Analysis of the Economic Impact of Medical and Optometric Driving Standards on Costs Incurred by Trucking Firms and on the Social Costs of Traffic Accidents

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Working Paper 98-06
March 1998

ISSN : 1206-3304

This research was supported in part by the ministère des Transports du Québec (M.T.Q.), the Fonds pour la formation des chercheurs et l'aide à la recherche (F.C.A.R.) and the Société de l'assurance automobile du Québec (SAAQ). The team would like to extend its thanks to several persons and companies which agreed to collaborate in this research: Transports Provost Inc., Cabano-Kingsway Inc., and a general insurance company. We are also grateful for the collaboration of the following persons: Bertrand Bordeleau, Guy Croteau, François Gagnon, Josée Genois, Anne Gibbens, Jean-François Guilloteau, Pierre Joly, Pierre Lafontaine, André McMahon, Robert Ouimet, Joseph-Arthur Servant, Alain Turcotte and Charles Vanasse.

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Version du 20 mai 1998

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by

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* This research was funded by the *ministère des Transports du* Québec (M.T.Q.), the *Fonds pour la Formation de chercheurs et l'aide à la recherche* (FCAR) and the *Société de l'assurance automobile du Québec* (S.A.A.Q.).

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Abstract

Recent studies do not agree on the possible relationships between medical conditions and traffic safety; most of them do not control for exposure factors. In this study, we estimate the effect of different medical conditions (namely diabetes, high blood pressure, coronary disease, and visual impairment) on the distribution of accidents of truck drivers. Our data and our model permit the simultaneous control for age, medical conditions and other characteristics of the truck drivers; exposure factors measured by hours, kilometers, and qualitative factors; and of the circumstances surrounding accidents described in police reports. The results show that truck drivers not in class 1 (79% are class 3) with diabetes have more accidents than the drivers in good health. No other medical condition studied has a significant effect on individual accident rates. Many risk exposure variables are significant. We have also estimated the parameters of the severity distribution. Our data limited the regression analysis of the severity in terms of the number of victims injured or killed. The results indicate that drivers with a visual impairment (binocular vision impairment) have more serious accidents than those in good health. Our cost estimations show that the expected average cost of drivers with diabetes is twice as high as the expected average cost of drivers in good health. The cost differences are less significant for the drivers with a visual impairment. The conclusion summarizes the main results.

Keywords: Medical condition, traffic safety, truck drivers, accidents, exposure factors, age, private accident costs, human capital costs, willingness to pay.

Introduction

The main goal of this research is to measure the effect of certain medical and optometric standards on traffic safety, on the private costs of trucking firms, and on the total or social costs incurred. More specifically, we want to check whether existing standards are linked to the significant factors used in calculating the rates of trucking accidents[1] (frequency and severity). In other words, do truck drivers with diabetes mellitus, coronary disease, visual impairment, or high blood pressure have a significantly higher accident rate and more serious accidents than drivers who are officially in good health. We also want to check what impact these potentially higher levels of the frequency and severity of accidents may have on the reimbursements made by private insurance companies and on the net costs for trucking firms. The social or total costs for society are also included in our research protocol. The data from the study have made it possible to establish statistical links between truckers' risk exposure and their accident rates. The results of this research are relevant to traffic safety regulations, because trucking accidents generate important externalities for society.

In conducting this research, we had access to a unique data bank. This data bank composed of 20,208 license holders which was created by the team of Laberge-Nadeau/Hamet. The information contained in the data bank came mainly from the computerized files of the public automobile insurer for bodily injuries in Quebec (SAAQ) and from a telephone survey conducted by a polling firm on risk exposure among licensed drivers. A private insurance company and two trucking firms also helped with the study by giving us access to information on the costs of traffic accidents within and outside of Quebec.

Part 1 presents the issue under study; the data bank used to estimate the frequency and severity of accidents; the methodology used in the study; and the statistical and econometric findings. Special attention has been given to risk exposure in order to account for the fact that drivers who are in good health can drive longer and further than those in poorer health. Qualitative measures of risk exposure have also been considered. These results on the frequency and severity of accidents had to be obtained in order to make rigorous calculations of variations in the accident costs associated with medical and optometric driving standards.

Part 2 calculates variations in the costs associated with current standards. More specifically, we show how a diabetic condition or visual impairment will increase the expected accident costs over a given period. The private and social costs of accidents are analyzed in detail. Finally, the study concludes with a summary of the main findings. Further developments of the study are also proposed.

1 In the text the terms trucking accidents and accidents with a truck are equivalent.

I. Analysis of factors explaining the frequency and severity of accidents

1. Motivation

Regulations for driving highway (or other) vehicles are generally justified by the externalities that certain drivers may generate for society. For example, a drunk driver generates higher accident risks for other drivers, cyclists, and pedestrians (see Boyer and Dionne, 1987 for further details). The same seems to hold true for persons with certain physical handicaps or certain chronic disorders (see Laberge-Nadeau *et al*., 1989, 1991 reports and Dionne *et al*., 1994 for a more in-depth discussion). Indeed, according to a large number of regulations, these persons represent implicitly higher accident risks. The underlying hypothesis is that their illness or handicap is an impediment to safe driving.

The findings of this research are important as they justify the validity of certain standards which several persons might find arbitrary and even unfair. They touch directly on certain principles and orientations of the new policy on trucking which state that trucking firms are responsible for their safety practices and that competitive pressures must not weaken the rules of traffic safety.

Results of an American study have shown that motorists with either epilepsy or diabetes have accident rates that are slightly higher than those of a control group. However, the conclusion of the study indicated that these differences are not large enough to warrant the introduction of new restrictions on driving rights (Hansotia and Broste, 1991). This conclusion was challenged by members of the Laberge-Nadeau/Hamet team for several methodological reasons (Ekoé *et al., 1991).* The most serious reason was linked to the lack of control for drivers' risk exposure. In comparing accident rates, Hansotia and Broste did not take into account the fact that drivers in the different groups could have different risk exposures.

Risk exposure must be considered when the research involves the comparison of groups of drivers to which regulations on medical conditions do or do not apply. One may reasonably suppose that drivers with one of the disorders studied (e.g. visual impairment or diabetes) will travel fewer kilometers annually due to a greater number of sick days or to the refusal to drive as far as other drivers in unfavorable conditions (e.g. at night) or to different driving assignments by their employers. The method used in this paper makes it possible to control for individual differences in risk exposure.

It should also be added that the concept of risk exposure covers a more complex reality than simply measuring the number of kilometers traveled. A review of the documentation dealing with exposure to the risk of traffic accidents (Joly *et al.,* 1991) has revealed that several researchers working in the field of traffic safety stress the importance of taking into account additional measures such as the type of traffic traveled or the fact that the driving is done during the day or at night. These observations led researchers in the Laberge-Nadeau/Hamet team to draw up a questionnaire on risk exposure which is capable of obtaining several quantitative measurements (e.g. kilometers driven, number of hours behind the wheel) and qualitative measurements (e.g. type of traffic, night or day driving). The questionnaire also ascertains whether a subject, selected because he has a class 1 or 3 license, actually does have a job driving a truck[2]. This by itself is already an important exposure data not captured by studies of the records of drivers classified on the basis of their class of driving license.

