2.4	2.2	2.0	1.3	1.5	—	—
19: 2-Veh Angle DR	3.4	3.5	3.6	2.9	2.6	3.3	3.3	1.9
20: 2-Veh R-End DR	7.1	7.6	3.6	5.3	4.5	4.4	2.8	2.4
21: 2-Veh Sswipe/Opp.	1.0	1.4	—	—	—	—	—	—
22: 2-Veh Head-On LT	3.0	3.0	2.0	1.8	1.7	1.8	1.8	2.0
23: 2-Veh Both LT	—	—	—	—	1.5	1.2	—	—
24: 2-Veh Both RT	—	—	1.6	1.1	2.5	2.2	1.2	—
TOTAL	96.6%	96.8%	97.4%	97.3%	97.8%	97.5%	97.8%	94.2%

Entries are percentages of total crashes for each vehicle type.
Percentages less than 1% not shown, so columns do not sum to 100%

TABLE D-3
Comparison of Crash Types for Key Truck Combinations with Truck as Vehicle 1

Crash Type	Straight Trucks		Bobtails		Singles		Doubles	
	1987	1988	1987	1988	1987	1988	1987	1988
0: 1-Veh Misc.	—	—	—	—	5.2	4.2	6.0	5.8
1: Overturn	4.0	3.4	4.1	1.8	3.3	3.1	8.6	9.8
2: 1-Veh w/ Train	—	—	—	—	—	—	—	—
3: 1-Veh w/ Pkd. Veh	8.7	9.0	3.2	3.6	4.5	4.8	3.5	—
4: 2-Veh Backing	6.2	6.9	3.8	3.6	4.6	4.7	1.6	1.9
5: 2-Veh Parking	—	—	—	—	—	—	—	—
6: 1-Veh w/ Ped.	—	—	—	—	—	—	—	—
7: 1-Veh w/Fixed Obj.	9.4	8.8	15.5	14.3	15.2	16.7	14.2	11.4
8: 1-Veh w/Other Obj.	—	—	—	—	—	—	—	1.2
9: 1-Veh w/ Animal	5.3	5.4	5.1	5.4	4.7	5.4	3.7	4.1
10: 1-Veh w/ Bike	—	—	—	—	—	—	—	—
11: 2-Veh Head-On	2.8	2.9	1.9	1.5	1.8	2.2	5.3	5.2
12: 2-Veh Angle/Str.	6.3	6.4	7.3	4.2	2.8	2.9	1.9	5.0
13: 2-Veh Rear-End	30.4	30.0	39.9	43.5	30.8	29.8	37.6	40.2
14: 2-Veh Angle/Turn	4.2	3.7	1.9	1.5	3.4	4.0	2.3	1.9
15: 2-Veh Sswipe/Sm	—	—	—	—	—	—	—	1.2
16: 2-Veh R-End LT	2.2	1.9	—	1.5	2.5	2.2	—	1.7
17: 2-Veh R-End RT	1.8	1.9	3.5	6.8	5.4	4.9	3.0	2.1
18: 2-Veh Other DR	1.8	1.8	1.9	1.5	1.1	1.0	—	—
19: 2-Veh Angle DR	2.6	2.9	3.2	2.4	2.0	2.6	2.8	1.0
20: 2-Veh R-End DR	6.5	7.1	3.5	3.9	3.9	3.7	3.2	1.9
21: 2-Veh Sswipe/Opp.	1.1	1.6	—	—	—	1.0	—	—
22: 2-Veh Head-On LT	2.3	2.2	—	—	1.3	1.4	1.9	2.1
23: 2-Veh Both LT	—	—	—	1.2	1.6	1.2	—	—
24: 2-Veh Both RT	—	—	—	—	2.4	2.1	1.2	—
TOTAL	95.6%	95.9%	94.8%	96.7%	96.5%	97.9%	96.8%	96.5%

Entries are percentages of total crashes for each vehicle type.
Percentages less than 1% not shown, so columns do not sum to 100%

TABLE D-4
Distribution of Severities in Truck-Involved Crashes by Selected Vehicle Types (1987–1988)

