Differential Truck Accident Rates for Michigan

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Major changes in the trucking industry have resulted from federal legislation that relaxed the regulation of trucks in interstate commerce, allowed the use of double-trailer combinations nationwide on Interstate highways, and required states to regulate trailer length instead of overall length. Because Michigan has long had extremely liberal truck size and weight regulations, its experience with truck safety is of significant interest. A project by the University of Michigan and Michigan State University was undertaken to develop statistical information on accidents, travel, and the risk of accident involvement for Michigan-registered trucks in Michigan. The study objective was to calculate disaggregate truck accident rates by road class, day or night, and urban or rural operating conditions for tractors without trailers (bobtails) and in single- and double-trailer configurations. Major findings included the following: bobtails consistently have the highest accident rates; all-accident and casualty rates for single and double configurations are similar to one another; the most significant and consistent factor associated with truck accident rates was the roadway class (highest rates on the "local" road system, lowest on limited-access highways); urban accident rates were lower than rural rates; night rates were higher than day rates for casualty accidents but lower for all accidents; and tractor drivers aged 19–20 have an accident rate five times the average. The findings indicate that differences in truck safety by roadway class are more important than those between singles and doubles. Discussion and recommendations concerning improvements in truck accident and exposure data as well as further work on the relationship between truck accidents and geometry are included.

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

Not all of the national changes had the same impact on Michigan as on other states, because it has long had some of the most liberal truck size and weight regulations in the United States. For example, double-trailer combinations weighing up to 164,000 lb have operated legally in Michigan for many years. The use of double trailers and the experience of other combinations operating in Michigan is of significant interest both within the state and nationally.

Whereas truck regulations for the most part are seen as becoming more liberal, at the same time it is generally perceived that large trucks are not very safe. There are lingering questions about the safety of these vehicles and what, if anything, should (or can) be done to make them safer. In Michigan, accidents involving large trucks increased 81 percent from 1982 to 1986, but they decreased in 1987 and 1988. For the entire period from 1982 to 1988, the number of truck accidents increased by 64 percent, whereas all motor vehicle accidents increased by about 40 percent. During the same period, economic conditions improved substantially in the state, and truck travel increased. In the face of so many changes, the problem is to identify the significant factors associated with the risk of truck accidents while controlling for variations in the exposure of trucks to the possibility of an accident.

Despite the interest in truck safety, there are still significant gaps in the current knowledge about truck accident rates and the causal factors involved—both nationally and in Michigan. This is reflected to some degree in, for example, recent publications that decry the lack of consistent data concerning truck use (*1*) and, implicitly, the capability to produce reasonable accident involvement rates. In this context, a joint project by the University of Michigan's Transportation Research Institute (UMTRI) and Michigan State University's (MSU's) Department of Civil and Environmental Engineering was undertaken to develop statistical information on accidents, travel, and the risk of accident involvement for Michigan-registered trucks in Michigan (*2*). Operationally, the objective of the study was to calculate disaggregate truck accident rates [in terms of accident involvements per million vehicle miles of travel (VMT)] for combinations of the variables shown in Table 1.

In general, MSU was responsible for the accident data, and UMTRI was responsible for exposure data. Both the accident and travel data spanned the 12-month study period beginning in May 1987 and ending in April 1988. The following sections are addressed, in turn, to discussion of truck accidents, truck travel, the development of truck accident rates, and, finally, the findings, implications, and conclusions of the Michigan study.

TRUCK ACCIDENTS IN MICHIGAN

Because the reporting threshold for traffic accidents in Michigan is $200 of damage, virtually all accidents that occur on

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TABLE 1 STRATIFYING VARIABLES FOR DISAGGREGATE TRUCK ACCIDENT RATES

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

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

Assembling and preparing the accident data for the study year required a considerable manual effort because of significant coding errors that occurred when trucks were classified by type. This happened as a result of confusion in interpreting the instructions for coding truck accidents on the UD-10. Numerous tractor-semitrailer combinations were coded as bobtails (tractors without trailers). Thus, a copy of the UD-10 for each truck-involved accident was manually reviewed. The type of truck was verified using codes entered by the investigating officer and the illustration and narrative describing the accident. The manual review also included coding the vehicle's state of registration, which is recorded on the UD-10 but not captured for the computerized data base. The review indicated that the involvement of singles had been underreported by approximately 20 percent, whereas involvement of single-unit (straight) trucks had been overreported by about the same amount.

