DRAG, model of the Demand for Road use, Accidents and their Severity, applied in Quebec from 1956 to 1982.

by

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The works from which this article was taken have been subsidised first of all by *La Régie de l'Assurance Automobile du Québec*; they also have received the support of the F.C.A.C. program from the *ministère de l'Éducation du Québec* and the Natural Sciences and Engineering Research Council of Canada. Preliminary results have been presented to the *Régie de l'Assurance Automobile* in March 1984 and at the « International Workshop on the Methodology of Modelling Road Accidents and Injury Patterns », University of Sussex, England, in July 1984. To get a better understanding of the data used, readers can consult the complementary report of M. Gaudry, D. Baldino and T.C. Liem called « FRP, un Fichier Routier Québécois », publication # 360 from the *Centre de recherche sur les transports* and copybook # 8431 from the department of economics of the *Université de Montréal*.

Université de Montréal

Agora Jules Dupuit – Publication AJD-17

September 1984; revised May 2002

ABSTRACT

We develop a five-layer procedure to explain the impact of various factors on the monthly demand for road use and the number of road accident victims in Quebec as a whole from December 1956 until December 1982. The first layer consists of a model of total motor vehicle fuel sales (gasoline and diesel) from which we extract fuel sales for road use. This measure of transportation demand is the object of further analysis in the second layer and appears among the explanatory variables of both the number of accidents by type (material damages, non-mortal and mortal) and their severity (morbidity and mortality rates) which are explained in the third and the fourth layers, respectively. Results from the demand, accident and severity equations are combined to yield, in the fifth layer, evaluations of the effect of the factors considered on the number of persons hurt, killed, or on the total number of these road victims.

The nine equations estimated define a REFERENCE MODEL which involves 60 distinct factors, approximately 40 of which are used in any given equation. In addition, a number of MODEL VARIANTS are studied: they require an additional 20 variables. Explanatory factors considered belong to seven major categories: demand, prices, motor vehicles (quantities and characteristics), network (legal regimes and police, service levels of modes, infrastructure quality), consumer characteristics (general, age, sex, vigilance), economic activities and trip purposes, and other (administrative, aggregation and seasonal/constant).

The statistical model makes extensive use of flexible (Box-Cox) functional forms and simultaneously estimates the error distribution parameters (multiple autocorrelation and heteroscedasticity of a general nature) in order to obtain white noise constant variance equation residuals.

KEY WORDS: GASOLINE, DIESEL, ACCIDENTS, SEVERITY, VICTIMS, BOX-COX TRANSFORMATIONS, AUTOCORRELATION, HETEROSCEDASTICITY

ACKNOWLEDGMENTS

We want to thank, in the academic community, the following persons:

- Marcel Boyer, Georges Dionne and Leonard Dudley for useful discussions on the risk theory;
- Marcel G. Dagenais and Jean-Marie Dufour for successful exchanges on the economic and econometric formulation of the model;
- Leonard Dudley, for the permission to use "Felix, the friendly forecaster" Copyright 1984, his graphical interactive software with which we did the graphics of PROVASS, VTRP1617 and VTRP1819, PROHTCUM and PRODECUM, and RASC7978 variables;
- Roger Gaudry, Louis-Philippe Pigeon and Denise Gaudry, for advises in biochemistry and law;
- Domenico Baldino, Tram Cong Liem, analysts without whom the development of the model would not have been possible;
- Assistants Chantal Lacroix, Michel Pelletier, Daniel Théoret and Jean-Victor Côté who have also made considerable contributions; other assistants: Menouar Boulahfa, Farouk Bennani, Najib Boujjedaine Tsouli, Omar Drissi-Kaitouni, Robert Gagné, Daniel Guillaume-Sam, Abdellah Hindi, Patrice Lemyre, Christian Michaud, Mohammed El Filali El Youssefi, Joachim Ottro and Alain Pilon;
- Michel Bienvenu, Robert Bourbeau, Claire Laberge-Nadeau, Serge Lecours, Bernard Leduc and Rodrigue Tremblay who gave information on data or on some medical aspects.

In the private sector, several persons have provided information:

- Pierre Asselin, Marlin Detroit Diesel Inc.;
- Roberta Cole, International Medical Statistics;
- Michel Pelletier, Voyageur;
- Association des Brasseurs du Québec

Several committees, groups and people from the public sector have offered their support:

- Police de la C.U.M. (*C.U.M. Police*): Pierre Leclair, André Pilon, Jean-Guy de Repentigny, Louic Rossignol, Marcel St-Aubin and Eliane Tousignant;
- Ministère du revenu du Québec (*Quebec Minister of Revenue*): Michel Marquis, Gilles Gosselin and Laura Gosselin;
- Bureau de la Statistique du Québec: Simon Haince, Fernand Pichette, Jean Renaud and André Viel;
- Commission de transport de la Communauté Urbaine de Montréal (*Montreal Urban Community Transit Corporation*): André Arbic and Guy Lafontaine;
- Commission de transport de la Communauté Urbaine de Québec (*Quebec Urban Community Transit Corporation*): Daniel Dupuis and Paul-André Robert;
- Ville de Montréal (*Montreal city*): Marcel Crépault;
- Ministère de l'énergie et des ressources: Jean Servais;

- Ministère des transports du Québec: Michel Bérard, Jean De Montigny, Rodrigue Deschênes, Denis Laplante, Gilles Laplante and Monique Plamondon;
- Statistique Canada (Statistics Canada): Jeannine Bustros;
- Société des alcools du Québec: Gilles St-Michel;
- Sûreté du Québec: Claude Chagnon, Pierre Chevrier, Claude Rochon and Luc Tremblay;
- Ministère du travail: Michel Robitaille.

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1. INTRODUCTION

1. INTRODUCTION

Use of roads for people transportation and merchandise transportation involve accidents that frequently cause material damages and victims. In this study, we try to explain the road use *demand*, the *accidents* and their *severity* by using a methodology that is able to evaluate the importance of various explanatory factors and also by getting all the useful information of the unexplained part, or error, associated with each phenomenon to be understood. More precisely, we conjointly analyse *two* road demands (measured by gasoline and diesel fuel consumption), three accident classes (according to the fact that they include only material damages, at least one injured person and at least one dead person) and *two* severity measurements (that is to say the number of injured people or the number of dead persons by accident with bodily injuries).

These seven equations of DRAG model represent the processes that determine the demand for road use and the total monthly number of road accidents and victims reported for all the province of Quebec. The explanatory factors used in the model belong to the seven main following categories: the layer and the composition of ROAD USE DEMAND and PRICES, the availability or the characteristics of VEHICLES, the nature of the NETWORKS (such as the governmental LAWS or REGULATIONS and their enforcement by the police, the transportation modes levels of SERVICE and the INFRASTRUCTURE characteristics), the general and specific characteristics of the DRIVERS, the level or composition of the final or intermediate ECONOMICAL ACTIVITIES as well as ADMINISTRATIVE practices of measurement and accountancy. We use approximately 60 distinct factors in our reference model and about twenty additional ones when we study sub-problems. Details on the construction of the relevant time series are provided in a complementary report on the *Fichier Routier Québécois* (Quebec road file) constructed for DRAG model (Gaudry *et al.*, 1984).