Vehicle Type (Vehicle 1)		Severity[1]					TOTAL
		Fatal	A-Injury	B-Injury	C-Injury	PDO	
1987	Singles	26(.004)	218(.037)	313(.053)	591(.100)	4,762(.806)	5,910
	Doubles	6(.014)	19(.044)	23(.053)	40(.093)	343(.796)	431
	Other Truck	35(.004)	360(.043)	490(.058)	1,095(.130)	6,473(.766)	8,454
	Auto/Pickup	81(.012)	446(.067)	550(.083)	811(.122)	4,744(.715)	6,632
	TOTAL	148	1043	1376	2,537	16,323	21,427
1988	Singles	41(.007)	205(.034)	288(.048)	563(.094)	4,886(.817)	5,983
	Doubles	2(.004)	26(.054)	26(.054)	48(.100)	380(.788)	482
	Other Truck	34(.004)	260(.032)	418(.051)	969(.119)	6,465(.794)	8,146
	Auto/Pickup	96(.014)	445(.067)	535(.081)	828(.125)	4,718(.712)	6,622
	TOTAL	152	1,041	1,502	2,848	17,869	21,233

Vehicle Type (Vehicle 2)		Severity[1]					TOTAL
		Fatal	A-Injury	B-Injury	C-Injury	PDO	
1987	Singles	44(.015)	243(.083)	258(.088)	291(.099)	2,099(.715)	2,935
	Doubles	10(.043)	24(.103)	21(.090)	32(.137)	146(.627)	233
	Other Truck	55(.011)	280(.058)	356(.074)	601(.125)	3,509(.731)	4,801
	Auto/Pickup	28(.003)	370(.036)	491(.048)	1,273(.126)	6,873(.678)	10,141
	TOTAL	137	917	1,126	2,197	12,627	17,004
1988	Singles	63(.020)	221(.071)	241(.077)	335(.108)	2,250(.723)	3,110
	Doubles	8(.030)	35(.133)	27(.103)	28(.106)	165(.627)	263
	Other Truck	46(.010)	239(.053)	349(.077)	568(.126)	3,314(.734)	4,516
	Auto/Pickup	42(.005)	324(.036)	463(.052)	1,198(.134)	6,919(.773)	8,946
	TOTAL	159	819	1,080	2,129	12,648	16,835

(1) For this analysis, a crash was "classed" according to the most serious injury reported—e.g., a crash resulting in a fatality and an A-injury is classed as a fatal; the number of fatalities or injuries in a single crash was not considered; A=incapacitating injury, B=non-incapacitating injury, C=possible injury, PDO=no injury, and/or property damage only.

NOTE: Entries are frequencies, with row percentages expressed in parentheses.

TABLE D-5
Comparison of Driver-1 Age for Truck-Involved and Non-Truck-Involved Crashes (1982–1988)

	All Crashes						
Age Groups	1982	1983	1984	1985	1986	1987	1988
15 thru 21	27.2	27.6	27.9	27.5	27.0	27.0	26.2
22 thru 25	14.4	14.3	14.0	14.1	14.5	13.9	13.5
26 thru 30	13.5	13.5	13.7	13.8	13.9	13.9	13.9
31 thru 40	18.4	17.4	17.8	18.8	18.8	19.1	19.5
41 thru 65	20.8	21.2	20.7	20.0	19.8	20.0	20.6
65 thru 98	5.8	5.9	6.0	5.7	6.0	6.1	6.3
	Non-Truck Crashes						
Age Groups	1982	1983	1984	1985	1986	1987	1988
15 thru 21	28.9	29.5	30.3	29.7	29.0	27.9	28.0
22 thru 25	14.1	14.3	13.5	14.0	14.2	13.9	13.3
26 thru 30	13.3	12.9	12.9	13.1	13.3	13.7	13.2
31 thru 40	17.6	16.8	17.4	17.9	18.1	18.7	18.6
41 thru 65	20.0	20.2	19.3	19.2	18.9	19.5	20.0
65 thru 98	6.1	6.3	6.6	6.1	6.4	6.2	6.9
	All Truck Crashes						
Age Groups	1982	1983	1984	1985	1986	1987	1988
15 thru 21	12.8	12.5	12.6	12.8	13.7	12.9	12.1
22 thru 25	14.4	13.0	13.8	14.8	14.6	14.1	13.7
26 thru 30	16.1	16.6	17.4	17.1	17.1	17.3	17.3
31 thru 40	22.9	23.9	24.4	24.3	24.3	24.9	25.4
41 thru 65	29.9	30.2	28.1	27.5	26.3	27.0	27.1
65 thru 98	3.8	3.8	3.6	3.5	4.1	3.9	4.3

NOTE: Percentages based on total of those crashes where age coded. "All Truck Crashes" includes all driver 1's, whether driving a truck or not, in a crash that involved a truck.