During the 12-month study period, there were approximately 21,900 reported accidents that involved a truck larger than a pickup or panel truck. Of these, just over 10,000 involved bobtails, singles, or doubles [the rest involved single-unit trucks (straight trucks) for which no rates were calculated]. Some of the findings regarding truck accident frequencies in Michigan are summarized as follows. The frequencies indicate the magnitude of the truck accident problem relative to all traffic accidents. Findings based on accident rates, which identify configurations and operations with higher associated risks, are discussed later.

- Overall findings: About 5 percent of all accidents in Michigan involve a truck larger than a pickup or panel truck. These accidents are classified by type of truck involved in Table 2. Straight (single-unit) trucks (trucks with a cargo body mounted on the power unit chassis) are involved in about half of the truck accidents in Michigan. The other half are tractor configurations (bobtail, single, and double).

TABLE 2 DISTRIBUTION OF TRUCK AND ALL ACCIDENTS IN MICHIGAN FOR STUDY YEAR

truck type	accidents	percent
straight	10,993	2.7%
bobtail	458	0.1%
single	8,883	2.2%
double	678	0.2%
all trucks	21,827	5.3%
all accidents	408,066	100%

Source: Michigan State Police accident reports supplemented by manual review

- Types of accidents: Trucks are more likely than nontrucks to be involved in multiple-vehicle accidents—79 percent of truck-involved accidents involved two or more vehicles versus about 57 percent of non-truck-involved accidents. Single-vehicle truck accidents are less likely to occur at night (about 25 percent of all truck-involved accidents) than single-vehicle nontruck accidents (about 50 percent). Conversely, a higher percentage of truck-involved multivehicle accidents (46 percent) occurred during non-rush-hour daytime hours (9:00 a.m.–3:00 p.m.) than non-truck-involved multivehicle accidents (32 percent).
- Severity of accidents: Trucks appear to be overrepresented in both fatal and property-damage-only (PDO) accidents. Whereas the absolute number of fatal accidents involving trucks is low (a total of 179 in 1988 for all types of trucks), the proportion of accidents that result in fatalities is about twice as high for accidents involving trucks as it is for non-truck-involved accidents.
- Driver age: In general, drivers of doubles are older than singles drivers, who are in turn older than the drivers of straights. (This finding is based only on the ages of drivers who are involved in accidents.)
- Roadway type: In general, truck-involved accidents were more likely to occur on US- and state-numbered routes than on city streets and county roads.

A summary of accident involvements by Michigan-registered trucks in Michigan is given in Table 3 (top). The involvements are stratified by truck type, roadway type, time of day, and whether the accident occurred in an urban or rural area.

TRUCK TRAVEL IN MICHIGAN

To develop truck accident rates, accurate exposure data as well as accurate accident frequencies are needed. VMT was selected as the measure of travel for this study. Although MDOT collects vehicle count data at numerous counting stations, it is impossible to accurately disaggregate these data according to truck configuration, road type, area of operation, and time of day. To address this need, UMTRI initiated a program to collect travel information with enough detail to calculate the required accident rates, the Michigan Truck Trip Information Survey (*3*).

TABLE 3 TRAVEL AND ACCIDENT INVOLVEMENT DISTRIBUTIONS OF MICHIGAN-REGISTERED TRUCKS IN MICHIGAN

Accident Involvement in Michigan by Michigan-registered trucks						
	bobtail		single		double	
category	# involv	%	# involv	%	# involv	%
limited day rural	17	5.41	768	14.83	86	16.90
limited night rural	9	2.87	200	3.86	25	4.91
major day rural	41	13.06	971	18.75	112	22.00
major night rural	8	2.55	182	3.51	17	3.34
other day rural	69	21.97	948	18.30	86	16.90
other night rural	14	4.46	89	1.72	6	1.18
limited day urban	40	12.74	455	8.79	66	12.97
limited night urban	4	1.27	63	1.22	4	0.79
major day urban	36	11.46	445	8.59	41	8.06
major night urban	0	0.00	64	1.24	5	0.98
other day urban	65	20.70	926	17.88	53	10.41
other night urban	11	3.50	68	1.31	8	1.57
TOTALS	314	100.00	5179	100.00	509	100.00