Each considered equation is composed of a so-called *fixed* part, which includes the explanatory factors, and of a so-called *random* part, which is a model of the error associated with this equation. Each of the two parts contains an important number of parameters: 40 and 7, respectively, for the typical equation of the reference model – about 350 for the model – and a larger number during studies of particular problems (examination of variants from the fixed or random part, study of variable functional forms). The 27 year-period from which is drawn our sample includes the 313 consecutive months from December 1956 to December 1982.

Even if the size of the considered equations system and the coherence required between the equations do not allow any exact formulations of the consumer's adjustment mechanisms, we are able to identify, considering the constraint of an aggregated model and the available data, relations that are strong enough to show the approximate impact of a large number of factors and to indicate situations that would require advanced microeconomical studies.

2. STRUCTURE OF THE PROBLEM AND INTERPRETATION

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2.1. Conceptual framework and general idea of DRAG model

Indeed, we have at our disposal monthly aggregated data on the fuel sales DR, the number of accidents AC and the road victims VI. Let's suppose that our main interest is the explanation of the number of victims and that we want to consider the demand for road use in order to explain this number. Let's also suppose that we want to explain the road demand itself so as to explore the influence of various factors on road safety by taking into account their impact on road use. We then have to formulate at least a two-layer model:

$$DR \leftarrow (\quad X^{dr}) , \qquad \text{(D)}$$

$$VI \leftarrow (DR, X^{vi}) , \qquad \text{(P)}$$

where the arrow means « determines in a certain way » and the X refers to a group of explanatory factors of road demand DR or victims VI. In this structure, an explanatory factor that would belong to X^{Dr} and X^{Vi} – snow, for example – would have a direct effect on the number of victims, to a given road demand, by X^{Vi}, and an indirect effect by its impact on road demand DR. Our DRAG model is an explanation of this simple structure composed of an explanatory part of the road use demand and of an explanatory part of the safety-performance of the entire road network. This distinction between *demand* and *performance*, which we have detailed elsewhere (Florian and Gaudry, 1980, 1983), is frequently used in the analysis of transportation systems.

2.2. Meaning of the framework

Can we indicate an underlying mechanism that helps understanding the Demand-Performance structure used? The fundamental assumption of the microeconomical theory about the consumer's behaviour is that he maximises a utility function exposed to an income constraint. The simplest forms of this mechanism

- do not consider the time needed to consume each good; the time is considered only in employment, which allows a transformation of time worked in money;
- do not deal with uncertainty;
- suppose that the use does not depend on the states of nature (user's wealth, for example)

To be accurate, the explanation for transportation demand and the number of victims would require difficult developments in all its ways. Indeed, speed, for example, is a decision variable that affects the time available for other activities. Yet, there is still no complete theory on the use of time: demand functions used in transportation are generally of intuitive formulation and they take into account the levels of service of transportation modes, or they are strongly linked to a particular problem. As for the literature concerning risk, it has considerably improved in the last few years (see for example the Hirschleifer and Riley abstract, 1979). We distinguish essentially between states of nature - according to an accident occurring or not – and we generally suppose that the accident probability π_a is exogenous and is not affected by people's actions; we also generally presume that utility is not affected by the state of nature. Recent additions tend to modify these hypotheses in order to incorporate the explanation of behaviours, such as speed, which change the probability of the states of nature, as well as their anticipated utility, by modifying the accident probabilities or the severity of occurring accidents (see for example Boyer and Dionne, 1983).

If we exclude a precise differentiation that would incorporate all these elements, we can therefore sketch a relevant structure. The individual tends to maximise a utility function

$$u = u\,(W_n, W_{ag}, \pi^*_{ag}) \;, \qquad g = 1,\ldots, G \qquad \text{(U-1)}$$

where W_n indicates the goods in a non accident case, W_{ag} goods in an accident case at a certain severity level $\underline{g}$, and π^*_{ag} the subjective accident probability of each expectable severity 1, …,G.

Let's suppose that the utility function is quadratic and that the accident severity follows a normal distribution of average μ^*_g and of variance σ^{*2}_g. Lets accept that an activity has autoprotection effects on the accident probability π^*_a and/or autoinsurance effects on the subjective expectation of accident severity $\overline{g}^*$; or of perceived variance (also called perceived risk, σ^{*2}_g). Insecurity, or the overall subjective probabilities of having accidents of all kinds of severity Π^*_{ag} is therefore decomposed in 1 element of autoprotection and in 2 elements of autoinsurance. We presume moreover that 5 activities and 2 states have a particular influence on these elements:

$$\Pi^*_{ag} \equiv \begin{bmatrix} \text{accident probability} & : \pi^*_a \\ \text{average severity} & : \overline{g}^* \\ \text{risk} & : \sigma^{*2}_g \end{bmatrix} \leftarrow \text{(D, M-C, M-M, B, V, XP, XE)} \qquad \text{(U-2)}$$

where the selected factors of interest are

D	: distance in kilometres demand
M-C	: vehicles characteristics at purchase,
M-M	: maintenance level of vehicles,
B	: level of the use of a seatbelt or a shoulder belt,
V	: speed,
XP	: personal characteristics of the consumer, or state of his faculties,
XE	: state of the driving environment : visibility, pavement condition, etc.

The transportation activities D and the speed V can help produce goods

$$W = w\ (D,V) \tag{U-3}$$

and several of the variables controlled by the consumer will affect his budget. In fact, the choice of speed and maintenance will involve consumption rates of fuel C and the wear of vehicles U, for vehicles with characteristics M-C :

$$(C,U) \leftarrow (M\text{-}C, M\text{-}M, V)\ . \tag{U-4}$$

The consumer who maximises his utility adjusts the level of his activities, in regards to his particular state, to the driving environment state, and to his budgetary constraint. If we exclude the purchase of vehicles, considered here as exogenous, we will be able to write the following derived demands:

$$\begin{matrix} \pi_a^* & \bar{g}^* & \sigma_g^{*2} \end{matrix}$$
$$\begin{bmatrix} \surd & - & - \\ \surd & \surd & \surd \\ \surd & \surd & \surd \\ - & \surd & \surd \end{bmatrix} \Leftarrow \begin{bmatrix} D \\ M-M \\ V \\ B \end{bmatrix} \leftarrow (P, Y, XP, XE) \quad , \qquad (U-5)$$

where P indicates all the prices in the economy, Y the income, and the last two elements indicate the personal factors and the driving environment factors. The matrix of impacts associates, to each element of derived demand, an effect on the subjective accident probability, the subjective expectation of severity and the subjective variance of severity. We think that the maintenance state of vehicles and the speed affect the autoprotection and the autoinsurance, while the distance in kilometres affects only the autoprotection and the use of a seatbelt and a shoulder belt affects the autoinsurance. Can we make reasonable predictions about the effects of the modifications of the various factors on the final demand of the safety elements? We will suppose that the three elements are substitutes, meaning that a « riskophobic » consumer can be maintained at the same utility level by giving up a component for any other one or for the two others following a diminishing marginal rate of substitution. Let's now formulate impact predictions with the help of this simplifying supposition that will allow us an approximate representation of the choices between the insecurity Π_{ag}^* components.

