THE MICHIGAN HEAVY TRUCK STUDY

A Joint Project of

Michigan State University
Department of Civil and
Environmental Engineering

Richard W. Lyles
Polichronis Stamatiadis

University of Michigan
Transportation Research Institute

Daniel F. Blower
Kenneth L. Campbell

FINAL REPORT

April 1990
Sponsored by
Michigan Office of Highway Safety Planning
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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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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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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>
<thead>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>295,195</td>
<td>300,990</td>
<td>335,303</td>
<td>387,069</td>
<td>400,840</td>
<td>397,388</td>
<td>410,587</td>
</tr>
<tr>
<td>Trucks</td>
<td>12,928</td>
<td>13,696</td>
<td>16,497</td>
<td>21,307</td>
<td>23,412</td>
<td>21,427</td>
<td>21,233</td>
</tr>
</tbody>
</table>

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.
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

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

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tractors</td>
<td>34,577</td>
</tr>
<tr>
<td>Average Annual Miles in Michigan</td>
<td>25,500</td>
</tr>
<tr>
<td>Total Travel in Michigan</td>
<td>883,230,000</td>
</tr>
</tbody>
</table>

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 per-
cent 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

<table>
<thead>
<tr>
<th>Registrations</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Current Registration</td>
<td>25,375</td>
</tr>
<tr>
<td>IRP Expired</td>
<td>10,484</td>
</tr>
<tr>
<td>Non-IRP Expired</td>
<td>4,937</td>
</tr>
<tr>
<td>Total</td>
<td>40,796</td>
</tr>
</tbody>
</table>

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 1,085 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>
<thead>
<tr>
<th>Table 2-2</th>
<th>Michigan Truck Trip Information Survey Sample Cases And Population Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Cases</td>
<td>Population Estimates</td>
</tr>
<tr>
<td>N</td>
<td>Percent</td>
</tr>
<tr>
<td>Complete</td>
<td>1,085</td>
</tr>
<tr>
<td>Incomplete</td>
<td>200</td>
</tr>
<tr>
<td>Non-Sample</td>
<td>59</td>
</tr>
<tr>
<td>Expired Reg</td>
<td>212</td>
</tr>
<tr>
<td>Total</td>
<td>1,556</td>
</tr>
</tbody>
</table>

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 sur-
vey 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 con­
cerning 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 per-
mit 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 sur-
vey 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>
<thead>
<tr>
<th>Registered Weight</th>
<th>Straight Truck</th>
<th>Tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Trucks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 80,000</td>
<td>Not Sampled</td>
<td>24,687</td>
</tr>
<tr>
<td>More than 80,000</td>
<td>991</td>
<td>9,890</td>
</tr>
<tr>
<td><strong>Average Annual Miles in Michigan</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 80,000</td>
<td>Not Sampled</td>
<td>21,315</td>
</tr>
<tr>
<td>More than 80,000</td>
<td>34,547</td>
<td>36,100</td>
</tr>
<tr>
<td><strong>Total Travel in Michigan (Miles)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 80,000</td>
<td>Not Sampled</td>
<td>526,200,000</td>
</tr>
<tr>
<td>More than 80,000</td>
<td>34,220,000</td>
<td>357,030,000</td>
</tr>
</tbody>
</table>

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

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

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.
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.
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-semi-trailer, 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*

<table>
<thead>
<tr>
<th>Travel Category</th>
<th>Bobtail</th>
<th>Single</th>
<th>Double</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Miles</td>
<td>%</td>
<td>Miles</td>
</tr>
<tr>
<td><strong>Travel Miles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited Day Rural</td>
<td>2.10</td>
<td>20.3%</td>
<td>204.43</td>
</tr>
<tr>
<td>Limited Night Rural</td>
<td>0.24</td>
<td>2.3%</td>
<td>41.95</td>
</tr>
<tr>
<td>Major Day Rural</td>
<td>2.10</td>
<td>20.3%</td>
<td>128.65</td>
</tr>
<tr>
<td>Major Night Rural</td>
<td>0.07</td>
<td>0.7%</td>
<td>17.64</td>
</tr>
<tr>
<td>Other Day Rural</td>
<td>0.26</td>
<td>2.5%</td>
<td>31.77</td>
</tr>
<tr>
<td>Other Night Rural</td>
<td>0.06</td>
<td>0.6%</td>
<td>1.29</td>
</tr>
<tr>
<td>Limited Day Urban</td>
<td>2.63</td>
<td>25.4%</td>
<td>177.25</td>
</tr>
<tr>
<td>Limited Night Urban</td>
<td>0.37</td>
<td>3.6%</td>
<td>29.88</td>
</tr>
<tr>
<td>Major Day Urban</td>
<td>0.93</td>
<td>9.0%</td>
<td>59.82</td>
</tr>
<tr>
<td>Major Night Urban</td>
<td>0.07</td>
<td>0.7%</td>
<td>6.84</td>
</tr>
<tr>
<td>Other Day Urban</td>
<td>1.44</td>
<td>13.9%</td>
<td>59.73</td>
</tr>
<tr>
<td>Other Night Urban</td>
<td>0.09</td>
<td>0.9%</td>
<td>3.78</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>10.35</td>
<td>100.0%</td>
<td>763.03</td>
</tr>
</tbody>
</table>

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.
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.
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 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 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.
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 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 MITIS travel data. Crash rates by age will be presented in section 4.