Travel in Michigan by Michigan-registered trucks						
	bobtail		single		double	
category	10^6miles	%	10^6miles	%	10^6miles	%
limited day rural	2.096	20.26	204.434	26.79	23.163	25.90
limited night rural	0.237	2.29	41.949	5.50	9.473	10.59
major day rural	2.099	20.29	128.647	16.86	15.040	16.82
major night rural	0.067	0.65	17.642	2.31	2.401	2.68
other day rural	0.258	2.50	31.765	4.16	3.207	3.59
other night rural	0.058	0.56	1.289	0.17	0.224	0.25
limited day urban	2.627	25.39	177.251	23.23	21.163	23.67
limited night urban	0.372	3.59	29.884	3.92	3.474	3.88
major day urban	0.930	8.99	59.822	7.84	5.530	6.18
major night urban	0.068	0.66	6.839	0.90	0.460	0.51
other day urban	1.439	13.91	59.731	7.83	4.952	5.54
other night urban	0.093	0.90	3.775	0.49	0.341	0.38
TOTALS	10.346	100.00	763.029	100.00	89.427	100.00

The survey was conducted between May 1987 and April 1988, the same period covered by the accident file. The sampling universe consisted of truck tractors with an empty weight of more than 6,000 lb—virtually all medium and heavy-duty truck tractors in Michigan. The sampling frame included trucks registered under the International Registration Plan with Michigan as the base state. A stratified random sample of 1,556 cases was drawn from registration files maintained by the Michigan Department of State. Of the sampled cases, 301 were determined to be either expired registrations or not a truck according to the definition of the survey protocol. Of the remaining 1,255 cases, 1,055 were completed, for a completion rate of 84 percent.

With 1,055 cases, the sampling fraction is substantial. When allowances are made for expired registrations and nontrucks incorrectly registered as trucks, estimates from the survey data indicate that there were 34,577 truck tractors registered in Michigan. Almost 10,000 of the tractors were registered to gross over 80,000 lb.

The objective of the survey was to collect detailed information about the actual travel of Michigan-registered tractors on Michigan roads. The operators of each truck were contacted by telephone four times over the course of the study year for a detailed description of the activities of the truck during the 24 hr of a randomly sampled day. If the truck was not used on that day, the day of the truck's last use was substituted. [The procedure for calculating the weights when a year's travel is estimated is described elsewhere (*3*).] Information gathered about the truck's use included the total travel for the day, the number and type of trailers pulled, the actual route driven by the truck, and the time of operation as well as other data. The route for the day was plotted on a map, and the accumulated mileage was recorded for each combination of road type, time of day, and area type. Both vehicle description and route data were reviewed and edited by experienced personnel so that problems with vehicle descriptions or the routes traveled were identified and subsequently clarified through additional calls.

Interviews for 8,464 trips on 3,603 sample days were completed. (The number of trips is higher than the number of sample days because a new "trip" started whenever a truck's configuration, loading, or driver changed. This allowed the desired disaggregation of VMT by the study variables noted.) The truck tractors in the study traveled 470,017 mi on those days. The routes for 96.1 percent of those miles were described in sufficient detail to be broken down by road type, time of day, and area type. Additional technical detail on the procedure used for this study is provided elsewhere (*2,3*) as are other applications (e.g., *4*).

Findings concerning the travel patterns of Michigan-registered trucks in Michigan are summarized in the following and in Table 3.

Travel Characteristics

On the basis of the survey, it is estimated that Michigan-registered tractors traveled approximately 883 million mi within

the state during the study period—an average of approximately 25,500 mi annually in Michigan. Tractors with semitrailers (singles) account for more than 88 percent of the estimated total travel, doubles account for 10.4 percent, and bobtails just 1.2 percent.

Approximately half the total travel by singles is on limited-access highways during the day—which are split between rural (54 percent) and urban (46 percent) roads. Another 25 percent of the total travel by singles is on major highways during the day (68 percent rural and 32 percent urban). The highest percentage of night travel (by highway and area type) is on limited-access highways in rural areas (5.5 percent of the total travel). Overall, about 59 percent of the singles travel was on limited-access roadways.

The distribution of travel by doubles is similar to that of singles, with the principal exception that about 11 percent of total travel by doubles is on limited-access highways in rural areas at night. Overall, approximately 64 percent of the total travel by doubles was on limited-access highways—about 5 percent more than the comparable figure for singles. Conversely, doubles log about 3 percent less of their travel on local streets and roads than singles.