First, let's fix the individual's characteristics XP and the ones of the available infrastructure XE. What will be the effects of price changes if we disregard the effects of the income? To answer this question, let's associate to D a toll P_d, to M-M a price P_{mm}, to V a price P_v and to B a price P_b. The anticipated effects of the increases in prices are therefore

	P_d	P_{mm}	P_v	P_b
D	-	-	+	-
M - M	-	-	-	+
V	+	-	-	−
B	+	+	−	−

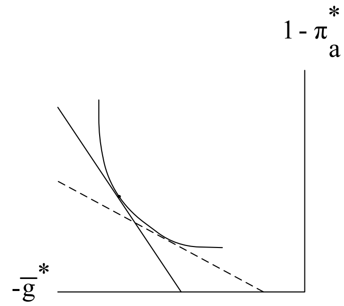
because, in (U-2), the rates by kilometre M-M, 1/V and B are among themselves technological substitutes while the distance in kilometres is their technological complement : we can keep a certain level of safety by combining "driving less" and "wearing less often our safety belt" or "driving faster" or "maintaining less our vehicle".

Let's consider, for example, a drop in the relative price of using a shoulder belt (an increase in imposed penalties if not worn) compared to the relative price of speed. We can represent the effect on speed in the two-dimensional figures 1.a and 1.b of table 1. We see in 1.a that the consumer increases his accident probability (reduces his protection) and reduces the severity of his accidents (increases his autoinsurance) by going from point 1 to point 2 on his indifference curve i. To do so, he increases his use of a shoulder belt, which moves the arbitrary curve between the probability of accidents and their severity (to constant perceived variance σ_g^{*2}) from A to B in i.b where these curves are arbitrarily drawn between V = 0 and V = 200. For the consumer it means substituting a form of insecurity for another, which is done in order to keep its utility constant.

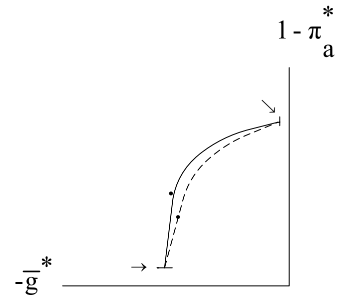
Conjecture 1

> When the income has no effects, an increase in the price of one of the activities reduces the demand for this activity and its technological complements and increases the demand for its technological substitutes in the safety production function.

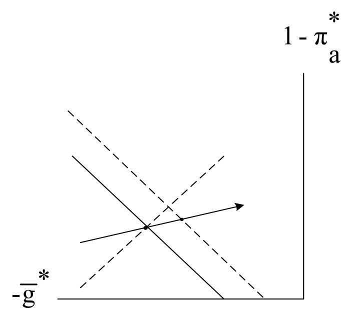
TABLE 1*:* Eight figures on the autoprotection ($1 - \pi_a^*$) and autoinsurance (-g*) demand



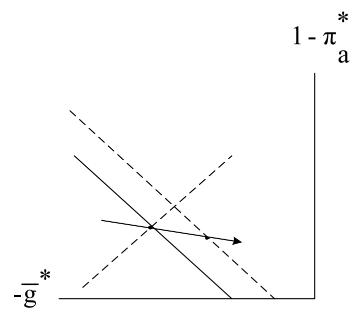
1.a. Decrease of the relative price of wearing a shoulder belt compared to the price of the speed



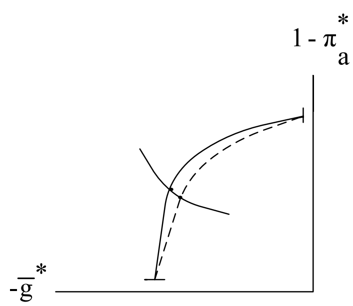
1.b. Arbitrage between π_a^* and $-\bar{g}^*$: with (B) and without (A) wearing a shoulder belt



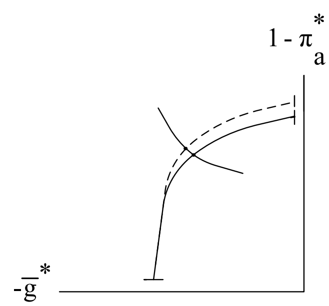
2.a. Increase in revenue



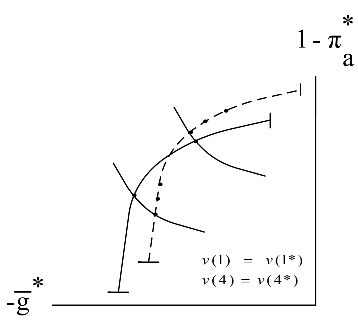
2.b. Increase in salary: Peltzman's case



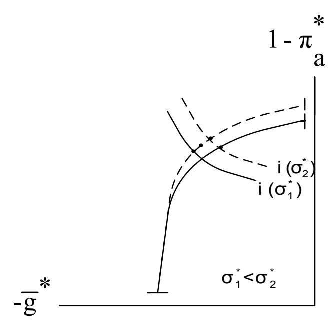
3.a. Improvement of cars



3.b. Better road maintenance



4. Transformation of a road (A) in highway (B)



5. Two possible effects of ebriety

What happens when a modification in the income does not affect the relative prices? This situation is illustrated in figure 2.a where moving from point 1 to point 2 represents the impact of an increase in the hourly wage. In a very particular case, where the consumer maximises his riches or his income and has to drive on a given distance in kilometres on a determined infrastructure, Peltzman (1975) arrives to an increase in accident probability and a drop in severity. This situation is illustrated in figure 2.b. Generally speaking, the effect of a rise in income, which is not subject to these constraints, is uncertain, even if the variance or severity risk σ_g^{*2} is constant.

Conjecture 2

When there are no changes in the relative prices, an increase in the income will raise the protection and insurance demand. We do not know if both of them will proportionally increase.

What can we expect if the prices and the consumer's income are fixed but the environmental characteristics change? Let's still suppose that the severity risk σ_g^{*2} is fixed. First of all, let's consider measurements that would reduce the severity of accidents occurring at a given speed, such as a modification (required by law) on vehicles, airbag for example, or the installation of buffer tools and spoilers surrounding the fixed objects installed along the roads; second of all, let's consider taking measures, such as night lightning and salt spreading in winter, that would, to a given speed, reduce the accident probability without affecting the distribution of their severity.

We can illustrate these cases in figures 3.a and 3.b. In the first one, we, for example, force the consumer to buy cars that are better assembled …. or we improve the medical help services for injured people. By moving from point 1 to point 2, located on the same indifference curve, the consumer increases his subjective probability of accidents and reduces their severity. In the second figure, we improve the roads maintenance, for example with sand spreading in winter. The consumer reduces his accidents probability but increases their severity.

Conjecture 3

> A technological or environmental modification that has no effect on the variance of accident severity will encourage the consumer, to whom it is imposed, to substitute to one an another, so to compensate, both the accident probability and their severity.

The effect is uncertain in the case of road improvements (such as the construction of limited access and large capacity freeways), which would affect both the probability of accidents and their severity to a given speed. As indicated in figure 4, where curve A goes to the north-east and becomes B, the consumer who would go from point 1 to point 2 would do as in 3.a, and the one who would go from point 4 to point 3 would do as in 3.b, always assuming that the severity variance is constant.*

* In reality, the variance of the severity is not constant. At points 2 and 3 the speed is so higher than at points 1 and 4, that the consumer will reduce it and will go to 5 or 6.