TABLE D-6
Comparison of Driver Age for Driver of Vehicle-1 Considering Vehicle Type Driven

Age Groups		Vehicle Type for Vehicle-1 in Truck-Involved Crash					
		Auto/ Pickup	Straight Truck	Single	Double	All Trucks	All Crashes
1987	15 thru 21	21.9	13.6	2.5	2.3	12.9	27.0
	22 thru 25	13.6	17.4	10.4	10.9	14.1	13.9
	26 thru 30	13.6	20.0	18.0	18.2	17.3	13.9
	31 thru 40	19.6	23.6	32.0	30.6	24.9	19.1
	41 thru 65	22.9	22.8	36.6	37.7	27.0	20.0
	65 thru 98	8.4	2.6	0.5	0.3	3.9	6.1
1988	15 thru 21	20.9	13.0	2.0	2.1	12.1	26.2
	22 thru 25	13.3	17.0	10.5	8.2	13.7	13.5
	26 thru 30	12.9	20.2	18.8	17.1	17.3	13.9
	31 thru 40	19.5	25.3	32.2	32.9	25.4	19.5
	41 thru 65	23.5	22.2	35.7	39.5	27.1	20.6
	65 thru 98	9.9	2.4	0.8	0.2	4.3	6.3

NOTE: Percentages based on total of those crashes where age coded.

TABLE D-7
Comparison of Truck and Non-Truck Crash Severity by Road Categories (Non-Local Roads Only)

		Severity				
Non-Truck-Involved Crashes						
	Road Type	Fatal	A-Injury	B-Injury	C-Injury	PDO
1987	Interstates	17.0	20.4	21.7	22.0	20.9
	US-Numbered	24.5	24.2	24.1	23.7	25.1
	M-Numbered	58.1	54.7	53.5	53.2	53.0
	Other	0.4	0.7	0.6	1.0	1.0
1988	Interstates	23.0	21.7	23.7	22.8	22.4
	US-Numbered	25.7	23.9	25.0	24.6	25.5
	M-Numbered	50.8	53.8	50.5	51.4	51.1
	Other	0.5	0.6	0.8	1.2	0.9
Truck-Involved Crashes						
	Road Type	Fatal	A-Injury	B-Injury	C-Injury	PDO
1987	Interstates	18.0	36.9	40.3	35.9	35.4
	US-Numbered	40.0	26.8	24.5	23.4	24.9
	M-Numbered	40.0	36.0	34.9	39.6	38.7
	Other	2.0	0.3	0.4	1.0	0.9
1988	Interstates	26.8	37.1	36.9	36.7	36.5
	US-Numbered	33.1	26.3	24.7	23.7	24.7
	M-Numbered	40.2	36.1	38.0	39.1	37.8
	Other	0.0	0.5	0.4	0.5	0.9

TABLE D-8
Truck Crash and Involvement Characteristics by Road Class, Truck Type, One- vs. Multi-Vehicle Crashes, and Time-of-Day

Truck-Involvements in One-Vehicle Crashes

Road Class	Truck Type: Straight Truck		Bobtail		Single		Double	
Limited	184/248	(.742)	17/29	(.586)	545/801	(.680)	48/80	(.600)
Major	339/447	(.758)	14/23	(.609)	459/599	(.766)	36/47	(.766)
Other	1,150/1,409	(.816)	21/32	(.656)	597/684	(.873)	33/39	(.846)
Total	1,673/2,104	(.795)	52/84	(.619)	1,601/2,084	(.768)	117/166	(.705)

Truck-Involvements as Vehicle 1 in Multi-Vehicle Crashes

Road Class	Truck Type: Straight Truck		Bobtail		Single		Double	
Limited	540/581	(.929)	47/49	(.959)	1,103/1,247	(.885)	93/108	(.861)
Major	1,350/1,451	(.930)	65/72	(.903)	1,018/1,139	(.894)	84/89	(.943)
Other	2,874/3,032	(.948)	94/105	(.895)	1,397/1,503	(.929)	72/76	(.947)
Total	4,764/5,064	(.941)	206/226	(.912)	3,518/3,889	(.905)	249/273	(.912)

Total Truck-Involvements as Vehicle 1

Road Class	Truck Type: Straight Truck		Bobtail		Single		Double	
Limited	724/829	(.873)	64/78	(.821)	1,648/2,048	(.805)	141/188	(.750)
Major	1,689/1,898	(.890)	79/95	(.832)	1,477/1,738	(.850)	120/136	(.882)
Other	4,024/4,441	(.906)	115/137	(.839)	1,994/2,187	(.912)	105/115	(.913)
Total	6,437/7,168	(.898)	258/310	(.832)	5,119/5,973	(.857)	366/439	(.834)

