3. TRUCK ACCIDENT ANALYSIS

3.1 Truck Accident and Exposure Data

The Ontario Ministry of Transportation, formerly the Ministry of Transportation and Communications (MTC) compiles annually all motor vehicle accident statistics in Ontario from provincial and municipal police reports. In recent years, these reports have been standardized for all police forces in the province. Each report contains information on road and vehicle characteristics, driver attributes, traffic and weather conditions. An attempt is made by the investigating officer to establish the causes of each accident and the consequent damages, in terms of fatalities, injuries and property impacts (PDO). In some cases, information on the causes and consequences of accidents is supported by back-up reports, such as medical or mechanical reports on the accident.

The Ontario accident data base consists of 4377 large truck accidents for 1983. Large trucks are defined as vehicles with Gross Vehicle Weights in excess of 11000 kg., gross weight of towed vehicle not exceeding 4600 kg. and requiring Class A or O driver permit. Truck travel over the entire road network was estimated from provincial link-specific truck counts, adjusted by weighing station estimates from the 1983 Commercial Vehicle Survey for Ontario (Buyco and Saccomanno, 1987b). For the purpose of model calibration, the data base was modified to exclude observations occurring at intersections and ramps, observations for which load status was unknown and accidents which took place in the Northern Region of the Province (Note that data on intersections and ramps were used in applying the accident analysis to the dangerous goods corridor; this analysis is given in Chapter 5). Northern Ontario data were excluded from calibration since road and traffic conditions differed from Southern Ontario, resulting in lack of model transferability. The number of accidents in the Northern Ontario data base was too few to produce good statistical models of accident rates. The modified data base, used in this analysis, consists of 1955 large truck accidents taking place in Southern Ontario.

As in most other jurisdictions, Ontario has not collected origin-destination information for individual truck shipments on the provincial road network. Therefore, exposure measures must be obtained from indirect sources of truck flow data. In Ontario, three such sources are available: the Commercial Vehicle Survey, the Provincial Highway Traffic Volumes and the Provincial Highway Inventory.

a) Commercial Vehicle Survey

MTC periodically conducts roadside surveys of truck movements at representative locations on the network. From this information, trends in traffic composition are generated for planning and operational purposes. These surveys include information on vehicle and driver characteristics, nature of cargo in transport, and the origin and destination of each shipment.

In 1983, commercial shipments were monitored at 43 network weighing stations, 8 US border crossings and 3 interprovincial

crossings. Counts at each station were taken for a single 24 hour period, based on pre-selected vehicle sampling rates for each location. The Commercial Vehicle Survey (CVS) was carried out from April to August, during which time 13,213 trucks were sampled.

b) Provincial Highway Traffic Volumes

MTC extracts information annually from permanent counting stations on the road network to obtain estimates of the Average Annual Daily Traffic (AADT) on all links of the provincial road network. Seasonal volumes, directional split, distance and percentage trucks for all major sections of the highway network are also obtained. The provincial road network for this data base includes freeways, primary, secondary and tertiary highways.

c) Provincial Highway Inventory

Each section of the highway network is surveyed annually to obtain information on various physical characteristics, such as number of lanes, roadside environment, median width, average highway speed, maximum safe speed, etc.

d) Other Sources

Supplementary information on driver-related factors is available from Provincial Driver Licensing statistics. This includes information on the gender and age distribution of truck drivers in the province for each class of license.

3.2 Estimation of Exposure Adjustment Factors

The accident rate is a primary measure of safety which accounts for both the frequency of accidents and the exposure to accident-causing factors. Exposure can be measured in various ways, e.g., truck-km, tonne-km, or shipments. In this study, exposure is expressed on a truck vehicle-kilometer basis for a given combination of mitigating factors that contribute to truck accidents.

In most jurisdictions, the only consistent measures of truck flow (exposure) on the network are the Average Annual Daily Traffic (AADT) for general vehicle traffic and the percentage of trucks. This information is not adequate for this type of study, since a more detailed profile of contributing factors for truck accidents is required. In order to estimate these compatible measures of exposure for accident rates on various links of the road network, adjustments to the reported AADT and percentage truck values are obtained from the weighing scale information in the 1983 Commercial Vehicle Survey.

In this study, four types of factors are considered important in explaining truck accident causation: road, vehicle, driver, and environmental-traffic characteristics. Depending on the nature of these mitigating factors, three procedures have been used for estimating compatible measures of exposure for accident rates and will be described in the following sections.

a) Road Characteristics

For these mitigating factors, information on truck volumes on each link of the network is used directly. Each link is classified into categories of road characteristics influencing accidents. The AADT and percentage trucks are obtained from Provincial Highway Traffic Volume data for 1983.

b) Vehicle, Driver and Environmental-Traffic Characteristics

The Commercial Vehicle Survey is used to derive adjustment factors for the known truck AADT's on each link of the network. In this procedure, all links and weighing stations are classified into a similar set of categories, based on road characteristics. The nature of the categories depends on available information in the survey, and on factors that are expected to affect truck accident rates.

Adjustment factors are used to reflect the nature of the vehicle distribution on the network for a given set of characteristics. For example, expressways in rural areas are expected to have a greater proportion of tractor-trailer combinations than urban highways, and these differences would be reflected in the CVS's proportion of tractor-trailer combinations for the two types of roads.

c) Situational Factors in the Accident Profile

A number of causal factors for truck accidents are situational in nature because they depend on the characteristics of each individual shipment. Since situational factors are unique for each shipment, average measures of exposure are not readily available for the aggregate traffic stream.

Although accident rates cannot be estimated for situational factors, it is possible to estimate the degree to which these truck accidents are over or under-represented relative to other vehicle accidents in the data base. For example, a delay in the application of brakes may occur more frequently in truck accidents than in accidents involving other vehicles. For each situational factor, an involvement ratio is defined for truck accident frequencies relative to other vehicle accident occurrences. If this ratio is greater than one, truck accidents are considered to be over-represented for a specified set of circumstances. Since the frequency of occurrence of these circumstances is expected to be the same for both vehicle types, differences in the value of this ratio may be due to the corresponding situational risks for large trucks.

3.3 Factors Affecting Truck Accident Rates

After examining the variables contained in the accident and exposure data bases, 22 variables were selected for analysis. These variables are given in Table 3.1. The statistical analysis performed depends on the availability of a compatible exposure measure. For variables with quantifiable accident rates, a chi-square statistical analysis was performed. For situational factors, the involvement ratios were estimated. The results for the four types of mitigating factors, road, vehicle, driver, and environmental, are discussed in the following sections.

TABLE 3.1

SELECTED VARIABLES FOR PRELIMINARY TRUCK ANALYSIS

CLASS	VARIABLE
ROAD CHARACTERISTICS	Road Type
	Roadside Environment
	Number of Lanes
	Traffic Volume
	Truck Percentage
	Terrain
VEHICLE CHARACTERISTICS	Truck Type
	Vehicle Load
	Model Year
	Vehicle Condition
	Vehicle Manoeuver
DRIVER CHARACTERISTICS	Driver Sex
	Driver Age
	Driver Action
	Driver Condition
ENVIRONMENT	Time
	-Hour-of-the-day
	-Day-of-the-Week
	-Month
	Visibility
	-Light Condition
	-Weather-Related
	Road Surface Condition
	Traffic Pattern

a) Road Characteristics

Truck accident rates and frequencies for various road characteristics are summarized in Table 3.2. Note that the accident rates are for one factor comparisons only.

Roads are classified as freeway and non-freeway, depending on the service they provide and their traffic characteristics. Non-freeways include primary, secondary and tertiary roads. While freeways accounted for only 7% of the Ontario network in 1983, this class of road accommodated 57% of all truck travel. Freeways experienced a lower accident rate than non-freeways. This is likely due to the higher design standards and reduced traffic conflicts associated with controlled access to these types of facilities. Other studies have arrived at a similar conclusion regarding freeway safety (Carsten, 1987; Radwan, 1976).