Conjecture 4

> Environmental factors that simultaneously modify the accident probability and their severity have uncertain effects.

What happens if the variance of severity is affected? The hypotheses of substitution stated previously involve a substitution in favour of the 2 other safety components. Eeckhoudt and Hansen (1984) demonstrate that we often expect a rise in accident probability when the variance, or risk, decreases without affecting the average severity. It is hard to imagine factors that influence the spreading of the distribution without also influencing its average. It might be the case with some of the factors such as driving under the influence of alcohol: it is possible that, to a given speed and a given accident probability, the perceived variance of severity increases due to impaired faculties. The consumer will try to reduce the accident probability and its average severity. In figure 5, the transition from point 1 to point 2, following the movement of the indifference curve towards the top, would cause less accident and less serious ones. If however a compensatory movement of the perceived arbitrage from A to B leads the consumer to increase his speed and to believe that he is at point 3 while he is, in reality, at point 1*, there is, at this point, more accidents than at 2 and the accidents are more severe; another movement of the perceived arbitrage would place him to the left of point 1 which is in reality more dangerous than the starting point.

Conjecture 5

> The environmental or personal factors that reduce the variance of severity will increase the probability of accidents and their average severity. If however, these factors also change, to a given speed, the perceived probability of having an accident or the anticipated severity of it, then their effect is uncertain.

The conjectures stated previously do not all consider the possible difference between the subjective and objective values of the probabilities of having an accident, the severity of it and the risk. Even if the consumer knows the *direction* of an effect, he can be wrong about its *level*. A driver who is under the influence of alcohol can reduce his speed to compensate for his impaired faculties but can be wrong about the real level of probability associated to the reduced speed; he can overcompensate or undercompensate, even if he is looking for an exact compensation. If this ignorance is considered by the consumer as an important rise of the variance of severity, it can reduce accidents and their average severity. Otherwise, its effect is uncertain.

Conjecture 6

> The consumer's difficulty to estimate the changes of insecurity levels will have an uncertain effect on his probability of having accidents and on their

For our problem, it is important for transportation and its autoprotection and autoinsurance activities to be the object of a derived demand. It is also important that the individual adjusts these elements in order to obtain goods and a certain subjective accident *probability* of a certain subjective and average *severity* to which is linked a subjective variance, itself a measurement of "*certainty*" or risk. Moreover, for these three components of road safety, it is important that a deviation between their *subjective* dimension and their *objective* value remains. This deviation between the subjective components of Π^*_{ag} and the real values Π_{ag} should be more important for the environmental factors (rain, snow, mist) or the personal factors (ebriety, disease) than for the 5 activities demonstrated in (U-2). We can hardly imagine that an individual believes he reduces his safety by increasing his speed; we better imagine than an individual under the influence of alcohol insufficiently reduces his speed in order to compensate for his impaired faculties.

2.3. **Implications for components interpretation**

We can derive several useful information from this. Since the fuel consumption is the product of a kilometrage demand D and of a derived level of consumption C, the factors relating to demand functions (U-5) and to a production function of type (U-4) will be found in an explanatory function of the fuel demand. We can therefore rewrite (D) as followed

$$\begin{aligned} DR &\leftarrow (X^c, X^d) \ , \\ DR &\leftarrow ((\text{M-C, M-M, V}), X^d) \ , \end{aligned} \qquad \text{(SD)}$$

where X^c means the determinants of the consumption level and X^d the ones of the kilometrage demand. We can now see that there is a major inconvenience in observing the fuel consumption instead of the vehicles kilometrage: if a variable such as the vehicles maintenance cost is used to represent the maintenance condition of the vehicles (which is not observed) and if it belongs also to the ensemble X^d of the variables that determine the kilometrage demand, we will not know if its effect on fuel consumption is attributable to its effect on the kilometrage or on the level of consumption.

We can also better understand the meaning of the procedures such as (P) that establish the number of victims. Indeed, if we express the average value of insecurity $\Pi^*_{ag} = (\pi^*_a, \overline{g}^*, \sigma^{*2}_g)$ as a rate by distance unit Π^*_d for all the drivers, the derived demand of victims VI^d is given by

$$VI^d \leftarrow (DR, \Pi^*_d) \quad .$$

The performance of the system is however different from the derived demand because individuals can be wrong about the objective probabilities of accidents. Let's suppose that it is snowing or that a driver drinks alcohol: his estimation of the probability Π^*_d for himself can be different from the measurable objective probability. To obtain the objective performance of the system, we need to add a group of factors that can be significant even after the drivers' adjustments. We therefore have to rewrite (P) in the following form:

$$\begin{aligned} & VI \leftarrow (DR, \Pi^*_d, X^{mc}, X^{mm}, X^b, X^v) \\ \text{or} \quad & \\ & VI \leftarrow (DR, (M\text{-}C, M\text{-}M, B, V), X^{mc}, X^{mm}, X^b, X^v) \qquad \text{(SP)} \end{aligned}$$

where the X ensembles successively mean the determinants of vehicles characteristics, of their maintenance state, of the use of a shoulder belt and of speed, and they include the personal characteristics XP.

As for the aggregated performance function, this formulation allows to take into account, in part, the road demand composition, even if the variable DR cannot represent exactly the influence of someone's actions on the actions of others. We did not consider this influence in the previous formulation since the real equilibrium of speeds between all the drivers interacting on a road without congestion is a very difficult microeconomical problem for which the eventual resolution would have little influence on our aggregated formulation.

If we observed the state of vehicle maintenance M-M, the use of a shoulder belt B and the speed V, we could therefore ask the following question: do the drivers correctly estimate the objective probabilities? Indeed, a driver who would have taken alcohol, for example, could have adjusted his speed so to get a certain subjective accident probability. In that case, the alcohol consumption variable enclosed by X^v would have no effect since the driver would have compensated for his ebriety by adjusting his speed: once the observed speed is taken into consideration, the alcohol consumption would not be useful to any explanation. Of course, it is possible that the driver underestimates or overestimates the objective accident probability. Considering the speed adjustment, the objective accident probability might be lower than before because the driver will have overcompensated. Hence, if the speed coefficient is negative, the alcohol or snow coefficient will be positive (under-compensation) or negative (over-compensation) depending on the case. That is also the case for the other actions that modify the probability of accidents or their anticipated severity, such as the vehicle maintenance or the use of a shoulder belt: nothing guaranties the equality of the subjective and objective probabilities of accidents or of their severity.

2.4. Problem of the non observed endogenous variables

The equations (SD) and (SP) are structural equations. Unfortunately, they contain variables, in particular the state of the vehicle maintenance M-M, the use of a seatbelt and a shoulder belt B and the speed V, for which do not exist any data in time series even if we have localised spot samples on the use of a seatbelt (Paquet, 1980; Haince, 1981a, 1981b; Paquet and Viel, 1982) and on speeds on different points of the network[1]. Usually, the solution to this problem is to substitute, to each of these variables in the considered equation, all of its explanatory variables. If, for example, due to the equation of speed demand (when there is no road congestion) taken form (V-5), the speed linearly depends on the fuel price X_{10} and the income X_{11}, as followed

$$V = v_0 + v_{10}\, X_{10} + v_{11}\, X_{11} \qquad ,$$

and that the function of structural demand (SD) already includes these two variables in X^d in addition to the speed X_q, we will have by substituting this function (supposedly linear) :

$$DR = \ldots + (\delta_q\, v_{10} + \delta_{10})\, X_{10} + (\delta_q\, v_{11} + \delta_{11})\, X_{11} \qquad .$$

The estimated coefficients of this equation, called reduced form, will be mixes of the coefficients of the structural equations. They will generally be of ambiguous sign, according to the relative values of their components. Presence of endogenous variables, for example, of DR in the equation of speed demand, complicates the estimated coefficient of the reduced form.