Classification of the travel of all tractors by approximate gross combination weight of the vehicle indicates that the 20,000- to 40,000-lb group (virtually all empty, or nearly empty, singles) accounts for about 39 percent of all travel, the 40,000- to 80,000-lb group accounts for about 43 percent, and about 14 percent of all travel is at weights in excess of 80,000 lb.

For singles, nearly 44 percent of travel is while empty or very lightly loaded. About 20 percent each is in the 40,000- to 60,000-lb and 60,000- to 80,000-lb ranges, and about 10 percent occurs at weights over 80,000 lb. For doubles, the distribution of travel by weight is somewhat different. Whereas about 43 percent of the travel is while empty, the percentages are lower (relative to singles) for intermediate weights, rising gradually to 26 percent in the 140,000- to 160,000-lb range. This indicates that doubles are more likely to run fully loaded in one direction and return empty—a typical pattern for the commodities (e.g., gravel) carried by very heavy trucks in Michigan.

Driver Characteristics

The distribution of truck drivers by age indicates that only 3.5 percent are 24 or younger, about 14 percent are 25 to 29, and 18 percent are 30 to 34. The percentages then drop gradually until 50 to 54, which accounts for 10.5 percent, and then more abruptly. Only 6 percent are 55 to 59, about 2 percent are 60 to 64, and less than 0.5 percent are over 64.

Only about 15 percent of the drivers definitely had driver training consisting of a combination of classroom and on-the-road training, whereas about 54 percent did not. It was not known whether the remaining 31 percent had any formal training. (The drivers themselves were not always interviewed, and this information was often unknown to the actual respondents.)

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

TRUCK ACCIDENT RATES IN MICHIGAN

The accident involvement and exposure data were combined to produce differential truck accident rates for various combinations of the stratifying variables described earlier (Table 1). Because the exposure survey covered only travel in Michigan by Michigan-registered tractors, only accident involvements of Michigan-registered tractors were used for the rate calculations. About 62 percent of the tractors involved in accidents in Michigan were registered in Michigan. The summaries of mileage and accident involvements are given in Table 3.

In addition to the rates based on all combinations of the stratifying variables and all accidents in Michigan by Michigan-registered tractors, rates were also calculated for (only) casualty accident involvements. The calculated rates for all police-reported, Michigan-registered tractor accident involvements, in their most disaggregate form, are given in Table 4. The rates are presented as accident involvements per million miles traveled and are shown with approximately 95 percent confidence intervals. The variance of the accident rates was calculated from the variances of the numerator (accidents) and denominator (travel) on the basis of the assumption that they are independent. Although the accidents are a census of all police-reported accidents during the study period, they were assumed to follow a Poisson distribution, and a variance assigned accordingly. Calculation of the variance of the travel estimates follows directly from the sample design, a stratified simple random sample. Ninety-five percent confidence intervals are approximated as plus and minus twice the standard error of the rate.

In comparing any two rates (e.g., Table 4), if the respective confidence intervals overlap, the rates are not significantly different. In general, the confidence intervals reflect the sample size and the observed variability in accidents and travel. Rates with large confidence intervals are usually based on relatively small samples of accidents or travel. Principal findings based on the accident rates are summarized as follows:

- In virtually all instances, bobtail accident involvement rates are far higher than those for singles and doubles, although the differences are not always statistically significant.
- Rates for doubles are generally somewhat lower than those for singles. This is the case regardless of whether all, one-vehicle, or multivehicle accidents are considered (the breakdown by number of vehicles involved is not shown in Table 4).
- Although there are just over 300 bobtail involvements, the highest rates tend to be at night, generally in rural areas, and, most clearly, on the lowest class of roadway.
- Singles involvement rates are always higher for lower classes of roadways—rates for major highways are typically 2 to 3 times higher than for limited-access highways; rates for other highways (local streets and roads) are typically 7 to 10 times higher than for limited-access highways.