Total Truck-Involvements as Vehicle 2

Road Class	Truck Type: Straight Truck		Bobtail		Single		Double	
Limited	417/456	(.914)	29/37	(.784)	846/1,079	(.784)	59/83	(.711)
Major	1,005/1,091	(.921)	30/36	(.833)	758/919	(.825)	65/81	(.802)
Other	2,180/2,353	(.926)	47/67	(.701)	902/1,010	(.893)	60/69	(.870)
Total	3,602/3,900	(.924)	106/140	(.757)	2,506/3,008	(.833)	184/233	(.790)

TABLE D-8 (continued)

Total Truck-Involvements as Vehicle 1 and Vehicle 2								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	1,141/1,285	(.888)	93/115	(.809)	2,494/3,127	(.798)	200/271	(.738)
Major	2,694/2,989	(.901)	109/131	(.832)	2,235/2,657	(.841)	185/217	(.853)
Other	6,204/6,794	(.913)	162/204	(.794)	2,896/3,197	(.906)	165/184	(.897)
Total	10,039/11,068	(.907)	364/450	(.809)	7,625/8,981	(.849)	550/672	(.818)

NOTE: Entries are [day involvements]/[total involvements] with the day percentages shown in parentheses.

TABLE D-9
Truck Crash and Involvement Characteristics by Road Class, Truck Type, One- vs. Multi-Vehicle Crashes, and Urban/Rural

Truck-Involvements in One-Vehicle Crashes								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	182/248	(.734)	20/29	(.690)	664/803	(.827)	71/80	(.888)
Major	363/451	(.805)	20/23	(.870)	492/603	(.816)	38/47	(.809)
Other	841/1,418	(.593)	23/33	(.697)	382/687	(.556)	25/39	(.641)
Total	1,386/2,117	(.655)	63/85	(.741)	1,538/2,093	(.735)	134/166	(.807)

Truck-Involvements as Vehicle 1 in Multi-Vehicle Crashes								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	273/581	(.470)	20/49	(.408)	811/1,247	(.650)	57/108	(.528)
Major	798/1,452	(.550)	39/72	(.542)	697/1,138	(.612)	58/89	(.652)
Other	1,363/3,041	(.448)	48/105	(.457)	725/1,507	(.481)	45/76	(.592)
Total	2,434/5,074	(.480)	107/226	(.473)	2,233/3,893	(.574)	160/273	(.586)

Total Truck-Involvements as Vehicle 1								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	455/829	(.549)	40/78	(.513)	1,475/2,050	(.720)	128/188	(.681)
Major	1,161/1,903	(.610)	59/95	(.621)	1,189/1,742	(.683)	96/136	(.706)
Other	2,204/4,459	(.494)	71/138	(.514)	1,107/2,194	(.505)	70/115	(.609)
Total	3,820/7,191	(.531)	170/311	(.547)	3,771/5,986	(.630)	294/439	(.670)

Total Truck-Involvements as Vehicle 2								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	226/456	(.496)	14/38	(.368)	720/1,079	(.667)	54/83	(.651)
Major	621/1,091	(.569)	19/36	(.528)	650/921	(.706)	63/81	(.778)
Other	1,102/2,357	(.468)	29/67	(.433)	511/1,013	(.504)	40/69	(.580)
Total	1,949/3,904	(.499)	62/141	(.440)	1,881/3,013	(.624)	157/233	(.674)

TABLE D-9 (continued)

Total Truck-Involvements as Vehicle 1 and Vehicle 2								
Road Class	Truck Type							
	Straight Truck		Bobtail		Single		Double	
Limited	681/1,285	(.530)	54/116	(.466)	2,195/3,129	(.702)	182/271	(.672)
Major	1,782/2,994	(.595)	78/131	(.595)	1,839/2,663	(.691)	159/217	(.733)
Other	3,306/6,816	(.485)	100/205	(.488)	1,618/3,207	(.505)	110/184	(.598)
Total	5,769/11,095	(.520)	232/452	(.513)	5,652/8,999	(.628)	451/672	(.671)

NOTE: Entries are [rural involvements]/[total involvements] with the rural percentages shown in parentheses.