The lack of observations concerning M-M, B and V will force us to interpret cautiously the estimated effects, in particular for the variables which we suspect the presence in the equations determining the speed and their presence in the structural equations of demand or performance. If we could have had the data on these variables, our results would have been more effective, and it would have been easier to explain the estimated coefficients. We will see that these difficulties in the interpretation do not seem to negatively affect our thoughts on the estimated "net impacts".

So, we have at our disposal reduced forms for the demand and the performance: the set X^{dr} in (D) includes the explanatory variables of speed and of the other unobserved endogenous variables, in addition to the variables related to this structural relation; the variables X^{vi} in (P) play, at the same time, an explanatory role of the absent endogenous variables as well as a "residual" explanatory role that they would have played if the endogenous variables would have been available.

2.5. <u>Framework explanation: a 5-layer model</u>

Even if our equations will be "reduced forms", we will continue to use the expressions "demand" and "performance". Before explaining the model more precisely, a first clarification of this structure is required for a properly use of the existing data. The structure that we plan to develop has in reality 5 layers.

As for the demand, there are no data on the fuel sales for highway use, but only data on fuel sales for these uses and other uses (agricultural, building sites etc.). We will therefore need a preliminary stage of data correction to get a measurement of the fuel sales for highway use. The proposed model serving this purpose has the following linear form for every monthly t observations (we here overlook this index):

$$DC = (DNR + DR) = \sum_i \beta_i \, X_i^{dnr} + \sum_j \beta_j \, X_j^{dr} + e^{dr} \quad , \qquad (D-1)$$

where

DC = total fuel sales observed,

DNR = fuel sales for off-highway uses (unobserved),

DR = fuel sales for highway uses (unobserved),

X^{dnr} = explanatory factors of the sales for off-highway uses,

X^{dr} = explanatory factors of the sales for highway uses,

e^{dr} = residual error.

From this first layer, we get the fuel sales for road use DR, which we obtain by adjusting the total sales[2] of the X_i^{dnr} influence. We subject these adjusted data to a second-level explanation:

$$DR \leftarrow (\quad X^{dr}) \quad , \qquad (D-2)$$

We also have to explain the performance (P). In fact, generally speaking, the study of the mechanism that determines the number of victims can be beneficial if distinguishing between the explanation of the number of accidents AC and the explanation of their severity GR defined as the number of victims by accident. We can write:

$$AC \leftarrow (DR, X^{vi}) \ , \qquad (P-3)$$
$$GR \leftarrow (DR, X^{vi}) \ , \qquad (P-4)$$
$$VI \ = \ AC \cdot GR \qquad (P-5)$$

where the layers 3 and 4 are subject to statistical evaluations and the fifth layer is a simple definition. Of course, there are particular cases (for example, logarithmic equations) where there is no use in making this operation. However, in our case, comparisons[3] between the simple procedure (P) and the procedure that distinctly studies accidents and their severity have indicated gains (essentially due to the fact that the functions are not generally logarithmic).

3. CHOSEN FORMULATION

3. CHOSEN FORMULATION

In the previous section, we did a simple presentation of the framework used and we also observed that the lack of data on vehicles maintenance, the use of the seatbelt and shoulder belt and speed, limited us to a formulation of reduced forms to explain the road demand and the safety-performance of the Quebec road network. We have also pointed out that, in order to correctly use our data, we had to distinguish 2 layers in the demand explanation and 3 layers in the performance-safety explanation. It is now time to precisely mention the elements of the demand and performance we will use and the categories of explanatory variables we will choose; we will also formulate the econometrical model and we will classify our formulation according to the current models of the literature. Comments concerning the individual explanatory variables will be made when presenting the results; we will only make general comments here on the role of these variables.

3.1. **Dependent variables**

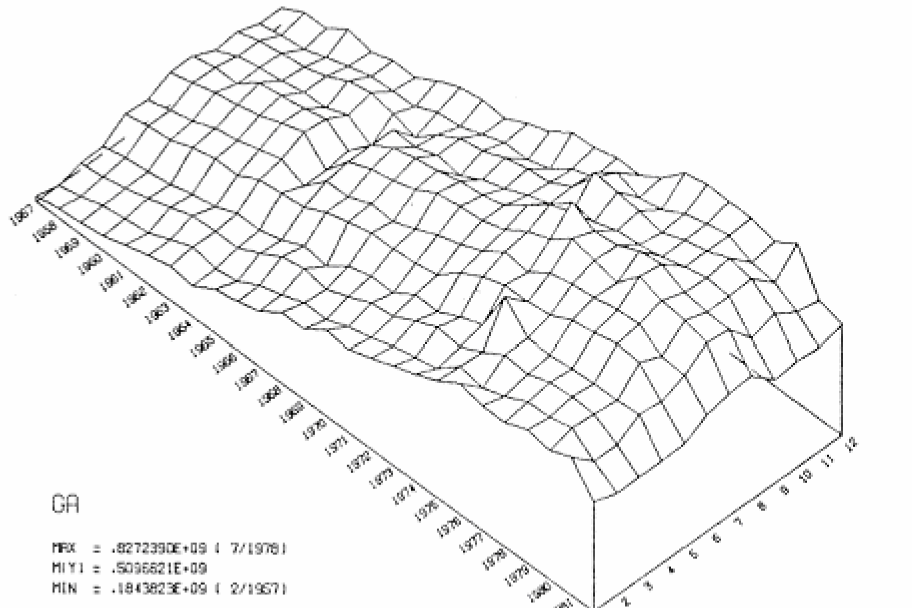
We will briefly describe the nature of each dependent variable used in the model and we will illustrate each of them with traditional graphics and three-dimensional graphics that show the variations otherwise. These graphics only show the superior section of the considered volume, more precisely the levels of the variable located between the minimum and maximum values of the observations. The graphics of the sequences start in January 1957 and end in December 1982. Details on their construction are given in the complementary report on the file FRQ (Gaudry *et al.*, 1984) in which the sequences for parameters estimation, used later on in this research, start in December 1956.