TABLE 4 OVERALL TRUCK ACCIDENT RATES* (ALL INVOLVEMENTS) FOR MICHIGAN-REGISTERED TRUCKS ON MICHIGAN ROADS IN STUDY YEAR

urban/ rural	day/ night	road class	bobtails rates ± 2sd	singles rates ± 2sd	doubles rates ± 2sd
rural	day	limited	8.11 ± 5.02	3.76 ± 0.35	3.71 ± 1.09
		major	19.53 ± 10.38	7.55 ± 0.80	7.45 ± 2.38
		other	267.21 ±138.73	29.84 ± 4.15	26.81 ±11.20
rural	night	limited	38.00 ± 74.57	4.77 ± 0.86	2.64 ± 1.35
		major	118.69 ±153.57	10.32 ± 2.32	7.08 ± 4.96
		other	239.79 ±347.57	69.04 ±24.98	26.78 ±24.78
urban	day	limited	15.23 ± 6.37	2.57 ± 0.28	3.12 ± 0.94
		major	38.71 ± 16.66	7.44 ± 0.87	7.41 ± 2.98
		other	45.16 ± 14.19	15.50 ± 1.56	10.70 ± 4.15
urban	night	limited	10.76 ± 14.32	2.11 ± 0.58	1.15 ± 1.22
		major	---- ± ----	9.36 ± 2.89	10.88 ±10.82
		other	118.35 ± 93.08	18.01 ± 6.10	23.47 ±19.49
		OVERALL	30.35 ± 5.89	6.79 ± 0.22	5.69 ± 0.55

* rates are accidents per million vehicle-miles ± 2 std dev

- Singles involvement rates for rural, night conditions are, at worst, about twice as high as for daytime conditions. The difference between night and day is not as distinct for urban areas. However, urban rates are generally lower than rural rates regardless of roadway class.
- Although limited by sample size, doubles rates are lower than singles rates in most instances—the principal exception (from Table 4) is on urban, limited-access roads during the day.
- Further analysis indicated that doubles rates were higher than singles rates in some specific situations, such as one-vehicle involvements on rural limited-access highways during the day, multivehicle involvements on rural major roadways during the day, and urban limited-access roadways during the day. The higher one-vehicle accident rate is primarily due to rollover accidents, an accident type for which doubles are well known.

Rates considering only casualty accidents are given in Table 5. These results and those from related analysis (not shown here) can also be summarized (subject to the same caveats concerning confidence intervals and sample size as noted earlier).

- Although there is an even greater scarcity of bobtail data (relative to Table 4), bobtail rates are higher than those for either singles or doubles. The ratio of the rates is about the same as it was when all (casualty and noncasualty) accidents were considered.
- In contrast to the all-involvement rates, when only casualty accidents are examined, the overall doubles rate is higher than the singles rate. More specifically, it appears that doubles rates are higher than singles rates for day conditions in both rural and urban situations and regardless of roadway class.
- Also in contrast to Table 4, when only casualty accidents are considered, nighttime rates are generally higher than daytime rates. This finding is somewhat stronger in rural than urban areas.

Whereas the disaggregated casualty accident rates shown in Table 5 are of considerable interest, the sample sizes are small in many instances. However, the accident and travel

TABLE 5 OVERALL TRUCK CASUALTY ACCIDENT RATES* FOR MICHIGAN-REGISTERED TRUCKS ON MICHIGAN ROADS IN STUDY YEAR

urban/ rural	day/ night	road class	bobtails rates ± 2sd	singles rates ± 2sd	doubles rates ± 2sd
rural	day	limited	3.34 ± 2.83	0.92 ± 0.14	0.91 ± 0.44
		major	5.72 ± 4.12	1.87 ± 0.29	2.06 ± 0.91
		other	85.20 ± 53.44	6.30 ± 1.18	8.11 ± 4.30
rural	night	limited	8.44 ± 19.63	1.50 ± 0.41	1.16 ± 0.79
		major	---- ± ----	3.46 ± 1.06	2.08 ± 2.14
		other	119.89 ±185.22	17.07 ± 8.83	8.93 ±13.21
urban	day	limited	3.43 ± 2.47	0.60 ± 0.12	0.61 ± 0.36
		major	4.30 ± 4.46	1.54 ± 0.34	1.99 ± 1.30
		other	4.86 ± 3.79	1.98 ± 0.39	3.43 ± 1.91
urban	night	limited	---- ± ----	0.77 ± 0.33	0.29 ± 0.58
		major	---- ± ----	2.78 ± 1.37	---- ± ----
		other	43.04 ± 48.21	5.03 ± 2.60	17.60 ±16.29
		OVERALL	7.15 ± 2.01	1.51 ± 0.09	1.61 ± 0.28

* rates are accidents per million vehicle-miles ± 2 std dev

data can also be aggregated by the key variables to yield marginal rates, such as daytime rates for different truck types regardless of roadway class and urban-rural classification. The results of calculating such aggregated rates are discussed below in summary form. All rates are given in accidents per million vehicle miles.