Other risk factors must also be taken into consideration: socio-economic factors such as age; job characteristics such as size of work sector, type of truck driven (with or without trailer), and type of road most often traveled on the job. This sort of information is to be found in the data bank made available to the project and the econometric method presented in section 3 is capable of taking this information into account.

[2] See Table 3.2.1 for the definition of the license classes.

2. Objectives

The main goal of this research is to measure the effect of certain medical and optometric conditions on traffic safety. More specifically, we want to check whether existing standards are linked to the significant factors used in calculating the rate and severity of traffic accidents experienced by trucking firms. In other words, do truck drivers with diabetes mellitus, coronary disease, binocular visual impairments, or high blood pressure have a significantly higher accident rate than drivers who are officially in good health? Are their traffic accidents more serious in terms of the number of victims injured or killed? In other words, do these drivers generate higher average private and social costs of accidents than healthy ones?

The data from the study will also establish a statistical link between truckers' risk exposure and their accident rates. Trucking accidents cause proportionally more deaths than accidents involving only automobiles (R.A.A.Q., 1988). Several trucking firms are now involved in the transportation of hazardous materials which can mean environmental pollution after an accident, unless spills are cleaned up immediately. Cleaning up spills has an impact on a trucking firm's operating costs; with deregulation of the industry, this impact will expand. All factors explaining trucking accidents need to be well understood, and traffic safety regulations governing their activities must be based on scientific arguments.

3. Methodology

3.1 Data Used

The research team had access to a unique data bank containing 20,208 license holders. The information comes mainly from the computerized files of the SAAQ and a telephone survey on risk exposure conducted by a polling firm among these licensees.

The S.A.A.Q. data are drawn from five files:

1. The DRIVING LICENSE file identifies holders of driving licenses in the province of Quebec.

2. The MEDICAL file of the Department of Medical Evaluation shows the state of health of license holders responding to the standards. Every licensed driver is obliged to declare any disease(s) or disability (ties) from which he suffers. Moreover, in order to check a license holder's state of health, the regulations require medical examinations by a general practitioner or a specialist (often an ophtalmologist) with a signed form to be returned to the Department of Medical Evaluation. This department can in certain cases demand a more thorough medical examination by designated specialists. The frequency of these official medical checks depends on the driver's age and class of license. At the time of this study, they occurred

   - at the first application for a class 1 or 2 license and when the license holder, at the time of renewal, when the licensee has reached the age of 22, 28, 34, 48, 50, 52, 56, 58, 60, 62, 64, 66 and from then on annually.

   - at the first application for a class 3, 4A, 4B or 4C license and at the time renewal when the licensee has reached the age of 44, 50, 56, 60 and from then on every two years.

In the file all medical conditions including good health were evaluated. In other words, there is no self-reported information not evaluated by a physician. In the data base, those who were not in the Medical file were classified in the category no evaluation.

3. The ACCIDENTS file stores information contained in the accident reports filled out by the police. It contains information on accidents with material damage only (MDO), except in the case of an amicable report, as well as those with bodily injuries and deaths. It also contains information about the circumstances of the accident, the type of accident, the type of vehicle, and whether the occupants were injured or not.

4. The VIOLATIONS file contains information on the nature, status, and number of demerits points obtained after a traffic violation.

5. The SUSPENDED-REVOKED file contains information on the type, state, date, status, and nature of the reasons for suspending or revoking a license.

Concerning each license holder, we know:

- The license holder's age and the main class of license held on July 1, 1989.

- The medical condition based on the internal codes used by the S.A.A.Q. and contained in the MEDICAL file (July 1, 1989).

The history of accidents having occurred between 1 January 1985 and 31 December 1990. For each accident, the following characteristics contained in the accident report were retained:

- Date of the accident
- Day of the accident
- Time of the accident
- Driver's age at the time of the accident
- Number of vehicles involved
- License class
- Mass of the vehicle
- Type of accident
- Traffic conditions
- Movement of the vehicle
- Number of victims injured or killed

The history of violations having occurred between 1 January 1985 and 31 July 1990. For each violation, the following characteristics were retained:

- Nature of the violation
- Date of the violation
- Number of demerit points assessed

Data permitting an evaluation of the level of risk exposure were taken from a telephone survey of license holders. The questionnaire used contains 57 questions. For each license holder interviewed, the following questions were retained for the study:

- Does he drive a vehicle as part of his job?
- What type of vehicle does he drive as part of his job?
- For how many years has he been driving a truck?
- How many kilometers did he drive in 1990 as part of his job?
- Is he the owner of the vehicle?
- Does he drive often after 8 PM?
- How much territory does his job cover?
- On what type of road does he usually drive while on the job?
- Does the truck he drives have usually a trailer?
- How many hours did he spend behind the wheel during his last day on the job?
- How many days was he off the job in 1990?
  a) for vacation
  b) for unemployment
  c) for illness

d) or for other reasons

- How many days did he work during his last work week at the time of the interview?

We also know the reason for which the license holder was not interviewed.

3.2 Sample Retained for the Study

Table 3.2.1 gives, for the 20,208 license holders, the number of accidents having occurred between 1 January 1987 and 30 December 1990, and the average number of accidents per year per 100 license holders according to medical condition and main license class. These rates vary from 3.8 to 27.4 accidents per 100 license holders.

Obviously, all these license holders do not necessarily drive trucks. Measuring risk exposure will allow us to control for this important dimension of the information.

Table 3.2.1

3.2.1 Risk exposure

We obtained the telephone numbers of 18,197 license holders, i.e. 90% of the 20,208 license holders in the data bank. Data collection was entrusted to a private polling firm. It was carried out in three stages. The first stage (a pilot test) took place between 26 and 31 May 1990. The main stage of collection was carried out between 16 October 1990 and 29 August 1991. A total of 11,757 of the 18,197 license holders selected (65%) answered the questionnaire on risk exposure.

The 11,757 interviews conducted were double checked to make sure that the person reached by the interviewer was the right person. This operation left 11,661 license holders for which we had valid information on risk exposure. Table 3.2.1.1 presents the reasons for not responding to the questionnaire on risk exposure.

Table 3.2.1.1
Reason for not responding to the questionnaire on risk exposure (n = 8,547).

Reason for not responding	***Number***	***% (8,547)***	***% (20,208)***
Refusal by the person, or the household, hung up before interview completed	1,091	13%	5.4%
Disability	633	7%	3.1%
Language problems	80	1%	0.4%
Not eligible, not the right person	353	4%	1.7%
No answer after 5 attempts	1,608	19%	8.0%
Wrong number	2,049	28%	11.9%
Unknown number	2,011	24%	10.0%
Reason unknown	362	4%	1.8%
	8,547	100%	42,3%

In Table 3.2.1.1 we observe that the leading reason for failure to answer the questionnaire was the telephone number: either unknown or the wrong number (52% of 8,547). Only 13% of the 8,547 (5% of the 20,208) refused to answer the questionnaire. Among the 11,661 license holders for whom we have information on risk exposure, 3,014 (25.8%) said they drove a vehicle as part of their job (Table 3.2.1.2).

Table 3.2.1.2
Use of a vehicle at work by license class (n = 11,661).