TABLE D-10
One-Vehicle Truck Crash Involvements for Rate Calculations

Truck Type: Straight Truck (with no trailers)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	110	51	39	10	19	2	11	3
Major	237	68	71	11	20	7	20	0
Other	616	456	159	68	18	23	10	15

Truck Type: Bobtail (tractor with no trailer)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	4	5	6	1	5	3	5	0
Major	9	1	5	0	3	1	3	1
Other	13	5	5	0	1	2	4	2

Truck Type: Single (tractor and semitrailer)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	194	65	99	18	240	42	123	12
Major	236	56	76	8	119	40	50	4
Other	224	172	32	16	87	85	24	13

Truck Type: Double (tractor, semitrailer, and full trailer)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	27	5	13	1	15	0	15	3
Major	19	7	7	1	8	1	3	0
Other	16	10	2	1	3	2	2	0

TABLE D-11
Multi-Vehicle Truck Crash Involvements for Rate Calculations

Truck Type: Straight Truck (with no trailers)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	213	269	19	10	20	18	4	3
Limited-Veh 2	174	197	17	13	22	10	6	1
Limited-Total	387	466	36	23	42	28	10	4
Major-Veh 1	678	556	53	33	45	53	5	4
Major-Veh 2	522	408	44	31	42	26	7	3
Major-Total	1,200	964	97	64	87	79	12	7
Other-Veh 1	1,191	1,520	70	65	59	67	7	8
Other-Veh 2	978	1,120	73	87	30	34	7	5
Other-Total	2,169	2,640	143	152	89	101	14	13

Truck Type: Bobtail (tractor with no trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	9	19	0	1	6	8	0	1
Limited-Veh 2	4	16	3	2	5	3	2	1
Limited-Total	13	35	3	3	11	11	2	2
Major-Veh 1	25	24	0	0	9	5	4	3
Major-Veh 2	7	11	3	0	7	3	1	1
Major-Total	32	35	3	0	16	8	5	4
Other-Veh 1	37	41	2	4	6	10	2	2
Other-Veh 2	19	19	7	7	0	9	3	3
Other-Total	56	60	9	11	6	19	5	5

TABLE D-11 (continued)

Truck Type: Single (tractor and semitrailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	322	220	36	20	342	158	57	21
Limited-Veh 2	252	170	65	25	265	115	97	36
Limited-Total	574	390	101	45	607	273	154	57
Major-Veh 1	373	243	46	25	224	145	26	21
Major-Veh 2	362	146	60	31	161	70	50	18
Major-Total	735	389	106	56	385	215	76	39
Other-Veh 1	402	474	29	17	228	254	31	24
Other-Veh 2	322	280	28	35	130	154	20	22
Other-Total	724	754	57	52	358	408	51	46

Truck Type: Double (tractor, semitrailer, and full trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	35	42	4	2	8	4	8	0
Limited-Veh 2	24	19	8	1	10	4	10	4
Limited-Total	59	61	12	3	18	8	18	4
Major-Veh 1	48	24	1	1	8	4	1	2
Major-Veh 2	45	10	9	3	6	2	2	2
Major-Total	93	34	10	4	14	6	3	4
Other-Veh 1	36	23	2	1	6	6	0	1
Other-Veh 2	34	20	2	6	2	3	1	0
Other-Total	70	43	4	7	8	9	1	1

TABLE D-12
Total Truck Crash Involvements (One- and Multi-Vehicle) for Rate Calculations

Truck Type: Straight Truck (with no trailers)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	323	320	58	20	39	20	15	6
Limited-Veh 2	174	197	17	13	22	10	6	1
Limited-Total	497	517	75	33	61	30	21	7
Major-Veh 1	915	624	124	44	65	60	25	4
Major-Veh 2	522	408	44	31	42	26	7	3
Major-Total	1,437	1,032	168	75	107	86	32	7
Other-Veh 1	1,807	1,976	229	133	77	90	17	23
Other-Veh 2	978	1,120	73	87	30	34	7	5
Other-Total	2,785	3,096	302	220	107	124	24	28

Truck Type: Bobtail (tractor with no trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	13	24	6	2	11	11	5	1
Limited-Veh 2	4	16	3	2	5	3	2	1
Limited-Total	17	40	9	4	16	14	7	2
Major-Veh 1	34	25	5	0	12	6	7	4
Major-Veh 2	7	11	3	0	7	3	1	1
Major-Total	41	36	8	0	19	9	8	5
Other-Veh 1	50	46	7	4	7	12	6	4
Other-Veh 2	19	19	7	7	0	9	3	3
Other-Total	69	65	14	11	7	21	9	7