Several recent surveys (Uffen, 1983; National Roads and Motorists Association, 1986) have indicated that other road users perceive that a higher proportion of trucks in the traffic stream increases the overall accident rate. However, the accident rates in Table 3.2 are observed to be lower for higher percentages of trucks on the road. This is due to the interaction between trucks and road type, where most trucks are found on freeways with lower average truck accident rates.

The provincial highway inventory classifies the road network into four types of terrain: flat, rolling, rocky, and unknown. Results indicated that flat terrain has lower accident rates. This is not unexpected given the difficulties associated with large trucks negotiating steep gradients (Safwat and Walton, 1986). The high truck rate for rocky terrain may be due to low truck exposure values. Only 0.03% of all truck travel in the province is associated with rocky terrain.

Traffic volume is expressed as the average number of vehicles per day. In Ontario, values of the traffic volume ranged from a low of 100 AADT to a high value of 240,000 AADT, with the low volume roads experiencing the higher truck accident rates.

b) Vehicle Characteristics

Tables 3.3 and 3.4 summarize truck accident rates and frequencies for various environmental and situational vehicle characteristics, respectively. Five types of vehicle characteristics are considered in the analysis: truck type, vehicle load, model year, condition of the vehicle, and accident-related vehicle manoeuver. Two of these are situational variables (condition of vehicle, vehicle manoeuvre), for which information on truck exposure is unavailable. Information on truck type and body style is available from both general traffic and accident data bases. Again, only single factor interactions are considered.

Five truck types are considered: truck, truck and trailer, tractor, tractor and trailer (singles), and tractor and two trailers (doubles). These categories were taken from the truck survey. Table 3.3 indicates that trucks and tractors have higher

TABLE 3.2

ACCIDENT RATES FOR ROAD CHARACTERISITCS

VARIABLE	CATEGORY	NO. OF ACCIDENTS	TRUCK EXPOSURE (million truck-km)	ACCIDENT RATE per million truck-km	EXPECTED NO. OF ACCIDENTS	CHI-SQ VALUE
ROAD TYPE						
	FREEWAY	2072	2678.87	0.773	2501	73.70
	PRIMARY	2194	1905.89	1.151	1780	96.50
	SECONDARY	94	95.13	0.988	89	0.30
	TERTIARY	17	7.73	2.198	7	13.24
	TOTAL *	4377	4687.62	0.934		183.74
ROADSIDE ENVIRONMENT						
	RURAL	4229	4589.60	0.921	4286	0.75
	SEMI-URBAN	63	32.69	1.927	31	34.56
	URBAN	85	65.13	1.305	61	9.61
	UNKNOWN	0	0.20			
	TOTAL *	4377	4687.42	0.934		44.93
NUMBER OF LANES						
	1-2	1847	1681.56	1.098	1570	48.79
	3-4	1448	1882.91	0.769	1758	54.74
	5-6	622	742.18	0.838	693	7.28
	7-8	47	43.31	1.085	40	1.06
	9-10	109	74.15	1.470	69	22.83
	OVER 10	304	263.28	1.155	246	13.75
	UNKNOWN		0.22			
	TOTAL *	4377	4687.40	0.934		148.46
TERRAIN						
	FLAT	3460	3782.67	0.915	3533	1.52
	ROLLING	909	897.69	1.013	838	5.93
	ROCKY	4	1.43	2.799	1	5.32
	UNKNOWN	4	5.83			
	TOTAL *	4373	4681.79	0.934		12.77
TRUCK PERCENTAGE						
	10 OR LESS	1111	920.02	1.208	859	73.89
	10-15	1548	1419.91	1.090	1326	37.23
	15-20	802	889.64	0.901	831	0.99
	OVER 20	916	1458.05	0.628	1361	145.74
	TOTAL *	4377	4687.63	0.934		257.85
TRAFFIC VOLUME						
	0-2000	517	491.52	1.052	459	7.34
	2001-15000	1901	2078.19	0.915	1940	0.80
	OVER 15000	1959	2117.91	0.925	1978	0.17
	TOTAL *	4377	4687.62	0.934		8.32

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** SIGNIFICANT DIFFERENCES
DATA IS FOR ONTARIO - 1983

TABLE 3.3

ACCIDENT RATES FOR VEHICLE CHARACTERISTICS

VARIABLE/ CATEGORY	NO. OF ACCIDENTS	PERCENT SURVEY %	EXPOSURE million truck-km	ACCIDENT RATE per million truck-km	EXP. NO. OF TRUCK ACCIDENTS	CHI-SQ VALUE
TRUCK TYPE						
TRUCK	981	9.9%	461.73	2.125	431	701.031
TRACTOR	39	0.5%	25.31	1.541	24	9.981
TRUCK & TRAILER	67	4.0%	188.91	0.355	176	67.864
TRACTOR & TRAILER	3076	79.8%	3742.13	0.822	3495	50.158
TRACTOR & 2-TRAILER	191	5.2%	244.23	0.782	228	6.027
UNKNOWN	23	0.5%	23.44			
TOTAL *	4354	99.5%	4662.31	0.934	4354	835.061
VEHICLE LOAD						
EMPTY	1454	21.4%	1005.03	1.447	814	502.167
LOADED	2251	76.1%	3566.81	0.631	2891	141.496
UNKNOWN	672	2.5%	117.52			
TOTAL *	3705	100.0%	4571.84	0.810	3705	643.663
MODEL YEAR						
83	146	2.9%	135.94	1.074	142	0.093
82	322	10.0%	468.76	0.687	491	58.105
81	539	13.3%	623.45	0.865	653	19.864
80	611	13.0%	609.39	1.003	638	1.156
79	770	15.4%	721.89	1.067	756	0.260
78	456	9.3%	435.95	1.046	457	0.001
77	329	6.9%	323.45	1.017	339	0.279
76	220	3.7%	173.44	1.268	182	8.106
75	221	3.8%	178.13	1.241	187	6.367
74	260	3.6%	168.75	1.541	177	39.246
73	164	2.5%	117.19	1.399	123	13.884
72	103	1.3%	60.94	1.690	64	24.060
71	36	0.6%	28.13	1.280	29	1.455
<71	133	1.5%	70.31	1.892	74	47.864
UNKNOWN	67	12.2%	571.89			
TOTAL *	4310	87.8%	4115.73	1.047	4310	220.741

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** NOT SIGNIFICANT
DATA IS FOR ONTARIO - 1983

TABLE 3.4

INVOLVEMENT RATIOS FOR VEHICLE CHARACTERISTICS
(SITUATIONAL VARIABLES)

VARIABLE CATEGORY	TRUCK ACCIDENTS	ALL VEHICLE ACCIDENTS**	EXP. NO. OF TRUCK ACCIDENTS	INVOLVEMENT RATIO
CONDITION				
NO DEFECT	3745	305000	4162	0.900
BRAKE DEFECT	100	1287	18	5.695
STEER DEFECT	17	344	5	3.622
TIRE PUNC/BLOW	80	920	13	6.373
POOR TIRE TREA	17	808	11	1.542
HEADLAMP DEF	2	175	2	0.838
OTHER LIGHT DEF	21	440	6	3.498
ENGINE CONT DEF	16	565	8	2.075
WHEEL/SUSP DEF	60	362	5	12.148
VISION OBSCURED	1	176	2	0.416
TRAIL HITCH DEF	33	142	2	17.032
OTHER	169	2072	28	5.978
UNKNOWN	116	19150		
TOTAL *	4261	312291	4261	
MANOEUVER				
GOING AHEAD	3062	184935	2484	1.233
SLOW/STOP	263	21041	283	0.931
OVERTAKING	184	5676	76	2.414
TURNING LEFT	189	34878	468	0.403
TURNING RIGHT	83	10907	146	0.567
U-TURN	14	1138	15	0.916
CHANGING LANES	232	10572	142	1.634
MERGING	29	1018	14	2.121
REVERSING	58	8427	113	0.512
STOP/PARKED	213	42680	573	0.372
PULL AWAY CURB	11	2298	31	0.356
PULL INTO CURB	15	562	8	1.987
UNKNOWN/OTHER	24	7309		
TOTAL *	4353	324132	4353	

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** FROM MOTOR VEHICLE ACCIDENT FACTS FOR ONTARIO 1983
DATA IS FROM ONTARIO - 1983

accident rates than the combination vehicles. These findings may appear contradictory to the perception that larger trucks are more accident prone than other vehicles. Recent truck accident studies, however, support this conclusion (Polus and Mahalel, 1985; Chirachavala and Cleveland, 1986).