Class of license (1989)	Work with a vehicle (1990)								Total	
	yes		no		Doesn't have a job		Doesn't know			
	N	%	N	%	N	%	N	%	N	%
Class 1	1,335	44.3	997	18.6	198	6.1	1	16.7	2,531	21.7
Class 2	601	19.9	428	8.0	147	4.5	-	-	1,176	10.1
Class 3	634	21.0	654	12.2	141	4.3	-	-	1,429	12.3
Class 4b	75	2.5	182	3.4	31	0.9	-	-	288	2.5
Class 4c	146	4.8	98	1.8	22	0.7	-	-	266	2.3
Class 5										
female	16	0.5	900	16.8	594	18.2	--	--	1,510	12.9
male	207	6.9	2,111	39.3	2,138	65.4	5	83.3	4,461	38.3
Total	3,014	99.9	5,370	100.1	3,271	100.1	6	100.0	11,661	100.1

Among the 3,014 license holders driving a vehicle as part of their job, 1,324 (43.9%) drove a truck, 724 (24.0%) drove a bus, and 188 (6.2%) drove a taxi. Out of the 1,324 license holders who said they drove a truck as part of their job, we selected 1,312 for the study: They were male license holders with a medical condition diagnosed by a doctor, an ophthalmologist, or an optometrist, and whose answers to the questionnaire showed no anomalies.

3.2.2 Sample of 1,312 truck drivers

As of July 1989, 61% of the 1,312 truck drivers had class 1 as their main driving license. This class gives the right to drive a trailer truck. Class 2 and class 3 give the right to drive a straight truck. It should however be noted that the information on the main class license date from 1989, whereas the survey on risk exposure was conducted in 1990. It is possible that some changes in class of license may have occurred between 1989 and 1990. This explains why 5% (72) of the 1,312 truckers had 4b, 4c or 5 as their main license in 1989. We grouped the drivers into two categories according to the class of their license: class 1 or other. The latter includes all classes except class 1; however it is composed mainly of class 3 holders (79%).

In table 3.2.2.1, we observe that 23% of the 1,312 truck drivers are in good health (20% of the 806 class 1 drivers and 27% of the 506 drivers in the "other" class); that 22% were not medically evaluated in 1989 by the S.A.A.Q's Department of Medical Evaluation (26% of class 1 drivers; 15% of drivers in the "other" class); and that 55% of the 1,312 truck drivers have one of the four medical conditions under study (diabetes, coronary disease, high blood pressure, visual impairment).

Table 3.2.2.1
The sample of the 1,312 truck drivers, by medical condition and by main license class. Quebec, 1989.

Medical condition	Class 1		Class "other"		Total	
Good health	167	(20%)	137	(27%)	304	(23%)
Diabetes	124	(15%)	66	(13%)	190	(15%)
Coronary disease	152	(19%)	46	(9%)	198	(15%)
High blood pressure	150	(19%)	84	(17%)	234	(18%)
Visual impairment	-		97	(19%)	97	(7%)
Not evaluated	213	(26%)	76	(5%)	289	(22%)
Total	806	(99%)	506	(100%)	1,312	(100%)

3.3 Econometric Model

We estimated individual accident probabilities using a generalized Poisson (or negative binomial) model capable of accounting simultaneously for all the significant variables available in the data bank and for the fact that individual conditional variances for accidents may differ from conditional expectations. This model has already been used to estimate individual distributions of automobile accidents based on the S.A.A.Q. data (Boyer, Dionne, and Vanasse, 1992; Dionne and Vanasse, 1992) and individual distributions of air accidents for Transport Canada (Dionne, Gagné, Gagnon and Vanasse, 1997). For each driver, we want to model the number of accidents per year (Y_i) in terms of different exogenous or explanatory variables (vector X_i).

In the literature, it is often suggested that the number of accidents in which an individual is involved over a period *t* (>0) is distributed according to Poisson's law. Furthermore, the number of accidents (Y_i) of a driver *i* over a given period, is a function of the vector of exogenous variables (X_i) representing the characteristics of the individual (Gouriéroux *et al.*, 1984; Cameron and Trivedi, 1986; Dionne and Vanasse, 1992; Dionne, Gouriéroux and Vanasse, 1997). The individual probability of having *y* accidents will be expressed as follows:

$$P(Y_i = y|X_i) = \frac{e^{-\exp(X_i\beta)}[\exp(X_i\beta)]^y}{y!}, \quad y = 0,1,2,\ldots \tag{1}$$

where $\exp(X_i\beta) = E(Y_i|X_i) = Var(Y_i|X_i)$ and where $E(Y_i|X_i)$ is the conditional expectation, $Var(Y_i|X_i)$ is the conditional variance and β is a vector of parameters to be estimated using the maximum likelihood method. It should be noted that the restriction «variance equal to the mean» is not always compatible with the data, i.e. the heterogeneity is not always captured by the regression component $(X_i\beta)$.

Gouriéroux *et al.* (1984) suggested that the Poisson model be expanded by adding a random term ε_i to the regression component, in order to account for the effect of non-observable variables. If we suppose that $\exp(\varepsilon_i) \equiv \gamma_i$ follows a Gamma distribution with the density function

$$g(\gamma_i) = \frac{\gamma_i^{1/\alpha-1}e^{-\gamma/\alpha}}{\alpha^{1/\alpha}\Gamma(1/a)}, \quad \gamma_i > 0, \alpha > 0,$$

then $E(\gamma_i) = 1$ and $Var(\gamma_i) = \alpha$.

If we add the random term ε_i to $(X_i\beta)$ in equation (1), the individual probability of having *y* accidents becomes

$$P(Y_i = y|X_i) = \int_{-\infty}^{\infty} \frac{e^{-\exp(X_i\beta+\varepsilon_i)}[\exp(X_i\beta + \varepsilon_i)]^y}{y!} f(\varepsilon_i)d\varepsilon_i, \quad y = 0,1,2,\ldots \qquad (2)$$

or under the conditions previously defined on the γ_i

$$P(Y_i = y|X_i) = \frac{\Gamma(y+1/\alpha)}{\Gamma(1/\alpha)y!} \frac{[\alpha \exp(X_i\beta)]^y}{[1+\alpha \exp(X_i\beta)]^{y+1/\alpha}}, \quad y = 0,1,2,\ldots \qquad (3)$$

which is the negative binomial distribution with $E(Y_i|X_i) = \exp(X_i\beta)$ and $Var(Y_i|X_i) = \exp(X_i\beta)(1+\alpha \exp(X_i\beta))$.

The β and α parameters will be estimated with the maximum likelihood method. If $\hat{\alpha}$, the estimator of α, is significantly greater than 0, we will conclude that there is a «overdispersion» of the data, and we will reject the hypothesis that Y_i is distributed according to Poisson's law.

One of this study's principal objective is to check whether the β parameters of the state-of-health variables are different from zero, which means checking whether the individual probabilities for accidents are different for truck drivers with any of the diseases or physical disabilities selected for study in this research compared with healthy ones. The statistical results will also allow us to check if certain factors of exposure to accident risks are more significant than others in explaining the frequency of accidents.

3.4 Selection Criteria for Observations to Estimate the Frequency of Accidents

We carefully pondered what period of observation would be chosen for the dependent variable namely the number of truck accidents. At first sight, 1990 seemed the appropriate year, since the information on risk exposure also dates from that year. It remained to be seen whether 1990 was representative with regard to the frequency of truck accidents. To verify this, we calculated, by license class and medical condition, the average number of annual truck accidents for each year from 1987 to 1990 and over the 4-year period.