TABLE D-12 (continued)

Truck Type: Single (tractor and semitrailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	516	285	135	38	582	200	180	33
Limited-Veh 2	252	170	65	25	265	115	97	36
Limited-Total	768	455	200	63	847	315	277	69
Major-Veh 1	609	299	122	33	343	185	76	25
Major-Veh 2	362	146	60	31	161	70	50	18
Major-Total	971	445	182	64	504	255	126	43
Other-Veh 1	626	646	61	33	315	339	55	37
Other-Veh 2	322	280	28	35	130	154	20	22
Other-Total	948	926	89	68	445	493	75	60

Truck Type: Double (tractor, semitrailer, and full trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	62	47	17	3	23	4	23	3
Limited-Veh 2	24	19	8	1	10	4	10	4
Limited-Total	86	66	25	4	33	8	33	7
Major-Veh 1	67	31	8	2	16	5	4	2
Major-Veh 2	45	10	9	3	6	2	2	2
Major-Total	112	41	17	5	22	7	6	4
Other-Veh 1	52	33	4	2	9	8	2	1
Other-Veh 2	34	20	2	6	2	3	1	0
Other-Total	86	53	6	8	11	11	3	1

TABLE D-13
One-Vehicle Truck Casualty Crash Involvements for Rate Calculations (Injury and Fatal Crashes)

Truck Type: Straight Truck (with no trailers)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	40	19	13	5	9	1	1	0
Major	44	15	11	0	3	2	0	0
Other	134	52	41	12	4	2	3	5

Truck Type: Bobtail (tractor with no trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	0	0	1	0	1	1	3	0
Major	2	0	0	0	0	0	1	0
Other	4	1	3	0	1	0	0	0

Truck Type: Single (tractor and semitrailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	42	22	19	5	69	13	30	2
Major	39	7	9	0	16	3	11	1
Other	29	9	2	0	8	5	2	0

Truck Type: Double (tractor, semitrailer, and full trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited	5	2	4	1	1	0	2	0
Major	3	0	0	0	1	0	0	0
Other	4	1	1	0	0	0	0	0

TABLE D-14
Multi-Vehicle Truck Casualty Crash Involvements for Rate Calculations (Injury and Fatal Crashes)

Truck Type: Straight Truck (with no trailers)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	53	68	7	1	8	3	4	2
Limited-Veh 2	55	40	8	2	6	1	3	0
Limited-Total	108	108	15	3	14	4	7	2
Major-Veh 1	203	142	19	12	15	11	1	2
Major-Veh 2	143	79	23	9	11	6	4	0
Major-Total	346	221	42	21	26	17	5	2
Other-Veh 1	259	319	24	16	11	11	1	2
Other-Veh 2	267	239	30	31	7	11	2	1
Other-Total	526	558	54	47	18	22	3	3

Truck Type: Bobtail (tractor with no trailer)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	5	6	0	0	0	2	0	0
Limited-Veh 2	2	3	1	0	3	1	0	0
Limited-Total	7	9	1	0	3	3	0	0
Major-Veh 1	8	3	0	0	2	0	0	1
Major-Veh 2	2	1	0	0	1	1	1	0
Major-Total	10	4	0	0	3	1	1	1
Other-Veh 1	12	4	0	2	0	3	0	1
Other-Veh 2	6	2	4	2	0	1	2	2
Other-Total	18	6	4	4	0	4	2	3

TABLE D-14 (continued)

Truck Type: Single (tractor and semitrailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	84	40	9	6	103	30	19	6
Limited-Veh 2	62	45	35	12	77	24	47	16
Limited-Total	146	85	44	18	180	54	66	22
Major-Veh 1	94	53	17	6	53	26	7	3
Major-Veh 2	108	32	35	13	44	13	28	8
Major-Total	202	85	52	19	97	39	35	11
Other-Veh 1	80	59	10	2	32	40	8	3
Other-Veh 2	91	50	10	17	26	35	8	12
Other-Total	171	109	20	19	58	75	16	15

Truck Type: Double (tractor, semitrailer, and full trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	7	6	2	0	2	1	5	0
Limited-Veh 2	9	5	5	0	2	1	6	2
Limited-Total	16	11	7	0	4	2	11	2
Major-Veh 1	9	6	1	0	1	1	1	1
Major-Veh 2	19	5	4	0	1	1	6	1
Major-Total	28	11	5	0	2	2	7	2
Other-Veh 1	9	7	0	1	1	0	0	1
Other-Veh 2	13	9	1	5	1	0	0	0
Other-Total	22	16	1	6	2	0	0	1