In the first layer, we explain the total gross sales of fuels DC. These measurements include two unobserved components, sales for off-highway use DNR and highway use DR that we can "find" using the variables X^{dnr} for the first ones and X^{dr} for the others. The model has two equations: one for the total gross sales of gasoline and one for the gross sales of diesel:

$$DC = [DNR + DR] \begin{cases} \bullet\ GA = \text{gross sales of gasoline for highway use and off-highway use,} & \text{(D-1.1)} \\ \bullet\ DIC = \text{gross sales of diesel (corrected from railway use) for highway use and off-highway use} & \text{(D-1.2)} \end{cases}$$

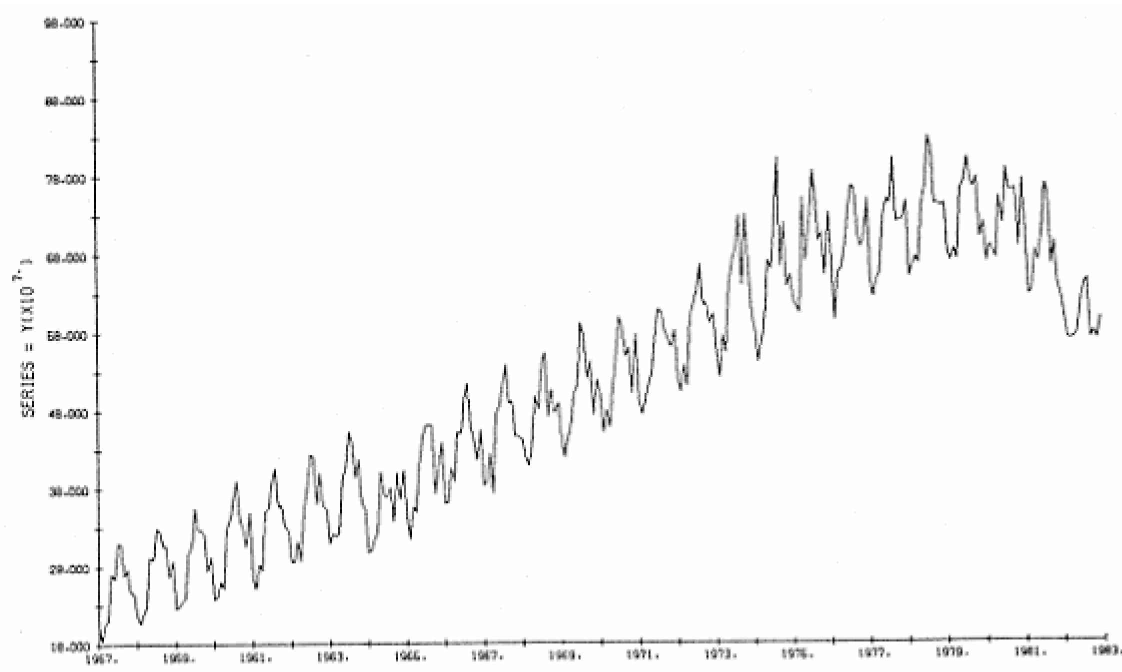
We will see in graphics GA and DIC that these two sequences differ a lot from one another and include important seasonal elements. We notice that the first 4 years of the sequence DIC have been subjected to a menzualisation. Tests of explanatory model DIC suggested that it would not affect much the results.

In the second layer, we explain the fuel demand for highway use DR as it is drawn from the first-layer results that has "cleared" the gross sales observed from their off-highway components. The level 2 is, in its simplest form, a component of level 1 (we are talking about the same lists of factors from which we have taken out, for gasoline, 2 variables and, for the diesel, 7 variables); in its more complex forms, a model of demand for motor vehicle fuels that uses data "adjusted" by level 1:



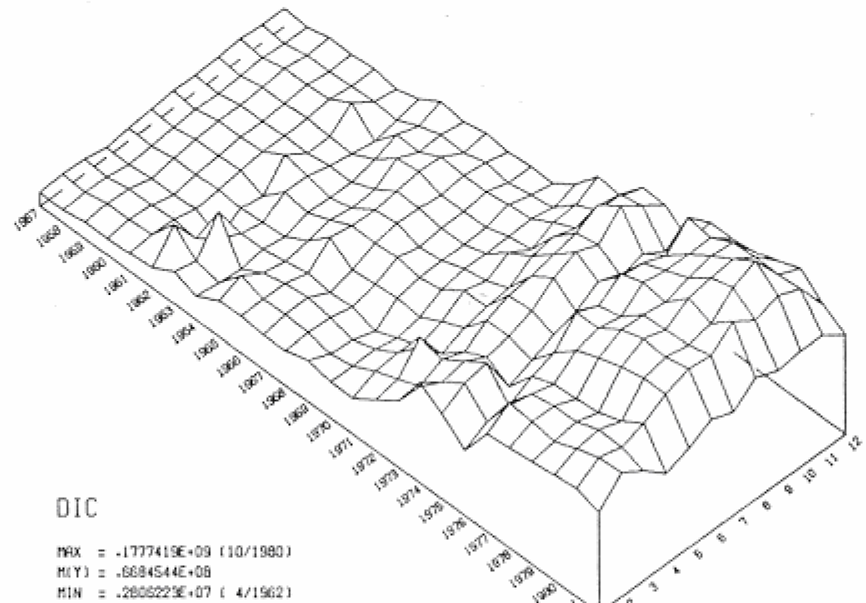
(JAN 1957 - DEC 1982)

GROSS GASOLINE SALES IN QUEBEC (LITERS)



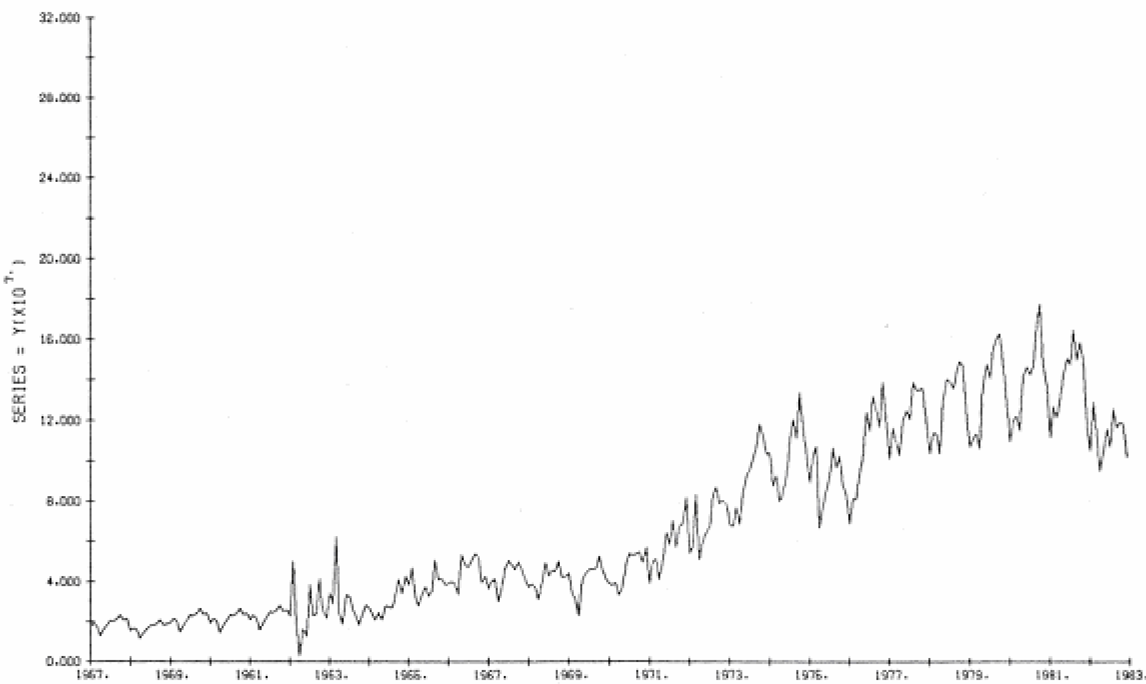
GROSS GASOLINE SALES IN QUEBEC (LITERS)