To ensure that the driver was using a truck during the period of observation, we used the following variables drawn from the questionnaire:

- Number of years of truck driving experience
- Same type of vehicle driven in 1989 as in 1990
- Number of kilometers driven on the job in 1990

Table 3.4.1
Selection criteria and number of drivers by observation period for accidents.

Observation period for accidents	Selection criteria	Number
1 January 1987 — 31 December 1987	Driver must have at least three years of experience driving a truck	1,242
1 January 1988 — 31 December 1988	Driver must have at least two years of experience driving a truck.	1,290
1 January 1989 — 31 December 1989	Driver must have at least one year of experience driving a truck and must be driving the same type of truck as in 1990.	1,285
1 January 1990 — 31 December 1990	Driver must have traveled at least one kilometer on the job in 1990.	1,307
Total of driver-years		**5,124**

		observations

In order to account for these variations in the annual averages for accidents, we used the 1-January-1987 to 31-December-1990 observation period, and, consequently, retained 5,124 driver-years instead of limiting ourselves to 1,307 truck drivers for 1990. It should be noted that not all the truck drivers answered all the questions selected to measure their risk exposure. Consequently the whole data set used to estimate the frequency of truck accidents includes 4,099 driver-years. For each model, we selected only those observations with answers to all the questions, so that our results would not be affected by variations due to number of observations (Table 3.4.2).

Table 3.4.2
Number of driver-years used to estimate the frequency of accidents.

Questions concerning risk exposure	Number of driver-years	
	Lost	Total
Initial sample		5,124
Number of kilometers driven on the job annually	438	4,686
Qualitative exposure variables • Driving after 8 PM • Driving a trailer truck • Territory covered on job • Type of traffic most frequently traveled	178	4,508
Number of hours per year behind wheel of a truck	409	4,099

3.5 Variables of the Counting Models with Regression Component to Estimate Frequency of Accidents

The following lines list the variables used in the count models with a regression component to estimate the frequency of truck accidents. Definitions of variables accidents rates are available from the authors.

3.5.1 Trucking accidents (on the job)

Dependent variables:

The number of annual truck accidents for the years 1987, 1988, 1989, 1990. We define a truck as a commercial vehicle weighing more than 3,000 kg. The observed domain of this variable ranges from 0 to 3 accidents per driver per year.

Explanatory variables:

- Period of observation
- Age
- Class of main license
- Medical condition
- Owner of truck
- Kilometrage on job

- Number of hours behind the wheel of a truck
- Driving a trailer truck
- Driving after 8 PM
- Territory covered on job
- Type of road most often traveled on job

3.6 Count Models with Regression Component to Estimate the Number of Victims Injured or Killed in a Traffic Accident

3.6.1 Selection criteria for observations

We gauge the severity of an accident in terms of the number of victims injured or killed during the accident. The observations are the accidents themselves. The observation period used in estimating the number of victims injured or killed in accidents goes from 1 January 1985 to 31 December 1990. We have also classified the accidents according to the type of vehicle driven (truck or passenger car). For the 1 January 1985 to 31 December 1990 observation period, 542 accidents were registered in which the driver was behind the wheel of a truck.

3.6.2 Variables

The variables used in the count models with a regression component for estimating the number of victims injured or killed in accidents are:

Dependent variables

The number of victims injured or killed during accidents with a truck.

Explanatory variables:

- Characteristics of the driver at the time of the accident
  - Age
  - Medical condition
  - Class of main license

- Characteristics of the accident
  - Year of the accident
  - Month of the accident
  - Day of the accident
  - Time of the accident
  - Number of vehicles involved in the accident
  - Type of accident
  - Impact code
  - Traffic conditions

- Characteristics of the vehicle at the time of the accident
  - Movement of the vehicle
  - Mass of the vehicle

4.3 Frequency of Trucking Accidents Estimated Using Counting Model with Regression Component

Table 4.3.1 in Appendix display the results of the parameters estimated using the model of maximum likelihood. The two models reject the hypothesis that the number of trucking accidents follows a Poisson distribution, since $\hat{\alpha}$,the estimator of α , is statistically greater than 0, at the 5% level of significance. In other words, the conditional variance is greater than the conditional mean, which means that a part of the heterogeneity among observations is not explained by the Poisson model. We expected this result, because an accident involving at least one truck is a rare event which can be explained by non-observable factors not measured by the variables included in the study (see Dionne and Vanasse, 1992 for similar results for accidents with a passenger car).

The results obtained with ***Model 1*** (Table 4.3.1 in Appendix), indicate that truck drivers from 46 to 55 and from 36 to 40 have fewer trucking accidents than those 25 and under (reference category). The results also show that diabetic drivers in the “other“ class have more accidents than those in good health of the same class. The dichotomic variable for the license class is not statistically significant, indicating that class 1 truck drivers do not have more accidents than drivers in the “other“ class when appropriate risk exposure variables are included. It should be noted that the medical conditions studied, other than diabetes, have coefficients that are not statistically significant at the 10% level.

Moreover, the dichotomic variables for kilometers on the job are positively significant in relation to the reference group, that is those who travel fewer kilometers. It is interesting to note that the variable “owner of truck“ for the “other“ class has a negative coefficient i.e. owners have lower crash rates. Introducing qualitative variables for risk exposure, for example “driving after 8 PM”, lowers the risk of accidents among drivers of the class "other".

Finally, ***Model 2*** shows that when the number of hours behind the wheel is introduced into ***Model 1***, the only age group which remains significant is the 46-to-50 bracket. For all the models, the coefficient for 1987 is negative, meaning that there are significantly fewer accidents in 1987 in comparison with the reference group (1990).

4.4 Severity of Accidents

Table 4.4.1 in Appendix gives the econometric results of the severity of accidents for the truck drivers involved in accidents while driving a truck. It is interesting to note that drivers with visual impairments have more serious accidents with their trucks than those in good health. These results were obtained by taking detailed account of the circumstances of the accident. To be specific, for accidents involving truck drivers, the significant variables were day of accident, impact code, traffic conditions, and certain movements of the vehicle.

4.5 Discussion

This result shows that drivers who state that they drive a truck on the job and have either coronary heart disease, high blood pressure, or visual impairments are not involved in more trucking accidents than those in good health. On the other hand, diabetic drivers in the “other” class (not class 1) chalk up more trucking accidents than those in good health, regardless of how measurements of risk exposure are handled in the model. Moreover, the effect of age disappears when a greater number of risk exposure variables are taken into account, except for the 46-to-50 age group.

It is difficult to explain why diabetic drivers in the “other” class represent a greater risk of truck accidents than drivers in good health, considering the fact that this result does not apply to class 1 drivers. Do trucking firms use stricter standards in selecting class 1 drivers than government standards require? Another possible explanation is that the level of diabetes is perhaps lower among class 1 drivers than among those in the “other” class. In our sample, class 1 contains fewer insulin-dependent diabetics than does the “other” class. In our calculations, we made a distinction between insulin-dependent diabetes and diabetes treated with oral hypoglycemic agents or diet.

Gower et al. 1992 has shown that that there are wide-ranging differences in the way licenses are issued in the different states of the United States. The FHWA (U.S.) does not allow insulin using diabetics to drive

CMVs. However, the Federal Highway Administration is considering opening up this possibility. In 1985, the Quebec government relaxed its regulations to allow a small number of insulin using diabetic drivers (245 in 1989) to obtain licenses to drive trucks across the province.