While five categories of load utilization are reported in the Commercial Vehicle Survey for 1983, the accident reports only indicate whether the vehicle is loaded or empty. Accident rates for empty trucks are considerably higher than for loaded trucks for all truck types except tractor - two trailer combinations. Two factors may be contributing to higher accident rates for "empties": 1) the load acts as a stabilizer under certain operating conditions, and 2) loaded vehicles are able to generate higher friction forces resulting in reduced stopping distances (Navin, 1986).

Model year indicates the age of the vehicle and may be used to reflect the situational variable "vehicle condition". Results shown in Table 3.3 indicate that accident rates for trucks increase with age, especially for trucks over 6 years old. A higher accident rate for new trucks is observed; this may be due to the driver's lack of familiarity with the vehicle. One and two year old trucks have the lowest accident rates.

An attempt was made to consider a subjective assessment of the vehicle condition from the police reports using an accident involvement ratio. The accident frequencies for trucks were compared with general vehicle accidents for various conditions, as shown in Table 3.4. For example, trucks with mechanical defects are over-represented in the accident distribution, relative to general vehicles (12.1% for trucks compared with 2.3% for general vehicles). The four most common types of vehicle defects associated with truck accidents are: brake failure (2.3%), tire puncture/blowout (1.8%), wheel/suspension defect (1.4%), and trailer hitch defect (0.8%).

Most truck accidents in 1983 occurred while the vehicle was moving ahead in a straight direction (70%). Given the exposure on the road network, this is not unexpected. Special manoeuvres, such as overtaking, changing lanes, merging, and pulling off the road are generally over-represented in truck accidents.

c) Driver Characteristics

Driver age, gender, and actions were analyzed to determine the effect of driver-related factors on truck accident rates. The results are summarized in Tables 3.5 and 3.6.

Hamelin (1987) showed that driver age is an important factor in truck accident occurrence. This analysis of Ontario truck accident data indicates that accident rates decrease proportionately with the driver age. In particular, drivers less than 35 years old have higher accident rates than other truck drivers.

The "driver action" variable in Table 3.5 indicates the action taken by the driver at the time of the accident. In most cases, this action is the most significant cause of the accident. Driver action is a situational factor, hence accident occurrence for trucks is compared to the general accident situation for all

TABLE 3.5

ACCIDENT RATES FOR DRIVER CHARACTERISTICS

VARIABLE/ CATEGORY	NO. OF ACCIDENTS	LICENSED DRIVERS**	EXPOSURE million truck-km	ACCIDENT RATE per million truck-km	EXP. NO. OF TRUCK ACCIDENTS	CHI-SQ VALUE
DRIVER SEX						
MALE	4216	290661	4622.527	0.912	4159	0.77
FEMALE	2	4093	65.093	0.031	59	54.64
UNKNOWN	159					
TOTAL *	4218	294754	4687.620	0.900		55.41
DRIVER AGE						
<21	100	2968	47.202	2.119	43	77.42
21-24	449	18391	292.481	1.535	264	129.89
25-34	1461	91712	1458.542	1.002	1316	16.01
35-44	1158	81135	1290.330	0.897	1164	0.03
45-54	754	60797	966.885	0.780	872	16.04
55-64	283	32518	517.150	0.547	467	72.21
>64	24	7233	115.030	0.209	104	61.33
UNKNOWN	148					
TOTAL *	4229	294754	4687.620	0.902	4229	372.94

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** FROM ONTARIO'S DRIVER LICENSING STATISTICS
DATA IS FOR ONTARIO - 1983

TABLE 3.6

INVOLVEMENT RATIOS FOR DRIVER CHARACTERISTICS
(SITUATIONAL VARIABLES)

VARIABLE/ CATEGORY	TRUCK ACCIDENTS	ALL VEHICLE ACCIDENTS **	EXP. NO. OF TRUCK ACCIDENTS	INVOLVEMENT RATIO
DRIVER ACTION				
NO APP. ACTION	78			
DRIVE PROPER	2389	132064	1952	1.224
FOLLOW CLOSELY	216	15829	234	0.923
SPEED FAST	546	26036	385	1.419
IMP. TURN	101	12165	180	0.562
DISOBEY SIGNAL	68	6044	89	0.761
DISOBEY STOP	11	3647	54	0.204
FAIL YLD ROW	116	33604	497	0.234
IMP. PASS	211	4696	69	3.040
LOST CONTROL	216	22861	338	0.639
WRONG 1-WAY	7	317	5	1.494
DISOBEY CONTROL	4	148	2	1.828
OTHER	262	23140	342	0.766
UNKNOWN	152	28704		
TOTAL *	4147	280551	4147	
DRIVER CONDITION				
PARKED VEHICLE	78			
NORMAL	4021	259265	3772	1.066
BEEN DRINKING	46	15491	225	0.204
IMP. ALCOHOL	35	8472	123	0.284
IMP. DRUG	1	211	3	0.326
FATIGUE	44	1107	16	2.732
MED/PHYS DEF.	4	609	9	0.451
OTHER	2	289	4	0.476
UNKNOWN	146	23811		
TOTAL *	4153	285444	4153	

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** FROM MOTOR VEHICLE ACCIDENT FACTS FOR ONTARIO 1983
Data is for Ontario - 1983

vehicles in the data base. Table 3.5 indicates that improper action was not an issue in 58% of the truck accidents, compared to a value of 47% for general vehicle accidents. For trucks, a number of improper actions were noted as being especially problematic, such as speeding, improper passing, and disobeying specific directions.

The "driver condition" variable in Table 3.5 applies to the condition of the driver at the time of the accident. The truck driver was normal in 97% of the accident occurrences, compared to 91% for general vehicle accidents. Though fatigue is over-represented in truck accidents, it accounted for only 1% of all truck accidents in 1983. The importance of driver fatigue as a cause of accidents has been suggested in several studies (Hamelin, 1987; Uffen, 1983; and Stocker, 1987).

d) Environmental Characteristics

Variables that represent weather conditions, traffic conditions and time of occurrence are classified as environmental-related characteristics. With the exception of time, exposure measures are unavailable for these types of factors. Time-related variables can act as non-situational surrogates for traffic and weather condition, even though they may not reflect any direct contribution to accident occurrences. Three variables in this classification with known exposure are: hour of day, day of the week, and traffic pattern. The results of an analysis of environmental-traffic factor effects are summarized in Tables 3.7 and 3.8 for non-situational and situational factors, respectively.

The 1983 CVS reported that hourly variation is different at each weighing station. However, for most locations on the road network, truck traffic is heaviest between 9:00 and 15:00. In the analysis, the period from 18:00 to 6:00 showed a higher rate of accidents.

MTC classified the road network according to the observed traffic pattern. The traffic pattern is expressed in terms of low, intermediate, and high variation roads. Low variation roads are characterized by low seasonal variation, similar weekday-weekend traffic distribution, and a peaking of traffic at morning and evening rush-hours. These roads are essentially commuter-oriented. High variation roads are used mainly for tourist and recreational travel, and reflect significant differences in traffic on a seasonal basis. The weekday and weekend traffic are markedly different and the hourly distribution is relatively uniform. Intermediate variation roads combine the commuter characteristics of the low variation roads and the relatively uniform hourly distribution of the high variation roads. Table 3.7 indicates that intermediate variation roads have the lowest accident rates.