TABLE D-15
Total Truck Casualty Crash Involvements (One- and Multi-Vehicle) for Rate Calculations (Injury and Fatal Crashes)

Truck Type: Straight Truck (with no trailers)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	93	87	20	6	17	4	5	2
Limited-Veh 2	55	40	8	2	6	1	3	0
Limited-Total	148	127	28	8	23	5	8	2
Major-Veh 1	247	157	30	12	18	13	1	2
Major-Veh 2	143	79	23	9	11	6	4	0
Major-Total	390	236	53	21	29	19	5	2
Other-Veh 1	393	371	65	28	15	13	4	7
Other-Veh 2	267	239	30	31	7	11	2	1
Other-Total	660	610	95	59	22	24	6	8

Truck Type: Bobtail (tractor with no trailer)

Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	5	6	1	0	1	3	3	0
Limited-Veh 2	2	3	1	0	3	1	0	0
Limited-Total	7	9	2	0	4	4	3	0
Major-Veh 1	10	3	0	0	2	0	1	1
Major-Veh 2	2	1	0	0	1	1	1	0
Major-Total	12	4	0	0	3	1	2	1
Other-Veh 1	16	5	3	2	1	3	0	1
Other-Veh 2	6	2	4	2	0	1	2	2
Other-Total	22	7	7	4	1	4	2	3

TABLE D-15 (continued)

Truck Type: Single (tractor and semitrailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	126	62	28	11	172	43	49	8
Limited-Veh 2	62	45	35	12	77	24	47	16
Limited-Total	188	107	63	33	249	67	96	24
Major-Veh 1	133	60	26	6	69	29	18	4
Major-Veh 2	108	32	35	13	44	13	28	8
Major-Total	241	92	61	19	113	42	46	12
Other-Veh 1	109	68	12	2	40	45	10	3
Other-Veh 2	91	50	10	17	26	35	8	12
Other-Total	200	118	22	19	66	80	18	15

Truck Type: Double (tractor, semitrailer, and full trailer)								
Road Class	Michigan				Non-Michigan			
	Day		Night		Day		Night	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Limited-Veh 1	12	8	6	1	3	1	7	0
Limited-Veh 2	9	5	5	0	2	1	6	2
Limited-Total	21	13	11	1	5	2	13	2
Major-Veh 1	12	6	1	0	2	1	1	1
Major-Veh 2	19	5	4	0	1	1	6	1
Major-Total	31	11	5	0	3	2	7	2
Other-Veh 1	13	8	1	1	1	0	0	1
Other-Veh 2	13	9	1	5	1	0	0	0
Other-Total	26	17	2	6	2	0	0	1

APPENDIX E
Tables—Rates

TABLE E-1
Crashes, Travel, and Crash Rates
For Bobtail, Tractor-Semi, and Tractor-Double-Trailer Combinations
By Twelve Travel Categories
For All Crashes—Michigan-Registered Tractors on Michigan Roads

Travel Category			Crashes			Travel (10^6 Miles)			Crash Rate		
			Bobtail	Single	Double	Bobtail	Single	Double	Bobtail	Single	Double
Rural	Day	Limited	17	768	86	2.1	204.43	23.16	8.10	3.76	3.71
Rural	Day	Major	41	971	112	2.1	128.65	15.04	19.52	7.55	7.45
Rural	Day	Other	69	948	86	0.26	31.77	3.21	265.38	29.84	26.79
Rural	Night	Limited	9	200	25	0.24	41.95	9.47	37.50	4.77	2.64
Rural	Night	Major	8	182	17	0.07	17.64	2.4	114.29	10.32	7.08
Rural	Night	Other	14	89	6	0.06	1.29	0.22	233.33	68.99	27.27
Urban	Day	Limited	40	455	66	2.63	177.25	21.16	15.21	2.57	3.12
Urban	Day	Major	36	445	41	0.93	59.82	5.53	38.71	7.44	7.41
Urban	Day	Other	65	926	53	1.44	59.73	4.95	45.14	15.50	10.71
Urban	Night	Limited	4	63	4	0.37	29.88	3.47	10.81	2.11	1.15
Urban	Night	Major	0	64	5	0.07	6.84	0.46	0.00	9.36	10.87
Urban	Night	Other	11	68	8	0.09	3.78	0.34	122.22	17.99	23.53
Total			314	5,179	509	10.35	763.03	89.43	30.34	6.79	5.69