The second conclusion deals with the severity of accidents. Given that we had fewer observations under this heading, we could not introduce nested variables for the medical conditions in this part of our analysis. In other terms, for the severity of accidents comparisons between medical conditions are established without taking into account classes of driving licenses, whereas for the frequency of accidents two classes of license were used to make comparisons within license classes (thus providing another control).

Econometric calculations indicate that truck drivers with visual impairments have more serious accidents (in terms of the number of victims injured and killed) in Quebec than those in good health. Our data did not allow us to do a similar analysis for severity in terms of material damages and of injuries and mortalities outside of Quebec.

The visual impairment category must be interpreted cautiously. Only class 3 drivers with binocular visual impairment were considered in this study. Truck drivers with high blood pressure and coronary heart disease are not more prone to have trucking accidents than those in good health.

II. Accident costs

5. Data sources for accident costs: the S.A.A.Q and the private sector

5.1 Costs obtained from the S.A.A.Q. for all accidents

Two sources of S.A.A.Q. data were used in our study. The first source is the research report on evaluation of the costs of traffic risks and prevention in Quebec (Bordeleau, 1992)[3]. We also obtained data from S.A.A.Q.'s Actuarial Department on the average costs reimbursed by the S.A.A.Q. to victims or their dependents for fatal, serious, or minor accidents in 1990, 1991, and 1992.

There is an important difference between these two sources of information. Bordeleau (1992) made his calculations by taking into account the value of lost production (ex: $381,277 for a death, human capital approach), whereas the Actuarial Department only takes into account the amount of compensation paid to victims or their dependents (ex: $50,647 for a death, private actuarial-cost approach) plus other direct fees such as those for ambulance or health services reimbursed by the RAMQ, etc. Both these sources base their calculations either on all victims or only on those victims filing a claim. We chose to use the data for all victims, which minimizes the average amount per victim, since the denominator is greater. Finally, we will present calculations using Transport Canada's $1.5-million, willingness-to-pay value (Lawson, 1992).

5.2 Data on costs of trucking accidents obtained from the private sector

In order to obtain more reliable data on conditions in Quebec, we sought the collaboration of two large trucking firms as well as that of a general insurance company well established in the area of selling insurance to trucking firms. These collaborators allowed us to determine the costs attached to material losses as well as certain costs associated with accidents involving physical injuries occurring outside of Quebec.

The data obtained from one source covered the years from 1985 to 1992, whereas that from a second source went from 1987 to 1991. The data from the general insurance company cover the 1987-to-1992 period. An agreement to protect the confidentiality of the data prevents us from revealing the specific calculations performed with these three sources of information. The results obtained by combining the information collected are the following:

Out of more than 17,000 cases, we obtain an average sum of $10,000 per trucking accident for material damages alone. To these $10,000 we must add $2,000 to cover the average costs linked to physical injuries outside of Quebec.

6. Analysis of costs of trucking accidents

We want to recall that our method for estimating the costs of accidents includes two principal steps. The first consists in checking whether the presence of certain medical conditions has any significant effect on the frequency and/or severity of trucking accidents. The second step consists in transforming the different variations in probability into monetary terms.

In the first part, we showed that diabetes had a positive effect on the frequency of accidents for drivers in the "other" class (79% holders of a class 3 license); whereas drivers with binocular visual impairment do not have more accidents than the group classified in good health, they do have more serious accidents. We can now calculate the costs associated with these two medical conditions.

To make this calculation, several scenarios can be used. The first is limited to considering only the average private costs assumed by trucking firms and their insurers. They do not include the costs

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3 We would like to thank Mr. Bordeleau for his help in interpreting certain results cited in his report.

associated with victims injured or killed covered by the C.S.S.T. and the S.A.A.Q. This first scenario is thus limited to material damages and certain physical injuries incurring outside of Quebec. The list of these costs (available from the authors) indicates that the average costs of a trucking accident is about $12,000. It is important to stress the fact that this amount does not include the physical injuries of Quebec drivers nor those inflicted on other users of Quebec's traffics. This amount may seem low but it is comparable to the average cost obtained from an Australian study (Cairney, 1991).

Let us now turn to a driver in good health in the "other" class. The econometric calculations in part 1 indicate that his annual accident expectation (E(Y|X)) is 0,0504: exp ($X_i\beta$) evaluated at the condition « good health/ "other" class » and at the average of all the other variables in the model.

The expected private costs of accidents for a driver rated as «in good health/ "other" class» are thus $605: $12,000 x 0.0504. If we calculate the expected costs for a diabetic driver in the same class, we obtain $1,403: $12,000 x 0.1169 where 0.1169 is his annual expectated number of accidents ($X_i\beta$) evaluated at the «diabetic/ "other" class» medical condition and at the average of all the other variables in the model. In conclusion, our results clearly indicate that diabetic drivers in the "other" class show a high expectation of additional accident costs of $798 per driver, for average costs of $12,000. In sum, being a diabetic driver more than doubles the mathematical expectation of private accident costs.

Let's now consider the costs for physical injuries in Quebec. Two approaches can be proposed: (i) to consider trucking accidents as work accidents and use the average compensations paid out by the C.S.S.T. or (ii) to use the average benefits paid by the S.A.A.Q. for injuries sustained by non-professional drivers. We have decided to use the costs calculated by the S.A.A.Q. for two main reasons. First, the data available on C.S.S.T. benefits are not sufficiently detailed to generate specific amounts paid out for work accidents on the traffic, whereas those of the S.A.A.Q. quite naturally offer this specificity, as they refer exclusively to traffic accidents. However, we must point out that the data on costs available at the S.A.A.Q. (Bordeleau, 1992) cover all traffic accidents and do not focus specifically on trucking accidents. Trucking accidents differ from most traffic accidents since they generate higher costs for society in terms of deaths and injuries per accident. If we wanted to calculate the total costs for victims involved in trucking accidents so as to evaluate different forms of regulation for trucking activities, we should take these differences into account. The following calculations do not take this correction into account.

For 1990, the average amount awarded for a minor injury was $4,218 and for a serious injury, $38,597. If we use the relative respective weights for the two categories of injuries, we obtain an average cost of $8,600 per injury (that is 4218 x 87% + 38,597 x 13% where 87% is the proportion of victims with minor injuries in Quebec in 1990). For a death, the S.A.A.Q. paid on average $50,647 to the spouse or dependents in 1990 (S.A.A.Q. Actuarial Department). If we use the average number of victims per accident involving a truck drawn from our data bank and if we weight for injuries and deaths, we obtain an average cost of $9,956 per accident with physical injuries ((8,600 x 18 + 50,647 x 0.6) ÷ 18.6), where 18% is the average number of injured per accident and 0.6% is the average number of deaths per accident. It is to be noted that 81.4% of the 542 trucking accidents (commercial vehicle weighing 3,000 kg or more) in our sample were accidents with property damage only (P.D.O). We can thus also calculate an average cost for physical injuries for all accidents, including those with P.D.O., obtaining $1,852 ((0 x 81.4 + 8,600 x 18 + 50,647 x 0.6) ÷ 100). This average cost must be added to the average cost for material damages to obtain the total direct average cost of $11,852 ($10,000 + 1852 where $10,000 is the average cost for material damages). It is to be noted that the average cost of physical injuries in our sample ($1,852) is slightly lower than that calculated based on data obtained from the private general insurance company and the two trucking firms having participated in our study for accidents outside Quebec. This difference may be explained by the fact that the Quebec insurance system is no fault for physical injury in Quebec.