Since the truck survey was conducted only during the summer months of 1983, the monthly truck travel cannot be generated. However, seasonality of shipments was noted in the survey. About 6.6% of the drivers indicated that the trip was seasonal. For about the same percentage, the drivers did not know or were not sure about the seasonal aspect of the trip. General vehicle seasonal variation ranges from +/- 0.20 to +/- 0.40, depending on the type of traffic. This indicates that truck travel does not

TABLE 3.7

ACCIDENT RATES FOR ENVIROMENTAL CHARACTERISTICS

VARIABLE/ CATEGORY	NO. OF ACCIDENTS	PERCENT SURVEY	EXPOSURE million truck-km	ACCIDENT RATE per million truck-km	EXP. NO. OF TRUCK ACCIDENTS	CHI-SQ VALUE
TIME - HOUR ENDING						
0100	135	2.2%	103.13	1.309	96	15.56
0200	103	2.0%	93.75	1.099	88	2.73
0300	118	1.9%	89.06	1.325	83	14.59
0400	111	1.6%	75.00	1.480	70	23.97
0500	104	1.8%	84.38	1.233	79	8.07
0600	123	2.6%	121.88	1.009	114	0.74
0700	164	4.7%	220.32	0.744	206	8.46
0800	238	5.2%	243.76	0.976	228	0.47
0900	262	6.0%	281.26	0.932	263	0.00
1000	220	6.7%	314.07	0.700	293	18.30
1100	269	6.2%	290.63	0.926	271	0.02
1200	220	6.5%	304.70	0.722	285	14.63
1300	237	6.2%	290.63	0.815	271	4.35
1400	260	6.4%	300.01	0.867	280	1.45
1500	291	6.3%	295.32	0.985	276	0.84
1600	302	5.2%	243.76	1.239	228	24.32
1700	259	6.0%	281.26	0.921	263	0.05
1800	231	5.1%	239.07	0.966	223	0.27
1900	141	4.0%	187.50	0.752	175	6.63
2000	133	3.1%	145.32	0.915	136	0.05
2100	112	3.0%	140.63	0.796	131	2.84
2200	116	2.6%	121.88	0.952	114	0.04
2300	118	2.4%	112.50	1.049	105	1.60
2400	110	2.3%	107.82	1.020	101	0.86
TOTAL *	4377	100.0%	4687.62	0.934		150.86
TIME - DAY						
SUNDAY	158	0.3%	11.72	13.482	11	1976.32
MONDAY	713	12.7%	595.80	1.197	556	44.13
TUESDAY	770	19.9%	932.37	0.826	871	11.62
WEDNESDAY	845	33.1%	1553.01	0.544	1450	252.50
THURSDAY	811	17.8%	832.05	0.975	777	1.50
FRIDAY	806	15.5%	727.05	1.109	679	23.81
SATURDAY	274	0.8%	35.63	7.691	33	1742.16
TOTAL *	4377	100.0%	4687.62	0.934		4052.03
TRAFFIC PATTERN						
LOW	1788		1648.16	1.085	1539	40.30
INTERMEDIATE	2102		2604.80	0.807	2432	44.83
HIGH	487		434.65	1.120	406	16.23
TOTAL *	4377		4687.61	0.934		101.36

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** NOT SIGNIFICANT
DATA IS FOR ONTARIO - 1983

TABLE 3.8

INVOLVEMENT RATIOS FOR ENVIRONMENTAL CHARACTERISTICS
(SITUATIONAL VARIABLES)

VARIABLE CATEGORY	TRUCK ACCIDENTS	ALL VEHICLE ACCIDENTS **	EXP. NO. OF TRUCK ACCIDENTS	INVOLVEMENT RATIO
TIME - MONTH				
JANUARY	293	14943	359	0.815
FEBRUARY	295	12189	293	1.006
MARCH	320	13298	320	1.001
APRIL	227	11790	284	0.801
MAY	300	14528	349	0.859
JUNE	371	14981	360	1.030
JULY	346	14375	346	1.001
AUGUST	348	14406	346	1.004
SEPTEMBER	377	14575	351	1.076
OCTOBER	348	16287	392	0.888
NOVEMBER	487	18789	452	1.078
DECEMBER	665	21838	525	1.266
TOTAL *	4377	181999	4377	
VISIBILITY - LIGHT				
DAYLIGHT	2762	113306	2725	1.014
DAWN	84	2287	55	1.527
DUSK	79	6422	154	0.512
DARK	1452	59984	1443	1.007
TOTAL *	4377	181999	4377	
VISIBILITY - WEATHER				
CLEAR	2922	134547	3236	0.903
RAIN	609	28167	677	0.899
SNOW/SLEET	722	16741	403	1.793
FOG, MIST, ETC.	124	2544	61	2.027
TOTAL *	4377	181999	4377	
ROAD SURFACE CONDITION				
DRY	2475	105792	2544	0.973
WET	905	46181	1111	0.815
LOOSE SNOW	229	7207	173	1.321
SLUSH	197	5162	124	1.587
PACKED SNOW	140	5350	129	1.088
ICE	422	11010	265	1.594
MUD	4	121	3	1.375
LOOSE SAND/GRAVEL	5	1176	28	0.177
TOTAL *	4377	181999	4377	

NOTE: * NOT INCLUDING UNKNOWN CATEGORY
** FROM MOTOR VEHICLE ACCIDENT FACTS FOR ONTARIO 1983
Data is for Ontario - 1983

vary considerably from season to season.

The truck accident distribution indicates a significant increase in the number of accidents during November and December (Figure 3.1); 27.3% of all truck accidents in 1983 occurred during these months. Since truck travel did not vary appreciably from month to month, it must be concluded that November and December represented a period of higher accident rates for trucks. A possible explanation for the December accident peak may be due to a higher consumption of alcohol in Ontario during these months. Figure 3.2 indicates the distribution of alcohol-related accidents for all vehicles peaks in December. However, a cross-tabulation between month and truck driver condition in the 1983 accident data base proved inconclusive. Another explanation for the higher accident rates for November and December may be due to the advent of winter driving conditions in Ontario and the lack of driver preparedness. For example, the first major snowfall of the season in Ontario is characterized by an unusually large number of accidents.

Restricted visibility has been identified as an important factor in accident occurrence (Uffen, 1983; Saccomanno and Chan, 1985). Visibility was represented in the accident data base for two types of restriction: light condition and weather-related. Light condition was classified in terms of daylight, dawn, dusk and dark. Weather-related visibility was classified as: clear, rain, snow/sleet and fog/smoke/mist conditions.

While exposure measures can be estimated for light conditions based on seasonal and daily travel distributions, light condition variables in this analysis were considered to be situational. Table 3.7 indicates that there are differences between truck and general vehicle accidents for dawn and dusk categories. In Ontario, there were more accidents at dusk involving general vehicles (3.53%) than trucks (1.80%). The number of truck accidents was about the same at dawn and dusk, while for general vehicles, accidents at dusk were three times more frequent than at dawn. The involvement ratios for daylight and dark categories were the same.

Daily variation in accident rates in the 1983 Ontario data base reflected traffic exposure. About 63.7% of truck travel took place between the hours of 8:00 and 18:00. The daily distribution of truck accidents reflected the general distribution of truck shipments in Ontario.

Weather-related visibility problems were overrepresented in the 1983 accident data (Table 3.8). This can be attributed to the absence of seasonal variability in truck travel compared to general vehicles. General vehicles' use is discretionary in nature and hence, may be less frequent during adverse weather conditions.