The rates in Table 6 highlight the fundamental differences between the different types of trucks and the impact of including PDO accidents in the rate calculation. The bobtail rates are significantly higher than those for combination trucks for both casualty and all involvements. When PDOs are included, the singles rate is significantly higher than the doubles rate. When only casualty accidents are considered, the doubles rate is higher, but not significantly.

The aggregated urban and rural rates (regardless of roadway type and time of day) in Table 7 indicate that rural rates are generally higher than those for urban areas (regardless of truck type and whether PDOs are included). The bobtail rates are still far higher than combination truck rates for both urban and rural conditions. The rates for singles and doubles are similar. PDO accidents tend to "drive" the overall rates. Similarly, singles dominate when rates are aggregated across configuration. In general, the subgroups with large sample sizes dominate the overall rate.

The differences between day and night rates given in Table 8 are less clear than the other aggregated rates. When all accidents are considered, the night rates are lower than the day rates, except for bobtails. For combination trucks, there is more of a difference for doubles than for singles (i.e., the night doubles rate is much lower than the day rate). However, when only casualty accidents are considered, the night rates are higher for both bobtails and singles. The doubles rate is still lower at night than during the day. The "overall" rate shows that when only casualty accidents are considered, combination trucks tend to have higher night rates—this is, however, driven by bobtails and singles.

The aggregated rates by roadway type (Table 9) indicate a clear and consistent trend: the lower the road class, the higher the accident rate, regardless of truck type or whether all accidents or only casualty accidents are considered. The rates for singles and doubles are also similar, although there is some divergence between the two when the lowest road class is considered.

TABLE 6 RATES* BY TRUCK CONFIGURATION, ALL ACCIDENTS AND CASUALTY ACCIDENTS

truck type	all accidents	casualty accidents
bobtails	30.35 ± 5.89	7.15 ± 2.01
singles	6.79 ± 0.22	1.51 ± 0.09
doubles	5.69 ± 0.55	1.61 ± 0.28

* rates are expressed as accidents per million vehicle-miles ± 2sd

TABLE 9 RATES* BY TRUCK CONFIGURATION AND ROAD TYPE, ALL ACCIDENTS AND CASUALTY ACCIDENTS

	all accidents		
truck type	limited	major	other
bobtails	13.13 ± 4.40	26.86 ± 9.11	85.99 ± 18.04
singles	3.28 ± 0.18	7.80 ± 0.44	21.03 ± 1.14
doubles	3.16 ± 0.50	7.47 ± 1.26	17.54 ± 3.09
total	3.37 ± 0.16	8.02 ± 0.37	21.87 ± 0.90
	casualty accidents		
truck type	limited	major	other
bobtails	3.38 ± 1.78	5.06 ± 2.85	21.63 ± 7.46
singles	0.84 ± 0.09	1.94 ± 0.20	3.72 ± 0.41
doubles	0.80 ± 0.24	2.01 ± 0.60	5.85 ± 1.69
overall	0.86 ± 0.08	1.99 ± 0.18	4.20 ± 0.40

* rates are expressed as accidents per million vehicle-miles ± 2sd

TABLE 7 RATES* BY TRUCK CONFIGURATION AND URBAN OR RURAL AREA, ALL ACCIDENTS AND CASUALTY ACCIDENTS

	all accidents		casualty accidents	
truck type	urban	rural	urban	rural
bobtails	28.21 ± 6.16	32.81 ± 9.20	4.34 ± 1.89	10.38 ± 3.79
singles	5.99 ± 0.29	7.42 ± 0.31	1.12 ± 0.12	1.82 ± 0.14
doubles	4.93 ± 0.78	6.20 ± 0.77	1.34 ± 0.39	1.79 ± 0.38
overall	6.22 ± 0.26	7.54 ± 0.25	1.19 ± 0.11	1.90 ± 0.13