The analysis of the preceding paragraph implicitly assumed that the average costs per accident (or severity, measured for the number of injured and/or killed per accident) were not affected by medical conditions. In other terms, we supposed that the severity of accidents was not affected by medical conditions. Our results in part 1 confirm this hypothesis for diabetics and for all the other medical conditions (class 1 and "other" class), with the exception of drivers with visual impairments. For the latter, we must adjust the variation in average severity due to their medical condition to the amount calculated above for drivers in good health. Therefore, if we calculate the expected average cost of accidents for a driver with visual impairment, we obtain interesting results. Before going on, let's recall certain figures which will be useful in our calculations:

Average frequency of accident for a driver in good health	0.0504
Average frequency of accident for a diabetic driver	0.1169
Average cost of material damages	$10,000
Average severity (injured and killed) for a driver in good health	0.07320
Average severity (injured and killed) for a driver with visual impairments	0.24256
Average cost of physical injuries in Quebec calculated based on all accidents involving physical injury	$9,956

A driver in good health thus has an average-cost expectation equal to :

0.0504 [0.07320 ($9,956) + $10,000] = $541

whereas a driver with visual impairment has an average-cost expectation of

0.0504 [0.24256 ($9,956) + $10,000] = $626

The other medical conditions do not have a significant effect on the severity of accidents. In order to make a detailed comparison of costs, we here present the calculation of average-cost expectation for a diabetic driver who, we remind you, has a higher frequency of accidents than a driver in good health (0.1169 against 0.0504), but the same frequency of severity (0.07320):

0.1169 [0.07320 ($9,956) + $10,000] = $1,254

which represents a more substantial difference when compared with drivers in good health. As another scenario, we can consider certain indirect costs of accidents so as to take into account, for example, the value of lost production, as calculated by the S.A.A.Q. (Bordeleau, 1992) or the economic value of a human life (or willingness to pay).

For a death, the S.A.A.Q. has calculated the amount of $381,277, to which can be added prevention costs divided among all motorists: about $250 for a total of $381,500. With this same basis of calculation, the S.A.A.Q. has estimated at $20,250 the average cost for an injury (serious or minor). With regard to the value of a human life, the summary of the literature indicates that it varies widely from one study to the next, depending, among other things, on the parameters selected to calculate this value. For our calculations, we will use the $1.5-million value for a death (Lawson, 1992), which is the one used by Transport Canada, and the value of $80,000 ($20,250 x 1.5 m ÷ 381,500) for an injury.

The figures drawn from S.A.A.Q. data are thus the following:

$381,500 (for a death) x 0.6 (the average number of deaths in 100 trucking accidents) = $228,900

$20,250 (for an injury) x 18 (the average number of injuries in 100 trucking accidents) = $364,500

(228,900 + 364,500) ÷ 18.6 =

$31,903 for physical injuries drawn from that source to which we must add the $10,000 for material damages.

Therefore, a driver in good health has a cost expectation which takes into account the value of lost production and material damages equal to:

0.0504 [0.07320 ($31,903) + $10,000] = $622

For drivers with visual impairments, the cost expectation is:

0.0504 [0.24256 ($31,903) + $10,000] = $894

and that for diabetic drivers is:

0.1169 [0.07320 ($31,903) + $10,000] = $1,442

Finally, if we calculate social-cost expectation by using the values of $1.5 million for a death and $80,000 for an injury, we obtain the following results:

($1.5 million X 0.6 = $900,000) + ($80,000 X 18 = 1,440,000) ÷ 18.6 = $125,806 for physical injuries instead of $31,903.

Good health: 0.0504 [0.07320 ($125,806) + $10,000] = $ 968
Visual impairments: 0.0504 [0.24256 ($125,806) + $10,000] = $ 2,042
Diabetes: 0.1169 [0.07320 ($125,806) + $10,000] = $ 2,246

7. Discussion

It is important to conclude part 2 by highlighting the estimative character of the costs drawn from the literature, especially those obtained by the willingness to pay method. As to costs obtained from the private sector, they are certainly a lot more precise, though they reflect only a portion of all the real costs. We have observed very wide deviations between the minimum and maximum amounts proposed to estimate what the death of a person costs society. We can also add that the costs retained for an injury might have been higher if we had been able to obtain amounts for the injured involved in a trucking accident rather than for all injuries regardless of the type of vehicle involved.

Two other elements which must be taken into account are the exchange of foreign currencies into Canadian dollars and the adjustment made for inflation. In most cases, the amounts estimated are adjusted on the general basis of the consumer price index (CPI), whereas health costs, vehicle repairs, and other costs do not necessarily have the same inflation rate.

The different regulations in force in Canada and the United States also have considerable impact on the costs obtained. For example, the settlements paid by the S.A.A.Q. (no fault system) are regulated and cannot exceed a maximum threshold set in terms of various types of injuries.

The regulations on medical standards for drivers or on the number of hours a trucker can drive also have an influence on the number and severity of accidents and, consequently, on the costs linked to accidents.

Despite the variations observed in the literature and given the necessity of evaluating the measures adopted to increase traffic safety, we were able to shed light on the significant statistical cost differences existing between drivers who are in good health and those with certain medical (diabetes) or optometric (visual impairments) conditions.

Conclusion

This paper contains two groups of important findings: Those in the first part which compare drivers who have certain medical conditions with a control group in good health, so as to evaluate statistically the effect on the frequency and severity of trucking accidents. Those in the second part which evaluate in monetary terms the variations in costs associated with significant variations in the frequency and severity of accidents.

The first findings in part 1 are related to the estimation of the frequency of accidents among the truck drivers in the sample. The different econometric estimations produce findings showing that only diabetic drivers in the "other" class have a significantly higher accident rate than drivers in good health in the same class. This latter group includes all the truck drivers in our sample who do not belong to the class 1 category (trailer truck), and it is composed namely of class 3 truck drivers (79%). Our findings also indicate that none of the class 1 drivers with the medical conditions studied (diabetes, coronary heart disease, visual impairment, and high blood pressure) have accident rates (or frequencies) significantly higher than class 1 drivers in good health. It is to be noted that drivers with a co-morbidity have been excluded from our sample for methodological reasons (Waller, 1991).

The results of the different econometric models also indicate that the age of drivers is not a strong explanatory factor for accident rates, when quantitative (km and time) and qualitative risk exposure variables (type of road, size of territory, driving after 8 PM, etc.) are introduced. Indeed, only drivers in the 46 to 50 age bracket have a significantly lower accident rate than those 25 and under. Another finding which carries some weight in the discussion of regulations is that the accident rate was lower in 1987 than in 1990. As a matter of fact , this is the only year among those selected for our study (1987, 1988, 1989, 1990) which contrasts sharply with 1990.

Other notable explanatory variables are the following: owning the vehicle reduces the frequency of accidents; the number of kilometers traveled increases the frequency of accidents, as does the number of hours behind the wheel; driving after 8 PM reduces the accident rate of drivers in the "other" class; covering a larger territory on the job increases the accident rate for class 1 drivers when hours are not included in the model. Finally, driving mainly on highways reduces the frequency of accidents among class 1 drivers.