The snow/sleet category of restricted weather visibility suggested that road surface condition has a significant effect on truck accident occurrence. In the accident data base, road surface conditions included the following categories: dry, wet, loose snow, slush, packed snow, ice, mud, and loose sand and gravel. The involvement ratios indicated an under-representation of truck accidents on dry road surfaces relative to general vehicles, and an over-representation of accidents on snow-related

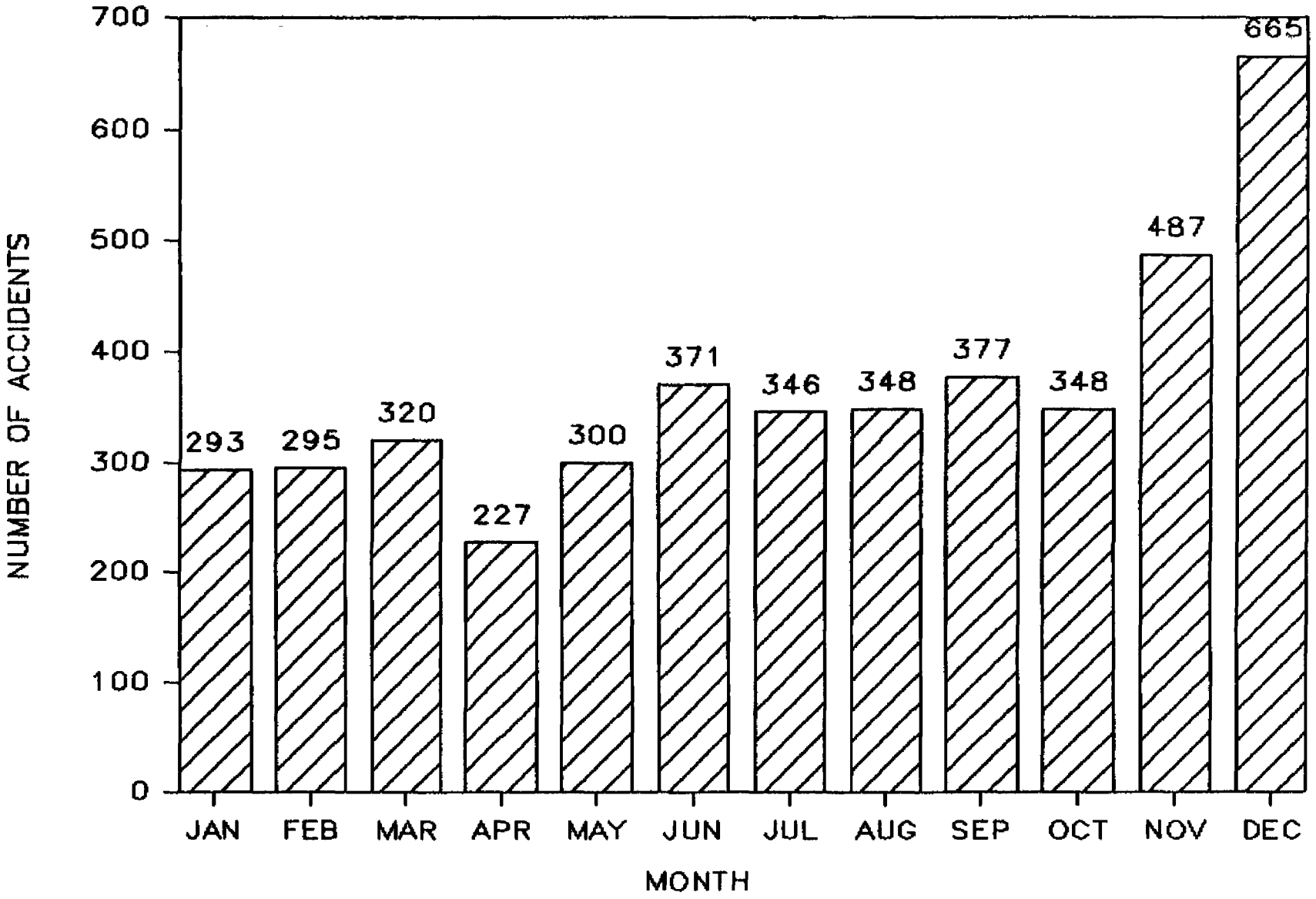
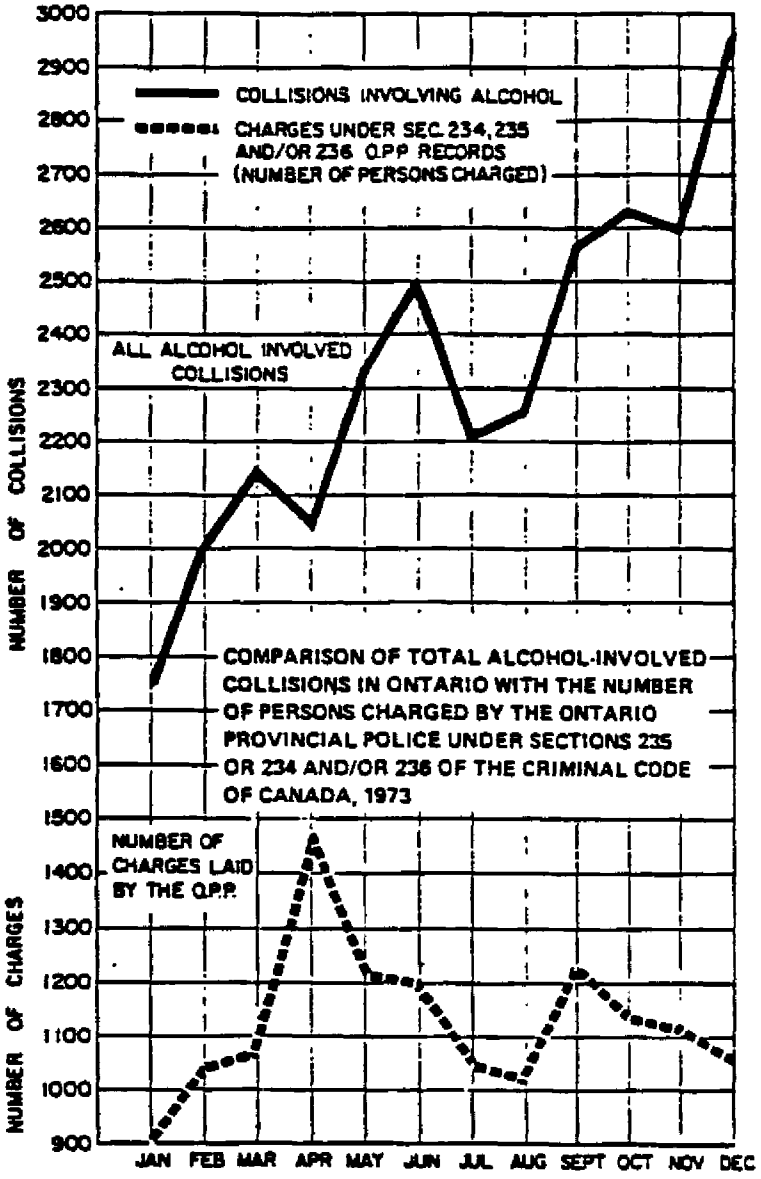


Figure 3.1

1983 ONTARIO TRUCK ACCIDENTS

BY MONTH



SOURCE: COMPUTER SEARCH OF THE ONTARIO MINISTRY OF TRANSPORTATION AND COMMUNICATIONS COLLISION FILE. ROUTINE MONTHLY REPORT PREPARED FOR STATISTICS CANADA BY THE CENTRAL RECORDS AND COMMUNICATIONS BRANCH OF THE ONTARIO PROVINCIAL POLICE ENTITLED "TRAFFIC ENFORCEMENT STATISTICS"

Figure 3.2 ALCOHOL-RELATED ACCIDENTS FOR ALL VEHICLES

road surfaces.

3.4 Accident Severity

The consequences of motor vehicle accidents in the 1983 police reports were classified into three types of damages: fatalities, personal injuries, and property damage only (PDO) accidents. Figure 3.3 indicates that, in 1983, truck accidents in Ontario resulted in a higher number of fatalities than was experienced in general vehicle accidents. Two percent of all truck accidents reflected one or more fatalities, compared with 0.4% for other general vehicle accidents. These results support the perception that truck accidents cause more damage (Uffen, 1983; National Roads and Motorists Association, 1986; Carsten, 1987). On the other hand, injury and PDO accidents did not indicate any significant differences based on vehicle type. In Ontario, however, police reports do not provide information on the nature of any injury or property damage, or on the resultant monetary loss. While the number of injuries for general vehicles is higher than for trucks, the extent of personal injury and property damages for truck accidents could actually be higher.

The distribution of truck fatality, injury and PDO rates does not vary significantly with road type. Figure 3.4 indicates that freeways generally reflect lower damages than primary or secondary roadways in Ontario. This appears to be surprising, given the higher speeds on freeways, but may be associated with the correspondingly higher truck volumes on this class of road. Higher truck volumes in the accident rate expression increases the denominator for a constant number of accidents in the numerator. Table 3.9 indicates that, even accounting for differences in exposure by road type, the actual number of truck involvements for fatalities, personal injuries and PDO's continues to be higher on primary highways. Very likely the lower severity rates on freeways may reflect better design standards and wider right-of-ways associated with these types of roads.