¹Fatal 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.

**Distribution of Travel by Driver Age**

*For Tractor Semitrailers*

![Bar chart showing distribution of travel by driver age for tractor semitrailers. The chart indicates that 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-semi­trailer travel.]

**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 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.

<table>
<thead>
<tr>
<th>Source of Training</th>
<th>% of Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>70</td>
</tr>
<tr>
<td>School</td>
<td>10</td>
</tr>
<tr>
<td>Co.&amp;Schl</td>
<td>5</td>
</tr>
<tr>
<td>Military</td>
<td>5</td>
</tr>
<tr>
<td>Unknown</td>
<td>5</td>
</tr>
</tbody>
</table>

**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.
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.

![Percent with Driver Training By Operating Authority](image_url)

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.
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 more one-vehicle miscellaneous, two-vehicle backing, and two-vehicle rear-end (all types) crashes; and

Compared to non-trucks, trucks have proportionately fewer 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 more one-vehicle miscellaneous, overturning, two-vehicle head-on, and two-vehicle rear-end crashes than all other truck types;

**Doubles** have proportionately fewer one-vehicle with fixed object (except relative to straight trucks), two-vehicle angle/straight, and driveway (except relative to singles) crashes;

**Singles** have proportionately more one-vehicle miscellaneous (except relative to doubles) and two-vehicle turning crashes;

**Singles** have proportionately fewer 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

<table>
<thead>
<tr>
<th></th>
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<td><strong>ALL CRASHES</strong></td>
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</tr>
<tr>
<td>Fatal</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.4%</td>
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<tr>
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</tr>
<tr>
<td>Fatal</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.3%</td>
</tr>
<tr>
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<td>5.3</td>
<td>5.4</td>
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<td>4.5</td>
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</tr>
<tr>
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<td>10.6</td>
<td>10.6</td>
<td>9.1</td>
<td>8.6</td>
<td>8.3</td>
<td>7.9</td>
</tr>
<tr>
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<td>15.8</td>
<td>16.0</td>
<td>14.9</td>
<td>14.6</td>
<td>14.1</td>
<td>14.3</td>
</tr>
<tr>
<td>PDO</td>
<td>68.4</td>
<td>68.0</td>
<td>67.6</td>
<td>70.8</td>
<td>72.0</td>
<td>72.8</td>
<td>73.2</td>
</tr>
<tr>
<td><strong>ALL-TRUCK CRASHES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatal</td>
<td>0.8%</td>
<td>0.9%</td>
<td>0.8%</td>
<td>0.7%</td>
<td>0.6%</td>
<td>0.7%</td>
<td>0.8%</td>
</tr>
<tr>
<td>A-injury</td>
<td>4.8</td>
<td>4.9</td>
<td>4.8</td>
<td>4.4</td>
<td>4.4</td>
<td>4.9</td>
<td>4.4</td>
</tr>
<tr>
<td>B-injury</td>
<td>7.3</td>
<td>7.3</td>
<td>7.1</td>
<td>6.9</td>
<td>6.4</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>C-injury</td>
<td>11.4</td>
<td>11.7</td>
<td>12.3</td>
<td>12.2</td>
<td>12.2</td>
<td>11.8</td>
<td>11.3</td>
</tr>
<tr>
<td>PDO</td>
<td>75.7</td>
<td>75.2</td>
<td>75.0</td>
<td>75.9</td>
<td>76.3</td>
<td>76.2</td>
<td>77.5</td>
</tr>
</tbody>
</table>

**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 0.3% 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 cal-
endar 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>
<thead>
<tr>
<th>Table 3-2</th>
<th>General Comparison of 1987, Study Year, and 1988 Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Category</td>
<td>1987</td>
</tr>
<tr>
<td>Total Crashes</td>
<td>397,388</td>
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<tr>
<td>All Trucks</td>
<td>21,427</td>
</tr>
<tr>
<td>Straights</td>
<td>10,774</td>
</tr>
<tr>
<td>Bobtails</td>
<td>450</td>
</tr>
<tr>
<td>Singles</td>
<td>8,726</td>
</tr>
<tr>
<td>Doubles</td>
<td>668</td>
</tr>
</tbody>
</table>

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, or 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, or 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