We also estimated the parameters of the distribution of the severity of accidents. Our data limited us to the study of severity in terms of injuries and deaths. Our model thus explains the distribution of the number of injuries and deaths in a trucking accident. The results indicate that drivers with binocular visual impairment have more serious accidents than those in good health. Other variables are also significant: the day of the accident, the impact code, traffic conditions, and certain movements of the vehicle. Yet, once again, the age of the driver has no significant effect. This last finding is difficult to interpret. The only explanation that we can come up with for the moment is that young drivers have different behaviors on the job or are subject to stricter codes by their employer than when they drive a private car.

As we mentioned above, our data did not permit us to make a detailed analysis of the factors explaining the distribution of costs for material damages nor that for physical injuries outside of Quebec. The same cost expectations for both these types of severity have been imputed to all drivers, regardless of their medical condition.

As indicated by our title, part 2 is devoted to the analysis of accident costs. Two categories of costs have been taken into account: (1) material damages (insured or not) and (2) costs of physical injuries (private or public). For this second category, three scenarios were considered for the costs of injuries and deaths in Quebec: (1) private costs at the S.A.A.Q.; (2) costs taking into account losses in human capital; and (3) costs evaluated using the willingness-to-pay approach. These different definitions are useful for trucking firms and those in charge of traffic safety. Trucking firms are mainly concerned about the direct costs of material damages and the compensation costs for work accidents. Unfortunately, the C.S.S.T. data available were not detailed enough to be used in calculating the compensation costs associated with on-the-job traffic accidents. We have used the S.A.A.Q. data, even though their average costs are for all traffic accidents. Officials responsible for drafting traffic safety codes will find the S.A.A.Q.'s average costs most relevant since, as we have already indicated, for each truck driver killed an average of four other (non-truck) deaths occur and the S.A.A.Q. pays out benefits for all these victims.

The results of our calculations indicate that the mathematical expectation of the average cost for a diabetic driver in the "other" class (79% class 3 drivers) is more than twice as high as that for a driver in good health, no matter which cost measurement is used: accident costs in Quebec of $1,254 vs. $541; human capital costs of $1,442 vs $622; and willingness to pay of $2,246 vs. $968. Since these calculations are limited to the use of the statistically significant variables from the econometric models on accident frequencies, they implicitly indicate that the average costs expected for class 1 drivers are the same regardless of medical condition and that those of drivers in the "other" class with a medical condition other than diabetes are equal to the expected costs for drivers in good health of the same class.

We can interpret these results in the following manner. If a trucking firm hires a diabetic class 3 driver, the mathematical expectation for the average costs of its accidents with this driver will be twice as high as those for a driver in good health in the same license class. Trucking-firm insurance premiums should thus be adjusted in accordance with the number of diabetic class 3 drivers working for these firms. Finally, the social costs incurred by these drivers are more than twice as high as those incurred by drivers in good health of the same class.

Our results also indicate that drivers with binocular visual impairments have higher cost expectations than those in good health, regardless of the driving class when we consider accident severity. But the differences in costs are smaller than for diabetic drivers, given that the weights the conditional frequency of serious accidents are a lot lower than those for non-conditional frequency. Indeed, holding to the three definitions of costs used in this study, we obtained the following results when we compared the cost expectations of a driver with visual impairments to those of a driver in good health: accident costs of $626 vs $541; human capital costs of $849 vs $622; and willingness to pay of $2,042 vs. $968.

Once again, these results on visual impairments must be interpreted cautiously. Even if our econometric model did not allow us to distinguish the effect of visual impairment from one class to the next (not enough observations on the severity of accidents), that does not imply that our results should be interpreted without making at least one important distinction. In our data bank only class 3 drivers had health problems of this nature in the initial sample.

Two questions remain to be clarified before penalizing all drivers with these two medical conditions: (1) Can precise measurement of the severity of these illnesses be used to distinguish the most dangerous cases from the others? (2) How can this information be used in effectively managing accident risks? One way of finding answers would be to conduct an in-depth study of the market behavior of the employers with respect to road safety.

Finally, only the 1987 variable had any significant negative effect in comparison with 1990 in the analysis of accident rates. It is interesting to recall that the economic deregulation of commercial trucking started in January 1988. It would also be worth checking relationships between the economic deregulation of this market and traffic safety regulations, especially as our significant results touch class 3 drivers who are more likely to be freelance drivers or owners.

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Table 4.3.1
Estimated count data regression models for the number of accidents with a truck per year (Models 1 and 2)

Explanatory variables	Count data regression					
	Model 1			Model 2		
	Coefficient	*t* statistic		Coefficient	*t* statistic	
Intercept	-2.70	-4.63	**	-3.26	-5.11	**
alpha	1.55	3.53	**	1.43	3.41	**
Observation period						
1987	-0.29	-1.68	*	-0.28	-1.65	*
1988	-0.20	-1.21		-0.19	-1.16	
1989	-0.25	-1.49		-0.24	-1.46	
1990	reference category			reference category		
Permit class						
Class 1	0.08	0.14		0.30	0.46	
Class others	reference category			reference category		
Age group						
25 years or less	reference category			reference category		
26 to 30	0.09	0.31		0.13	0.43	
31 to 35	-0.18	-0.59		-0.09	-0.29	
36 to40	-0.55	-1.76	*	-0.49	-1.54	
41 to 45	-0.36	-1.19		-0.27	-0.89	
46 to 50	-0.66	-2.16	**	-0.60	-1.96	**
51 to 55	-0.55	-1.77	*	-0.48	-1.54	
56 to 60	-0.40	-1.20		-0.33	-0.98	
More than 60 years	-0.15	-0.36		-0.14	-0.34	
Class 1 - Medical condition						
Good health	reference category			reference category		
Diabetes	0.12	0.51		0.12	0.51	
Coronary disease	0.18	0.80		0.16	0.73	
Hypertension	-0.34	-1.37		-0.36	-1.45	
No evaluation	-0.17	-0.78		-0.14	-0.66	
Class others - Medical condition						
Good health	reference category			reference category		
Diabetes	0.78	2.31	**	0.84	2.42	**
Coronary disease	-0.49	-0.76		-0.36	-0.55	
Hypertension	0.36	0.98		0.29	0.79	
Visual impairment	0.38	1.17		0.43	1.30	
No evaluation	-0.04	-0.10		-0.08	-0.18	
Class 1-Owner of the truck						
Yes	-0.04	-0.22		-0.05	-0.26	
No	reference category			reference category		
Class others-Owner of the truck						
Yes	-0.78	-2.45	**	-0.78	-2.40	**
No	reference category			reference category		
Class 1-Distance driven						
≤ 15 000 km	reference category			reference category		
15 001 to 40 000	0.64	2.69	**	0.57	2.37	**
40 001 to 87 500	0.99	3.98	**	0.90	3.57	**
> 87 500 km	1.22	4.52	**	1.08	3.97	**
Class others-Distance driven						
≤ 10 000 km	reference category			reference category		
10 001 to 22 500	0.68	1.69	*	0.30	1.45	
22 501 to 40 000	0.82	2.05	**	0.21	1.50	
> 40 000 km	1.05	2.66	**	0.74	1.81	*

Table 4.3.1 (Continued)