3.5 Loglinear Calibration of Truck Accident Rates Using GLIM

Recent attempts to calibrate reliable statistical models of truck accident rates have been hampered by two basic concerns:

1) incompatibility between continuous exposure information and categorical accident data, and

2) the absence in most jurisdictions of comprehensive information on truck exposure.

Incompatibilities in variable inputs restricts the methodology for analyzing truck accident rates to procedures that can incorporate both categorical and continuous information directly into the analysis. The absence of suitable exposure information has restricted the classification of accident environment to basic conditions where travel information is available. Frequently, the presence of second and third order interactions among environmental factors and their marginal contribution to truck accidents has been ignored, since information on truck flows for these interactive conditions is unavailable. A Generalized Linear Interactive Model (GLIM) form of loglinear

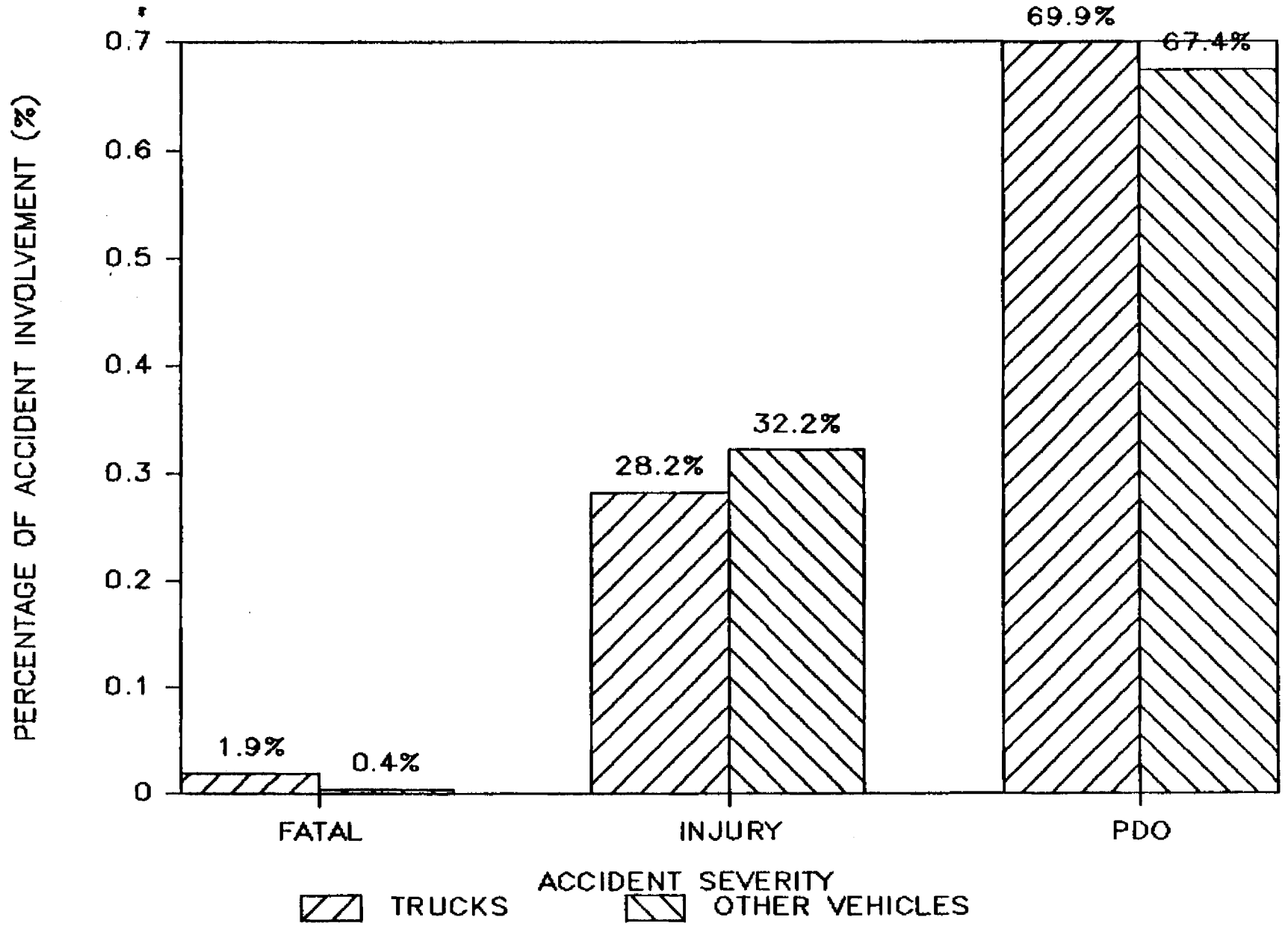


Figure 3.3

COMPARISON OF ACCIDENT SEVERITY

TRUCKS VS. OTHER VEHICLES

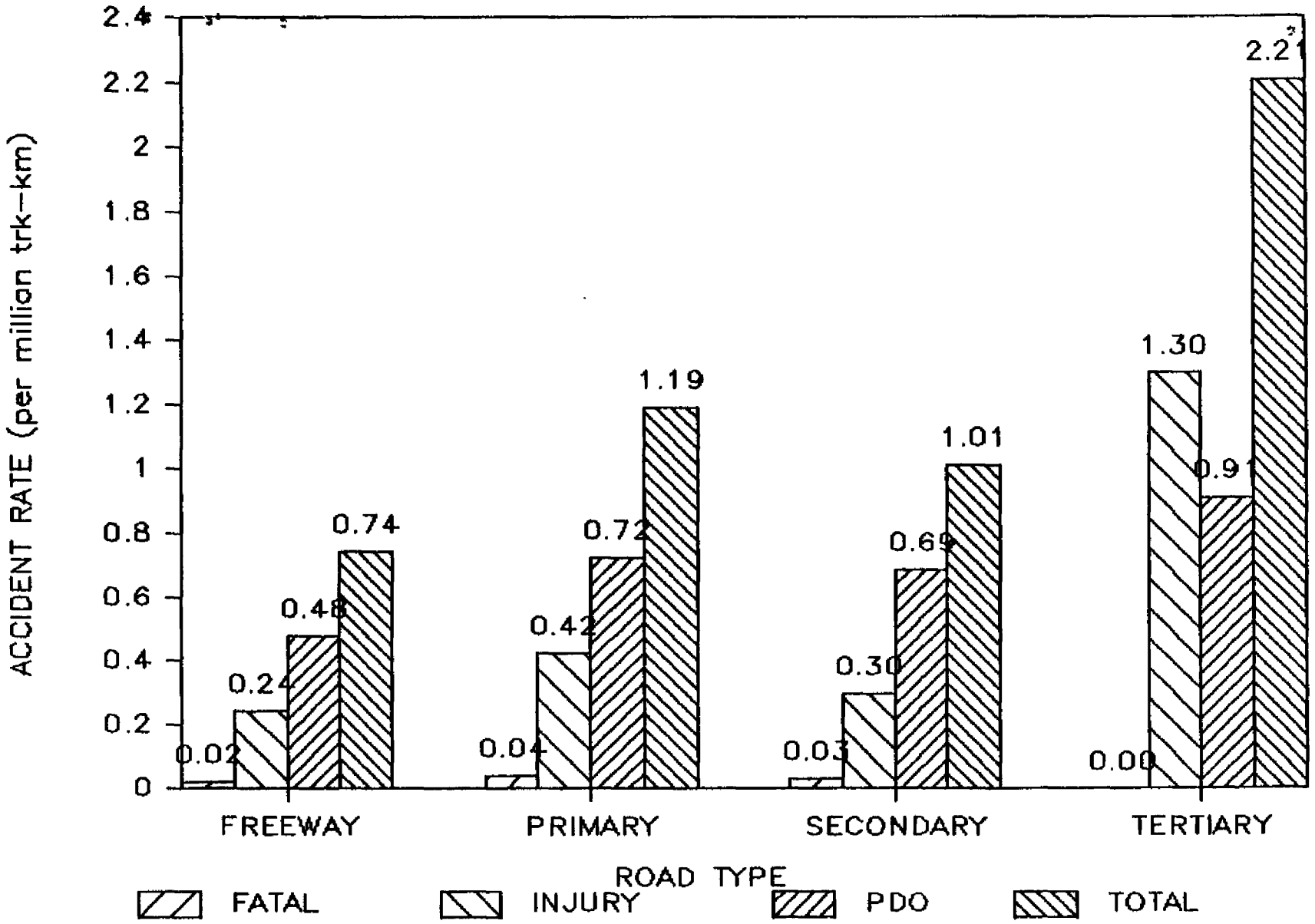


Figure 3.4

1983 ONTARIO TRUCK ACCIDENT RATES

ROAD TYPE BY SEVERITY

TABLE 3.9

NUMBER OF TRUCK ACCIDENTS
ROAD TYPE BY SEVERITY

ROAD TYPE	NUMBER OF ACCIDENTS				
	FATAL	INJURY	PDO	OTHER	TOTAL
FREEWAY	59	648	1284	4	1995
PRIMARY	76	807	1380	6	2269
SECONDARY	3	28	65	0	96
TERTIARY	0	10	7	0	17
TOTAL	138	1493	2736	10	4377

Data is for Ontario - 1983

expression is used, that incorporates both categorical accident involvement data and continuous exposure measures. This approach allows for a step-wise statistical analysis of higher order interaction effects for truck accidents, while adjusting for the continuous exposure factor.

Multivariate techniques, such as n-level analysis of variance, were applied to the Southern Ontario truck accident data base (consisting of 1955 observations for 1983) to produce a contingency table of 8 categorical factors affecting truck accident involvement (Table 3.10). This approach serves as an initial screening of candidate factors for calibrating loglinear expressions of truck accident causation. The contingency table of categorical factors consists of 960 cells, of which 132 cells are considered to be structurally empty (no observed exposure).

Model calibration of accident rates using the GLIM procedure involves fitting two separate loglinear expressions; the accident frequency expression is used to test the acceptability of the accident rate loglinear expression.

3.6 Results of Loglinear Calibration

Table 3.11 summarizes the hierarchical steps in fitting an expression as in Eq. 2.4 (Model A) to the data. Using Model A as a basis, terms were added and deleted in a step-wise analysis of individual factor interactions. The results were compared with the corresponding loglinear expression for accident frequency with the exposure term as a covariate (Eq. 2.6 or Model B). The "best fit" expression is obtained for step 3a, where the third order term RAM is added. This expression indicates that the addition of the term RAM is statistically significant at the 5% level. The model itself is not statistically different from the saturated expression. The format using exposure as a covariate (Model B) indicates that the term b for step 3a is not significant. From this analysis, the "best fit" truck accident rate expression using exposure as an offset is:

$$\begin{aligned}\log AR = {} & 1 + R + P + A + T + L + M + N + D \\ & + RA + RP + PA + RT + PT + PL + TL \\ & + RM + AM + TM + RN + PN + AN + TN \\ & + LN + MN + TD + RAM\end{aligned} \qquad [3.1]$$

where AR = expected accident rate and
R = road type
T = truck type
A = Average Annual Daily Traffic
N = time of day
D = driver age
P = traffic pattern
L = load status
M = model year.

The Lambda parameters in the above loglinear expression, which are summarized in Table 3.12, reflect the degree of association for different levels of interaction among the categorical factors influencing truck accident rates.

Table 3.13 summarizes other second order accident rate

TABLE 3.10

VARIABLES IDENTIFIED FOR
TRUCK LOGLINEAR CALIBRATION

VARIABLES	SYMBOL	CATEGORY DESCRIPTION
ROAD TYPE	R	(1) Freeway (2) Non-Freeway
TRAFFIC PATTERN	P	(1) Commuter (2) Non-commuter
TRAFFIC VOLUME	A	(1) Low (2) High
TRUCK TYPE	T	(1) Truck (2) Truck & Trailer (3) Tractor (4) Tractor & Trailer (5) Tractor & 2 Trailers
LOAD STATUS	L	(1) Empty (2) Loaded
MODEL YEAR	M	(1) Post-77 (2) Pre-77
HOUR OF DAY	N	(1) 18:00 - 6:00 (2) 6:00 - 18:00
DRIVER AGE	D	(1) <25 (2) 25-54 (3) >54

TABLE 3.11

STEP-WISE MODEL SELECTION

MODEL	NO. OF TERMS 2nd	3rd	TOTAL	MODEL A SCALE DEV	DIFF	DOF	DIFF DOF	CRIT (5% LOS)	CONCLU-SION	MODEL B SCALE DEV	DOF	LOGEXP	T-TEST
1. R+P+A+T+L+M+N+D	0	0	9	1144.4		815		882.5	S.				
2. (R+P+A+T+L+M+N+D)	28	0	37	663.2		757		821.8	M.				
.(R+P+A+T+L+M+N+D)					481.2		58	76.8	S.				
(Add 2nd Level Int.)													
3. MODEL 2 -D-int-M.(A+P+L)	15	0	24	686.5		779		844.8	M.	654.1	778	0.758	S.
-A.(R+T+L)-R.L+T.D+D													
(del D-int.,M.(P,A,L),					-23.3		-22	33.9	M.				
A.(R,T,L),R.L)													
4. MODEL 3 -T.D	14	0	23	713.9		787		853.1	M.				
(del T.D)					-27.4		-8	15.5	S.				
1A. MODEL 3 + R.A + A.M	17	0	26	681.3		777		842.7	M.	551.5	776	-0.003	M.
(add R.A, A.M)					5.2		2	6	M.				
2A. MODEL 1A - R.A	16	0	25	681.5		778		843.7	M.	651.5	777	0.765	S.
(del R.A)					-0.2		-1	3.8	M.				
3A. MODEL 1A + R.A.M. **	17	1	27	669.1		776		841.6	M.	541.2	775	-0.022	M.
(add R.A.M)					12.2		1	3.8	S.				
4A. MODEL 1A + P*T*L	18	1	28	642.1		775		840.6	M.	620.6	774	0.796	S.
(add P*T*L)					39.2		2	6	S.				
5A. MODEL 1A + R.P.A	17	1	27	675		776		841.6	M.	537.7	775	-0.06	M.
(add R.P.A)					6.3		1	3.8	S.				
6A. MODEL 1A +P*T*L+R.P.A	17	3	29	622.6		772		837.5	M.	517.9	771	-0.003	M.
+R.A.M													
(add P*T*L,R.A.M,R.P.A)					58.7		5	9.5	S.				

Note: Total number of terms includes main effects.
Refer to Table 3.10 for variable symbols.
** Model 3A is selected as the "best" model.

LEGEND
- R Road Type
- P Traffic Pattern
- A Traffic Volume
- T Truck Type
- L Load Status
- M Model Year
- N Hour of Day
- D Driver Age