* rates are expressed as accidents per million vehicle-miles ± 2sd

TABLE 8 RATES* BY TRUCK CONFIGURATION AND TIME OF DAY, ALL ACCIDENTS AND CASUALTY ACCIDENTS

	all accidents		casualty accidents	
truck type	day	night	day	night
bobtails	28.36 ± 5.85	51.37 ± 30.55	6.45 ± 1.97	14.52 ± 11.00
singles	6.82 ± 0.23	6.57 ± 0.63	1.43 ± 0.10	2.04 ± 0.31
doubles	6.08 ± 0.64	3.97 ± 1.13	1.63 ± 0.31	1.53 ± 0.65
overall	7.02 ± 0.19	6.55 ± 0.47	1.51 ± 0.09	2.06 ± 0.26

* rates are expressed as accidents per million vehicle-miles ± 2sd

DISCUSSION OF PRINCIPAL FINDINGS

Discussion of the principal findings of this project is organized by truck type and then by the other variables that were isolated (e.g., roadway type).

Bobtails

The bobtail configuration clearly has the most serious problem safely negotiating the highway system. It had the highest rates for every road type, area type, time of day, or combination of those variables. This was true regardless of whether all accidents or only casualty accidents were considered (see Tables 4 and 5). Though the differences were not always statistically significant, the bobtail rates were always the highest. The only exceptions were for cells that had no accidents. Moreover, for the overall (marginal) rates, the increased risk of bobtails over singles and doubles is highly significant for both casualty and all accidents.

This finding is consistent with vehicle design considerations. The handling, braking, and other systems for tractors are all designed to pull single or double configurations. Without a trailer attached, the handling properties of the tractor are significantly degraded, which must account for at least some of the rate differential. Though some manufacturers have recently introduced "brake proportioning" valves to improve tractor braking when no trailer is being pulled and drivers may compensate when driving bobtails, these factors are apparently insufficient to produce accident rates similar to other tractor configurations.

Singles and Doubles

There is a growing literature that compares the safety of singles and doubles. Estimates of the relative safety of doubles range from somewhat lower rates than for singles to rates two to three times as great (*1*). The statistics presented here for Michigan, which are based on a census of police-reported accidents and a statistically valid survey of actual travel, indicate that the performance of singles and doubles is generally similar in terms of overall safety. For all accidents, the doubles rate is significantly lower than the singles rate (5.69 versus 6.79), but for casualty accidents the rates are virtually identical.

When the rates are disaggregated by road class, time of day, and area type, other differences are apparent. Considering all accidents, the rates for doubles are the same or lower for all road types. For "other" roads, the rate for doubles is 17.54 versus 21.03 for singles (this difference is not significant at the 95 percent confidence level). However, for casualty accidents, doubles have a statistically significant higher rate (5.85 versus 3.72) on these same roads. Doubles accidents on such roads are more likely to involve injury or death than singles accidents.

The same pattern holds for area type: doubles rates are lower in both rural and urban areas when all accidents are considered. However, when only casualty accidents are considered, the rates are about the same in rural areas, and doubles rates are slightly higher in urban areas. This is consistent with the typical usage patterns for doubles—they accumulate a higher proportion of their travel on inherently safer limited-access roads. On the other hand, an accident involving doubles is more likely to involve a casualty, which offsets some of the doubles' advantage due to road type.

Similarly, the overall accident rate for doubles is lower than for singles for both day and night conditions, although for casualty accidents, doubles do somewhat worse during the day and significantly better at night. This is consistent with doubles use at night being on limited-access roads.

Road Type

The most significant and consistent effect on accident rates appeared to be due to the type of road. Accident rates for all types of trucks were highest on "other" roadways (local streets and roads) and lowest on limited-access highways. This was true in every case, when controlling for other variables, and for both casualty and all accidents. The effect of road type is so large that it must be taken into account in any analysis of truck accident rates, or it may mask the effects of other variables.

Area Type and Time of Day

Accident rates were generally lower in urban areas than in rural areas, regardless of combination type. The effect is not as great as that of road type, but it is consistent across the other variables in the study. For all accidents, the day rate was higher than the rate for night. However, when only casualty accidents were considered, the night rate was 2.06 versus 1.51 for day, with the difference being statistically significant. The explanation for these differences is probably that PDO accidents occur primarily during the day and are a function of traffic density, which is higher during the day and in urban areas. Casualty accidents are more likely to be associated with fatigue, higher speeds, and shorter sight distances due to darkness, which would lead to higher rural night rates.