Explanatory variables	Count data regression		Model 2	
	Model 1		Model 2	
	Coefficient	*t* statistic	Coefficient	*t* statistic
Class 1 - Pull a trailer				
Always or often	0.02	0.11	0.03	0.19

Rarely or never	reference category			reference category		
Class others - Pull a trailer						
Always or often	0.14	0.40		0.13	0.37	
Rarely or never	reference category			reference category		
Class 1 - Drive after 8 PM						
Very often or often	-0.27	-1.53		-0.26	-1.48	
Seldom or never	reference category			reference category		
Class others - Drive after 8 PM						
Very often or often	-0.58	-1.73	*	-0.65	-1.02	*
Seldom or never	reference category			reference category		
Class 1 - Working radius						
Less than 50 km	reference category			reference category		
Between 50-160 km	0.62	3.13	**	0.58	2.90	**
More than 160 km	0.42	1.68	*	0.34	1.38	
Class others - Working radius						
Less than 50 km	-0.30	-0.78		-0.13	-0.32	
Between 50-160 km	-0.39	-1.03		-0.30	-0.76	
More than 160 km	reference category			reference category		
Class 1 - Type of road						
Highways	-0.50	-1.94	*	-0.50	-1.94	*
Country roads	-0.39	-1.58		-0.38	-1.55	
City streets	reference category			reference category		
Highways & country roads	-0.04	-0.14		-0.03	-0.10	
City streets & country roads	-0.29	-0.90		-0.29	-0.90	
City streets & highways	-0.02	-0.08		0.02	0.07	
Class others - Type of road						
Highways	-0.06	-0.16		0.03	0.06	
Country roads	-0.17	-0.52		-0.17	-0.53	
City streets	reference category			reference category		
Highways & country roads	0.06	0.14		0.10	0.22	
City streets & country roads	-0.59	-1.05		-0.42	-0.74	
City streets & highways	0.07	0.22		-0.01	-0.04	
Class 1 - Number of hours						
≤ 720 hrs				reference category		
721 to 1 000				0.24	0.99	
1 201 to 1 728				0.62	2.72	**
> 1 728 hrs				0.49	2.07	**
Class others - Number of hours						
≤ 585 hrs				reference category		
586 to 1 000				-0.00	-0.01	
1 001 to 1 500				0.22	1.63	
> 1 500 hrs				1.05	2.61	**
Number of driver-years	4 099			4 099		
Number of variables	49			55		
Log-Likelihood	-1 085.66			-1 074.80		
Log-Likelihood Ratio Test Model 2 vs Model 1				$\chi^2_6 = 21.72$ **		

* Significant at 10%. ** Significant at 5%.

Table 4.4.1
Estimated count data models (Poisson distribution)
for the number of victims in a crash with a truck.

Explanatory Variables	**Truck** coefficient	t-ratio
Intercept	-2.979	-2.871**
Year of crash		
1985	-0.137	-0.289
1986	0.166	0.359
1987	-0.312	-0.647
1988	0.287	0.698
1989	0.544	1.314
1990	Reference category	
No. of vehicles in the crash	0.212	1.894*
Permit class		
Class 1	0.564	1.565
Class other	Reference category	
Medical condition		
Good health	Reference category	
Diabetes	0.422	1.119
Coronary heart disease	0.324	0.838
Hypertension	0.320	0.850
Binocular vision problem	1.198	2.071**
No evaluation	0.283	0.768
Age group		
≤ 25 years	Reference category	
26 to 30	-0.272	-0.478
31 to 35	-0.095	-0.169
36 to 40	0.310	0.547
41 to 45	-0.529	-0.869
46 to 50	0.238	0.421
51 to 55	-0.624	-0.955
more than 55 years	-0.939	-1.465
Type of impact		
Lateral frontal	Reference category	
Lateral same direction	-1.121	-2.397**
Lateral opposite direction	0.204	0.537
Rear	-0.507	-1.671*
No collision	-1.518	-2.377**
Other	-1.253	-3.752**
Type of crash		
With a vehicle	-0.333	-0.735
Other	Reference category	
Vehicle movement		
Straight ahead	Reference category	
Turned right	-0.467	-1.017
Turned left	-0.030	-0.073
Joined the traffic, slowed down or stopped	-1.239	-2.52 **
Parked or quit parking area on the curbside	0.058	0.089
Reversed	-1.557	-2.578**
Entered or left traffic or expressway overlook on the right or on the left, changed lanes, did a 180° turn, avoided an obstacle on the road, broke down, unknown	0.171	0.461

Table 4.4.1 *(continued)*

Explanatory Variables	**Truck**	
	coefficient	**t-ratio**
Month of accident		
March to June	-0.279	-1.059
July to February	Reference category	
Day of crash		
Friday to Sunday	0.488	1.941*
Monday to Thursday	Reference category	
Time of crash		
6:00 am to 8:59 am	0.285	0.964
9:00 am to 3:59 pm	Reference category	
4:00 pm to 5:59 pm	0.359	1.086
6:00 pm to 9:59 pm	0.277	0.646
10:00 pm to 5:59 am	0.504	1.368
Road surface condition		
Dry	0.822	2.588**
Wet	1.250	3.43**
Snow-ice-mud and other	Reference category	
No. of crashes	542	
No. of variables	44	
Log-likelihood	-232.53	

* Significant at 10% ** Significant at 5%

Table 3.2.1

Number of accidents between January 1, 1987 and December 30, 1990, and the average number of accidents per year per 100 licenses by medical condition and by main license class. Québec 1989.

License class	***Good health***			***Diabetes***			***Coronary disease***			***Hypertension***			***Vision problem***			***No evaluation***			***Total***		
	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%	N	S	$\frac{S}{N}$%
Class 1	877	513	14.6	796	449	14.1	670	403	15.0	700	395	14.1	--	--	--	911	449	12.3	3954	2209	14.0
Class 2	700	438	15.6	--	--	--	349	205	14.7	700	391	14.0	--	--	--	--	--	--	1749	1034	14.8
Class 3	504	297	14.7	345	194	14.1	231	103	11.1	366	137	9.4	370	252	17.0	420	155	9.2	2236	1138	12.7
Class 4b	360	105	7.3	--	--	--	30	14	11.7	88	33	9.4	--	--	--	--	--	--	478	152	7.9
Class 4c	404	375	23.2	--	--	--	--	--	--	--	--	--	177	194	27.4	--	--	--	581	569	24.5
Class 5																					
Women	489	83	4.2	698	129	4.6	--	--	--	--	--	--	1150	175	3.8	681	131	4.8	3018	518	4.3
Men	1805	429	5.9	1206	493	10.2	--	--	--	--	--	--	4069	960	5.9	1112	427	9.6	8192	2309	7.0
	5139	2240	10.9	3045	1265	10.4	1280	725	14.2	1854	956	12.9	5766	1581	6.9	3129	1162	9.3	20208	7929	9.8

N: Number of license holders

S: Number of accidents which occurred between January 1, 1987 and December 31, 1990

$\frac{S}{N}$%: Average number of accidents per year per 100 licenses

Note: For classes 1 to 4c we kept only men license holders since just a few women hold such licenses.

Class 1: Tractor-trailer

Class 2: Bus for more than 24 passengers

Class 3: Straight-body truck

Class 4b: minibus or bus for 24 or less passengers

Class 4c: taxicab

Class 5: passenger vehicle