TABLE 3.12

PARAMETER ESTIMATES OF
TRUCK ACCIDENT RATE MODEL

PARAMETER SYMBOL	LEVEL	PARAMETER ESTIMATE	STD. ERROR	PARAMETER SYMBOL	LEVEL	PARAMETER ESTIMATE	STD. ERROR
MEAN		-7.0390	0.2817				
R	2	-0.2130	0.2364	RM	22	1.0580	0.2105
P	2	0.6735	0.2278	AM	22	0.6930	0.1904
A	2	0.3838	0.1892	TM	22	-0.1569	0.4424
T	2	-2.4860	0.8023	TM	32	0.1504	0.4895
T	3	-0.9406	0.9072	TM	42	-0.9007	0.1278
T	4	-0.1221	0.2285	TM	52	-1.2790	0.3646
T	5	-1.4350	0.6422	RN	22	-0.4838	0.1463
L	2	-1.2110	0.1471	PN	22	-0.7740	0.1103
M	2	0.1495	0.2229	AN	22	0.3604	0.1342
N	2	0.6900	0.2144	TN	22	0.2150	0.5417
D	2	-0.8897	0.1440	TN	32	0.0041	0.5442
D	3	-0.9849	0.2033	TN	42	-0.4285	0.1572
RP	22	-0.4081	0.1901	TN	52	-1.5730	0.3059
RA	22	0.3783	0.2044	LN	22	0.4029	0.1053
PA	22	-0.5136	0.1763	MN	22	0.3176	0.1199
RT	22	1.0890	0.4591	TD	22	-0.0553	0.5724
RT	23	0.7122	0.6374	TD	23	-0.3286	0.8784
RT	24	0.6179	0.1299	TD	32	0.4436	0.7688
RT	25	1.1830	0.3111	TD	33	0.3637	1.0190
PT	22	0.1360	0.4378	TD	42	0.7311	0.1704
PT	23	0.3350	0.5669	TD	43	0.1083	0.2420
PT	24	-0.2899	0.1257	TD	52	0.9828	0.4868
PT	25	-0.6251	0.2864	TD	53	-0.1468	0.7551
PL	22	0.4044	0.0983	RAM	222	-0.9901	0.2898
TL	22	0.4993	0.4658				
TL	32	0.0000	aliased				
TL	42	0.2734	0.1214				
TL	52	2.6410	0.4485				

MODEL: SEE EQ. 3.1.

LEGEND
- R Road Type
- P Traffic Pattern
- A Traffic Volume
- T Truck Type
- L Load Status
- M Model Year
- N Hour of Day
- D Driver Age

TABLE 3.13

TRUCK ACCIDENT RATES
(TRUCK TYPE VS. OTHER VARIABLES)

VARIABLE/ CATEGORIES	TRUCK TYPE				
	TRUCK	TRUCK & TRAILER	TRACTOR	TRACTOR & TRAILER	TRACTOR & 2-TRAILERS
	(Accident rates are per million truck kilometers)				
ROAD TYPE					
-FREEWAY	0.88	0.07	0.34	0.78	0.21
-NON-FREEWAY	0.71	0.18	0.56	1.16	0.55
TRAFFIC PATTERN					
-COMMUTER	0.88	0.07	0.34	0.78	0.21
-NON-COMMUTER	1.71	0.16	0.94	1.14	0.22
LOAD STATUS					
-EMPTY	0.88	0.07	0.34	0.78	0.21
-LOADED	0.26	0.04	0.10	0.30	0.87
MODEL YEAR					
-POST-77	0.88	0.07	0.34	0.78	0.21
-PRE-77	1.02	0.07	0.46	0.36	0.07
HOUR OF DAY					
-18:00 to 6:00	0.88	0.07	0.34	1.78	0.21
-6:00 to 18:00	1.75	0.18	0.68	1.01	0.09
DRIVER AGE					
-<25 years	0.88	0.07	0.34	1.78	0.21
-25-54 years	0.36	0.03	0.22	0.66	0.23
->54 years	0.33	0.04	0.18	0.32	0.07

interactions for different truck types. Truck and trailer combinations consistently reflect the lowest accident rates among the five truck types for all conditions. A comparison between combination vehicles indicates that single trailer trucks have higher accident rates than doubles for most factors. Loaded doubles have accident rates that are 2.85 times higher than loaded singles.

Lambda estimates for the second order interaction between truck type and load status indicate that empty vehicles have higher accident rates (about 2.0 to 3.4 times) for all truck types except doubles. Loaded doubles have accident rates on average 4.0 times higher than empties of the same type.

Considering the second order interaction between truck type and road type, single unit trucks not travelling on expressways reflect average accident rates that are in general 23% lower than for the same type of vehicle travelling on expressways. This differs from other truck types where expressway travel generally reflects a safer situation.

Truck type and traffic pattern interaction indicate consistently higher accident rates for non-commuter roads for all truck types. Double combination vehicles are the exception with no difference in accident rates between commuter and non-commuter traffic conditions.

The age of the vehicle has more impact on the combination vehicles in accident causation than other vehicle types. Older vehicles register higher accident rates for singles (2 times) and doubles (3 times). The differences for other truck types were not significant. The age limit for vehicles in the accident rate expression appears to be six years, and may be related to resale of trucks to smaller carriers, where safety may be compromised by other financial considerations.

Truck type with hour of day interaction indicates that 6:00 a.m. to 6:00 p.m. has a higher accident rate than other hours for all truck types except for doubles. Hours between 6:00 p.m. to 6:00 a.m. increases accident rates for doubles by a factor of 2.4.

Considering different driver age groups, the highest accident rates are associated with drivers less than 25 years old consistently for all truck types except double combination units. Truck drivers who are older than 54 years appear to have the best safety record for all types of trucks.

Table 3.14 summarizes the second order interaction of road type with other mitigating factors. Road type and truck type interaction indicates lower risks associated with freeway travel. However, road type and interactions with traffic pattern and hour of day indicate lower truck accident rates for non-freeways.

Commuter roads reflect lower accident rates than non-commuter for both road types (freeway and non-freeway highway). The sensitivity of accident rates to traffic pattern is lower for non-freeways than freeways. The ratio of accident rates between commuter and non-commuter roads is 1.91 times for freeways compared to 1.30 times for non-freeways.

TABLE 3.14

TRUCK ACCIDENT RATES
(ROAD TYPE VS. OTHER VARIABLES)

VARIABLE/ CATEGORIES	ROAD TYPE FREEWAY	NON-FREEWAY
(Accident rates are per million truck km)		
TRAFFIC PATTERN		
-COMMUTER	0.88	0.71
-NON-COMMUTER	1.71	0.92
TRUCK TYPE		
-TRUCK	0.88	0.71
-TRUCK&TRA	0.07	0.18
-TRACTOR	0.34	0.56
-TRACTOR&TRA	0.78	1.16
-TRACTOR&2TRA	0.21	0.55
HOUR OF DAY		
-18:00 to 6:00	0.88	0.71
-6:00 to 18:00	1.75	0.87

The effect of hour of operation on road type with respect to truck accident rates is similar to traffic pattern; hours between 6:00 and 18:00 indicate higher accident rates.

Second order interaction of traffic pattern with other variables are presented in Table 3.15. In general, commuter roads reflect lower accident rates than non-commuter roads.

A third order interaction term that includes road type, road volume and model year is significant in the selected loglinear expression (Eq. 3.1). Table 3.16 shows that freeways reflect lower accident rates across all road volume and model year combinations. The highest accident rates are associated with non-freeway, high volume roads and trucks more than 6 years old; while the lowest rates reflect non-freeway, low volume roads and newer trucks. In general, newer trucks (less than 6 years old) register lower accident rates than older vehicles. Low volume roads likewise have lower rates than high volume roads.

TABLE 3.15

TRUCK ACCIDENT RATES
(TRAFFIC PATTERN VS. OTHER VARIABLES)

VARIABLE/ CATEGORIES	TRAFFIC PATTERN COMMUTER	NON-COMMUTER
(Accident rates are per million truck km)		
ROAD TYPE		
-FREEWAY	0.88	1.71
-NON-FREEWAY	0.71	0.92
TRAFFIC VOLUME		
-LOW	0.88	1.71
-HIGH	1.28	1.50
TRUCK TYPE		
-TRUCK	0.88	1.71
-TRUCK&TRA	0.07	0.16
-TRACTOR	0.34	0.94
-TRACTOR&TRA	0.78	1.14
-TRACTOR&2TRA	0.21	0.22
LOAD STATUS		
-EMPTY	0.88	1.71
-LOADED	0.26	0.77
HOUR OF DAY		
-18:00 to 6:00	0.88	1.71
-6:00 to 18:00	1.75	1.58

TABLE 3.16

TRUCK ACCIDENT RATES
(THIRD ORDER INTERACTIONS)

VARIABLES/ CATEGORIES	ROAD TYPE FREEWAY	NON-FREEWAY
(Accident rates are per million truck km)		
TRAFFIC PATTERN		
-COMMUTER		
MODEL YEAR		
-POST-77	0.88	0.71
-PRE-77	1.02	2.36
-NON-COMMUTER		
MODEL YEAR		
-POST-77	1.28	1.52
-PRE-77	3.00	3.78