TABLE E-2
Crashes, Travel, and Crash Rates
For Bobtail, Tractor-Semi, and Tractor-Double-Trailer Combinations
By Twelve Travel Categories
For Casualty Crashes—Michigan-Registered Tractors on Michigan Roads

Travel Category			Crashes			Travel (10^6 Miles)			Crash Rate		
			Bobtail	Single	Double	Bobtail	Single	Double	Bobtail	Single	Double
Rural	Day	Limited	7	188	21	2.1	204.43	23.16	3.33	0.92	0.91
Rural	Day	Major	12	241	31	2.1	128.65	15.04	5.71	1.87	2.06
Rural	Day	Other	22	200	26	0.26	31.77	3.21	84.62	6.30	8.10
Rural	Night	Limited	2	63	11	0.24	41.95	9.47	8.33	1.50	1.16
Rural	Night	Major	0	61	5	0.07	17.64	2.4	0.00	3.46	2.08
Rural	Night	Other	7	22	2	0.06	1.29	0.22	116.67	17.05	9.09
Urban	Day	Limited	9	107	13	2.63	177.25	21.16	3.42	0.60	0.61
Urban	Day	Major	4	92	11	0.93	59.82	5.53	4.30	1.54	1.99
Urban	Day	Other	7	118	17	1.44	59.73	4.95	4.86	1.98	3.43
Urban	Night	Limited	0	23	1	0.37	29.88	3.47	0.00	0.77	0.29
Urban	Night	Major	0	19	0	0.07	6.84	0.46	0.00	2.78	0.00
Urban	Night	Other	4	19	6	0.09	3.78	0.34	44.44	5.03	17.65
Total			74	1,153	144	10.35	763.03	89.43	7.15	1.51	1.61

TABLE E-3
Crashes, Travel, and Crash Rates
For Bobtail, Tractor-Semi, and Tractor-Double-Trailer Combinations
By Twelve Travel Categories
For Property Damage Crashes—Michigan-Registered Tractors on Michigan Roads

Travel Category			Crashes			Travel (10^6 Miles)			Crash Rate		
			Bobtail	Single	Double	Bobtail	Single	Double	Bobtail	Single	Double
Rural	Day	Limited	10	580	65	2.1	204.43	23.16	4.76	2.84	2.81
Rural	Day	Major	29	730	81	2.1	128.65	15.04	13.81	5.67	5.39
Rural	Day	Other	47	748	60	0.26	31.77	3.21	180.77	23.54	18.69
Rural	Night	Limited	7	137	14	0.24	41.95	9.47	29.17	3.27	1.48
Rural	Night	Major	8	121	12	0.07	17.64	2.4	114.29	6.86	5.00
Rural	Night	Other	7	67	4	0.06	1.29	0.22	116.67	51.94	18.18
Urban	Day	Limited	31	348	53	2.63	177.25	21.16	11.79	1.96	2.50
Urban	Day	Major	32	353	30	0.93	59.82	5.53	34.41	5.90	5.42
Urban	Day	Other	58	808	36	1.44	59.73	4.95	40.28	13.53	7.27
Urban	Night	Limited	4	40	3	0.37	29.88	3.47	10.81	1.34	0.86
Urban	Night	Major	0	45	5	0.07	6.84	0.46	0.00	6.58	10.87
Urban	Night	Other	7	49	2	0.09	3.78	0.34	77.78	12.96	5.88
Total			240	4,026	365	10.35	763.03	89.43	23.19	5.28	4.08

TABLE E-4
Crashes, Travel, and Crash Rates by Driver Age

Driver Age	Travel (10^6 Miles)	Crashes			Crash Rates		
		PDO	Casualty	All	PDO	Casualty	All
19–20	1.83	50	19	69	27.26	10.36	37.62
21–24	25.85	364	110	474	14.08	4.26	18.34
25–29	109.48	754	233	987	6.89	2.13	9.02
30–34	136.26	818	244	1,062	6.00	1.79	7.79
35–39	122.08	653	196	849	5.35	1.61	6.95
40–44	98.76	522	171	693	5.29	1.73	7.02
45–49	94.18	434	131	565	4.61	1.39	6.00
50–54	79.55	345	85	430	4.34	1.07	5.41
55–59	44.85	281	68	349	6.27	1.52	7.78
60–64	17.16	102	54	156	5.94	3.15	9.09
>64	3.67	35	12	47	9.53	3.27	12.80
Total	733.67	4,358	1,323	5,681	5.94	1.80	7.74