Driver Age

Accident rates for truck drivers in Michigan are strongly associated with driver age. Drivers under the age of 25 and over 60 had much higher accident rates than average—drivers aged 19 and 20 had rates 5 times higher than the average, and drivers over 60 had rates 1.5 times greater than average. This is consistent with previous work, which has indicated that younger drivers generally have higher rates for passenger cars and higher fatal rates in large trucks (*5,6*).

IMPLICATIONS FOR FUTURE WORK AND RECOMMENDATIONS

This work has attempted to advance both the quality and level of detail in the data on the study of truck safety. The accident data represented a census of 1 year of accidents involving Michigan-registered trucks operating in Michigan. The travel data similarly came from a survey of the actual travel of a representative sample of Michigan tractors. In both files a

level of detail was achieved that allowed the calculation of rates for groups determined by the cross-classification of several factors of interest. Rates can be examined not just by one or two factors at a time but by several (e.g., casualty accidents involving singles on limited-access roads in urban areas at night). This has allowed a significantly increased level of understanding of the complex interaction of the many factors associated with the risk of truck accidents.

It is clear that detailed accident and travel data are essential to useful safety analysis, but such data are not widely or readily available. For example, a recent report (*7*) indicated that there is no current national consensus on either the number of trucks involved in accidents or their annual travel. Moreover, whereas the quality of the data in the Michigan accident file is as good as any, extensive manual review of hard copies of the police reports was required to identify Michigan-registered trucks and to correct coding errors. Even then, no data were available on cargo body type, virtually none on loading, and only the most basic on truck configuration. Reliable Michigan travel data were simply unavailable from existing sources.

To answer detailed questions about truck safety, detailed data are required. The results here indicate that analyses must be able to control at least for road type, area of operation, and time of day. The TRB Committee on Truck Safety Data Needs has recommended important steps toward improving the quality of data available for truck traffic safety research. Moreover, implementation of the National Governors Association supplemental truck accident form would improve the amount of information available about vehicle configurations and hazardous cargo. Whereas the supplemental form contains many of the data elements used in this study, an urban/rural code is not included. Partially in response to the results of the study reported here, Michigan has implemented a supplemental truck accident report, which, in combination with the computerized accident file, provides considerable data for more thorough analysis.

The provision of better accident data is not, however, sufficient for the analysis that needs to be done. Exposure data are equally important but appear to command less attention despite the difficulty of collection. The TRB committee's recommendations on travel data would improve the situation, although it is not clear that even that is sufficient. Exposure data must be collected at the same level of detail as the accident data to calculate differential accident involvement rates and to allow examination of the interactions between variables of interest. Thus, a system of vehicle counts supplemented by descriptive information from random safety inspections may not produce adequate travel information. However, it produces timely and continuous data, which are crucial in an industry as dynamic as trucking.

Many important safety-related questions that could not be addressed during this study are logical extensions of this approach. The impact of carrier type, gross vehicle weight, and trailer cargo body are among the opportunities for further work. In an era of deregulation, differences in safety records of various categories of truck operators will be of increasing interest. The transport of hazardous cargo and pressure to increase the productivity of trucking by allowing heavier and longer combinations also raise important safety questions (*8*). Addressing them will require weight and length information as well as operating weight, cargo type, and cargo body.

One of the original objectives of this study was to explore the relationship between roadway geometry and truck type. As noted earlier, problems with data reduction limited the scope of the work. However, the study has clearly confirmed that restrictive geometry, as measured by road class, is a serious problem in truck safety. Examination of some truck accidents indicated that even the relatively low crash rates for limited-access highways may be overstated. A sizable number of one-vehicle accidents involving doubles resulted from overturns on ramps. These accidents were attributed to limited-access roads even though they occurred on the low-design-speed components of that system.

More work is required to identify the geometric characteristics specifically related to truck accidents. Not only the characteristics of the accident sequence and roadway but also truck loading and travel characteristics should be included. The accident risk on ramps, for example, is related not only to the interaction between truck type per se and ramp geometry, but also to the specifics of the trailer type, number of axles, cargo body style, and loading.

This sort of inquiry is of continuing importance as, for example, pressure is applied to allow triples in more states and other truck configurations are proposed. Whereas accurate prediction of the safety impact of new configurations or operating weights would be best (*8*), it is imperative that the data and analytical process be in place to allow accurate assessment of the effects of such policies. Some of the research techniques and methodologies to make such assessments have been demonstrated by this study.

ACKNOWLEDGMENT

More details on the study reported on here are contained in the final report on this project (*2*).

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