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Straight Truck</th>
<th>Str. Truck + Trailer</th>
<th>Bobtail</th>
<th>Single</th>
<th>Double</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRUCK-INVOLVEMENTS IN ONE-VEHICLE CRASHES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited</td>
<td>248</td>
<td>42</td>
<td>29</td>
<td>803</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Major</td>
<td>451</td>
<td>46</td>
<td>23</td>
<td>603</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>1,418</td>
<td>113</td>
<td>33</td>
<td>687</td>
<td>39</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td>2,117</td>
<td>201</td>
<td>85</td>
<td>2,093</td>
<td>166</td>
<td>1</td>
</tr>
</tbody>
</table>

| **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

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Straight Truck</th>
<th>Str. Truck + Trailer</th>
<th>Bobtail</th>
<th>Single</th>
<th>Double</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited</td>
<td>721/801 (90.0)</td>
<td>101/116 (87.1)</td>
<td>45/73 (61.6)</td>
<td>975/1,971 (49.5)</td>
<td>129/182 (70.9)</td>
<td>47/54 (87.0)</td>
</tr>
<tr>
<td>Major</td>
<td>1,711/1,866 (91.7)</td>
<td>141/159 (88.7)</td>
<td>64/93 (68.8)</td>
<td>1,063/1,695 (62.7)</td>
<td>108/135 (80.0)</td>
<td>68/72 (94.4)</td>
</tr>
<tr>
<td>Other</td>
<td>4,162/4,369 (95.3)</td>
<td>283/301 (94.0)</td>
<td>108/137 (78.8)</td>
<td>1,370/2,119 (64.7)</td>
<td>91/111 (82.0)</td>
<td>136/145 (93.8)</td>
</tr>
</tbody>
</table>

MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 2

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Straight Truck</th>
<th>Str. Truck + Trailer</th>
<th>Bobtail</th>
<th>Single</th>
<th>Double</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited</td>
<td>401/440 (91.1)</td>
<td>35/40 (87.5)</td>
<td>25/37 (67.6)</td>
<td>512/1,025 (50.0)</td>
<td>52/80 (65.0)</td>
<td>55/62 (88.7)</td>
</tr>
<tr>
<td>Major</td>
<td>1,005/1,063 (92.3)</td>
<td>63/69 (91.3)</td>
<td>21/33 (63.6)</td>
<td>600/900 (66.7)</td>
<td>67/79 (84.8)</td>
<td>100/107 (93.5)</td>
</tr>
<tr>
<td>Other</td>
<td>2,262/2,338 (96.7)</td>
<td>127/136 (93.4)</td>
<td>52/67 (77.6)</td>
<td>668/994 (87.2)</td>
<td>62/68 (91.1)</td>
<td>221/225 (98.2)</td>
</tr>
</tbody>
</table>

ALL MICHIGAN-REGISTERED TRUCK-INVOLVEMENTS AS VEHICLE 1 AND VEHICLE 2

<table>
<thead>
<tr>
<th>Road Class</th>
<th>Straight Truck</th>
<th>Str. Truck + Trailer</th>
<th>Bobtail</th>
<th>Single</th>
<th>Double</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited</td>
<td>1,122/1,241 (90.4)</td>
<td>136/156 (87.2)</td>
<td>70/110 (63.6)</td>
<td>1,487/2,996 (49.6)</td>
<td>181/262 (69.1)</td>
<td>102/116 (87.9)</td>
</tr>
<tr>
<td>Major</td>
<td>2,716/2,949 (92.1)</td>
<td>204/228 (89.5)</td>
<td>85/126 (67.5)</td>
<td>1,663/2,595 (64.1)</td>
<td>175/214 (81.8)</td>
<td>168/179 (93.9)</td>
</tr>
<tr>
<td>Other</td>
<td>6,424/6,707 (95.8)</td>
<td>410/437 (93.8)</td>
<td>160/204 (78.4)</td>
<td>2,038/3,113 (65.5)</td>
<td>153/179 (85.5)</td>
<td>357/370 (96.5)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10,262/10,897 (94.2)</td>
<td>750/821 (91.4)</td>
<td>315/440 (71.6)</td>
<td>5,188/8,704 (59.6)</td>
<td>509/655 (77.7)</td>
<td>627/665 (94.3)</td>
</tr>
</tbody>
</table>

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.
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 sep-
arate 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](image-url)
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

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

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

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 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 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.
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>
<thead>
<tr>
<th>Area Type</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ALL CRASHES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>7.54</td>
<td>7.51</td>
</tr>
<tr>
<td>Urban</td>
<td>6.38</td>
<td>5.01</td>
</tr>
<tr>
<td><strong>CASUALTY CRASHES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>1.82</td>
<td>2.36</td>
</tr>
<tr>
<td>Urban</td>
<td>1.13</td>
<td>1.59</td>
</tr>
<tr>
<td><strong>PROPERTY DAMAGE ONLY CRASHES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>5.72</td>
<td>5.14</td>
</tr>
<tr>
<td>Urban</td>
<td>5.25</td>
<td>3.42</td>
</tr>
</tbody>
</table>

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.