(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

GROSS DIESEL SALES RECORRECTED, QUEBEC (LITERS)



DIC

GROSS DIESEL SALES RECORRECTED, QUEBEC (LITERS)

(JAN 1957 - DEC 1982)

$$DR \begin{cases} \bullet\ GAR1 = \text{gross sales of gasoline for highway use,} & \text{(D-2.1)} \\ \bullet\ DICR1 = \text{gross sales of diesel for highway use.} & \text{(D-2.2)} \end{cases}$$

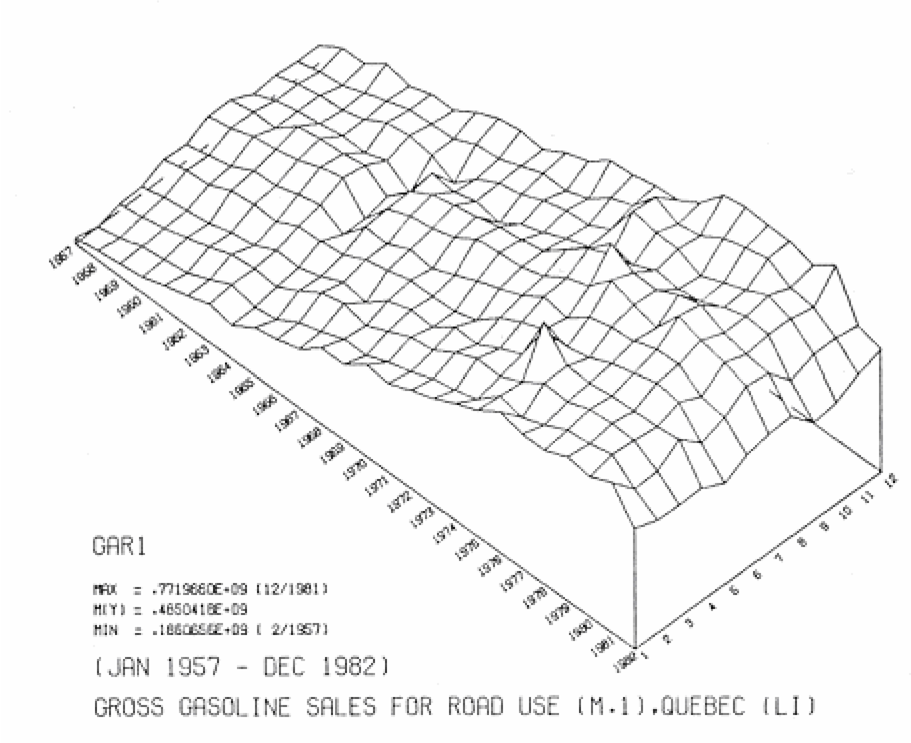
We will see in the graphics that these measurements, obtained from the results shown later on (which define the adjustment "1"), involve an average reduction of 4,8 % for GAR1 compared to GA and of 11,1 % for DICR1 compared to DIC; except for the estimation bias, highway fuel uses are closer to the total sales than we expected because some of the variables for which we estimated the importance (tax evasion, for example) force us to increase the apparent sales. Most of the considered factors (agricultural interests, for example) oblige us to subtract quantities to the total sales and involve a downward correction.

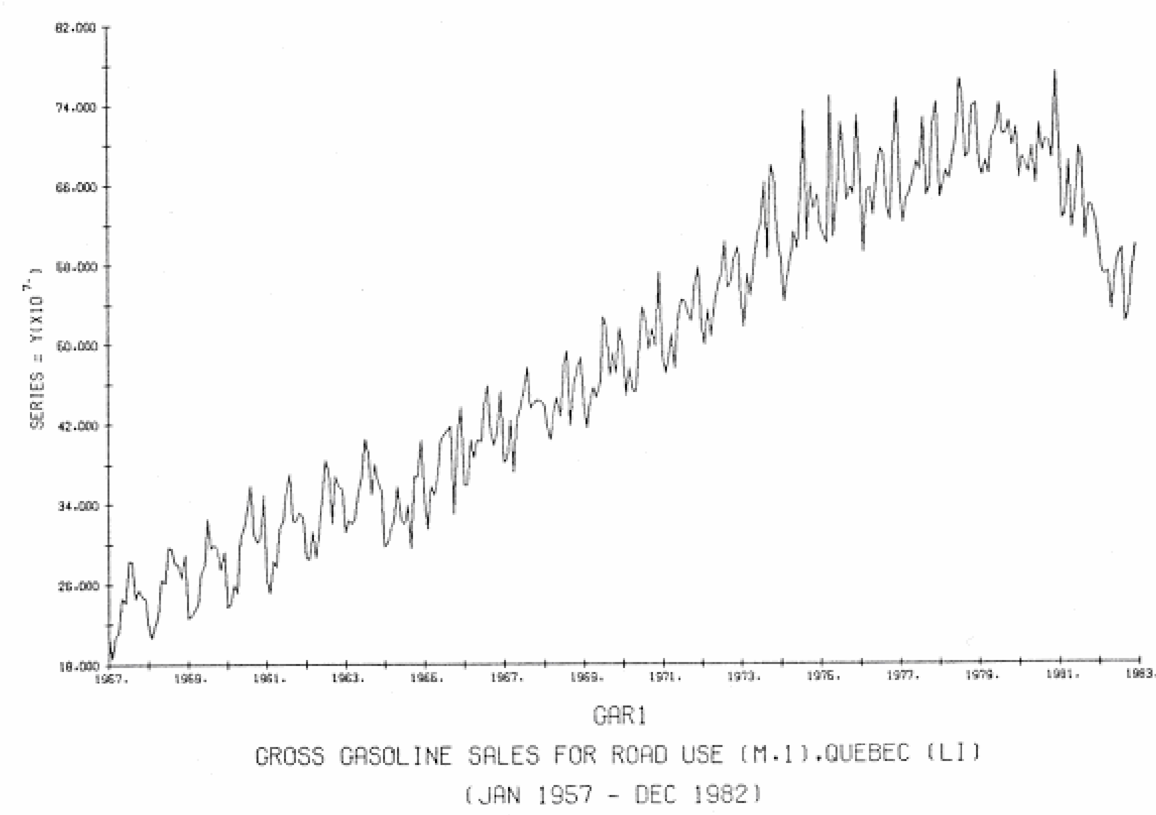
In the third layer, we explain AC that includes 3 accident categories and two aggregations of these categories:

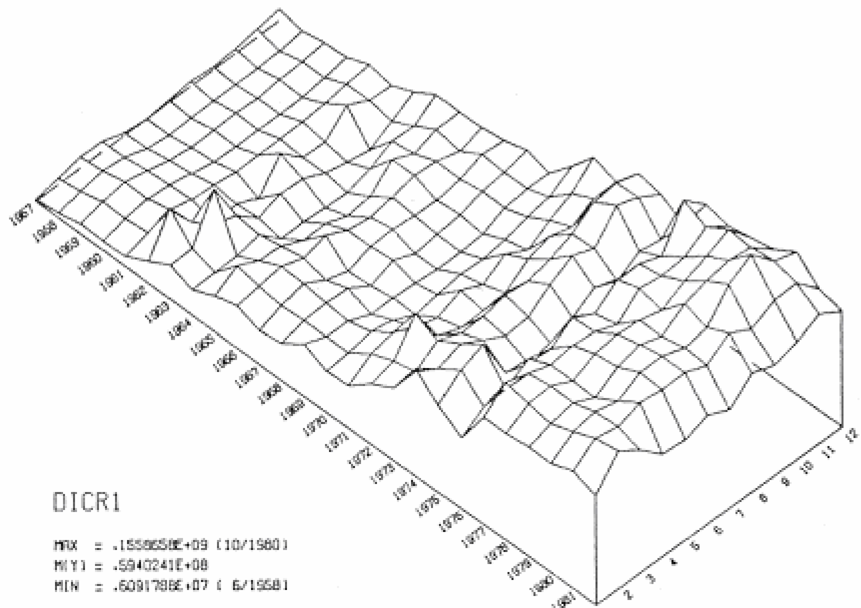
$$AC \begin{cases} \bullet\ MA = \text{accidents with material damages only}^{*}, & \text{(P - 3.1)} \\ \bullet\ NM = \text{accidents with at least 1 injured person,} & \text{(P - 3.2)} \\ \bullet\ MO = \text{accidents with at least 1 person killed,} & \text{(P - 3.3)} \\ \left[\begin{array}{l} \bullet\ COR = NM + MO = \text{accidents with bodily injuries,} \\ \bullet\ ACC = MA + NM + MO = \text{total number of accidents} \end{array} \right] & \begin{array}{l} \text{(P - 3.4)} \\ \text{(P - 3.5)} \end{array} \end{cases}$$

Since 1978, the police reports, from which these data were taken and where all the reported accidents that occurred on the public way are displayed (pedestrians, cyclists, cars, etc.), distinguish between accidents with serious injuries and slight injuries. We do not use theses sub-totals of NM because the sequences are shorter than the others and should be subjected to a distinct analysis.

* Excluding the accidents of an estimated value lower than a certain limit.

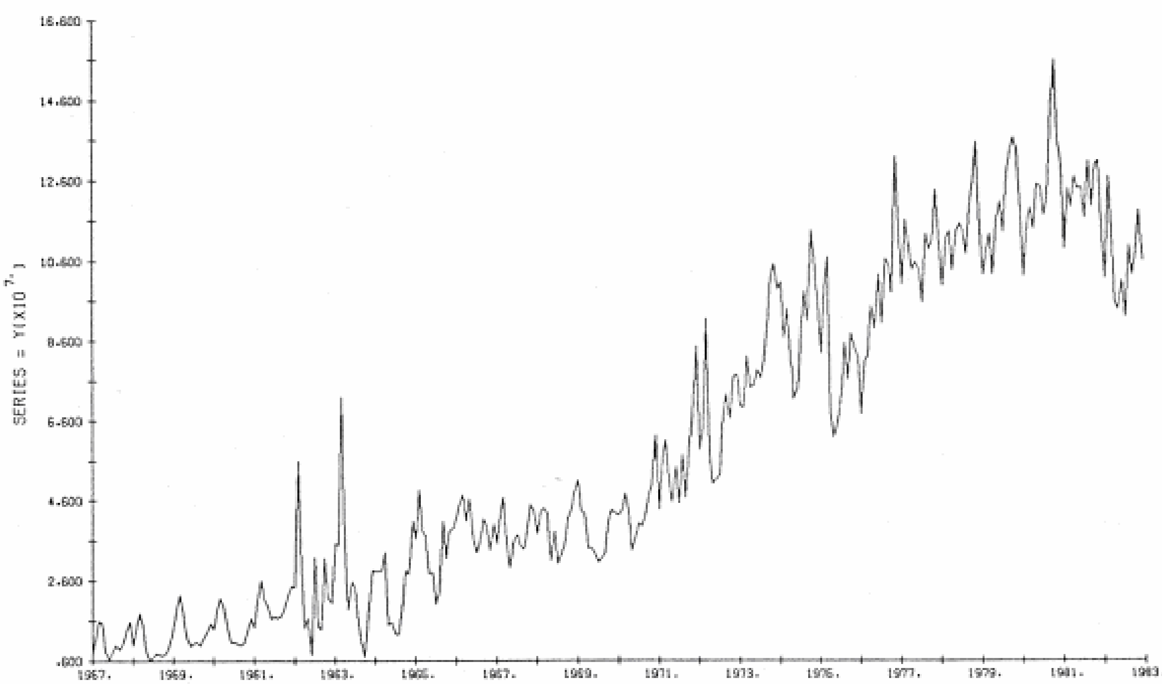

GAR1
MAX = .7719660E+09 (12/1981)
M(Y) = .4650418E+09
MIN = .1860656E+09 (2/1957)
(JAN 1957 - DEC 1982)
GROSS GASOLINE SALES FOR ROAD USE (M.1),QUEBEC (LI)


82.000
74.000
66.000
58.000
50.000
42.000
34.000
26.000
18.000
SERIES = Y(X10 7)
1957.
1959.
1961.
1963.
1965.
1967.
1969.
1971.
1973.
1975.
1977.
1979.
1981.
1983.
GAR1
GROSS GASOLINE SALES FOR ROAD USE (M.1),QUEBEC (LI)
(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

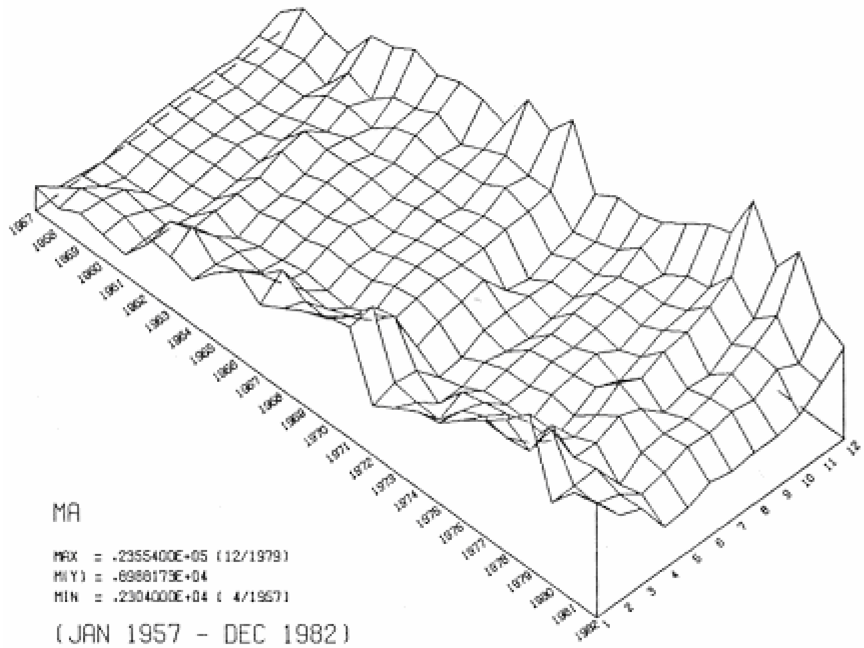
GROSS DIESEL SALES RECO.FOR ROAD USE (M.1).QUEBEC (LI)



DICR1

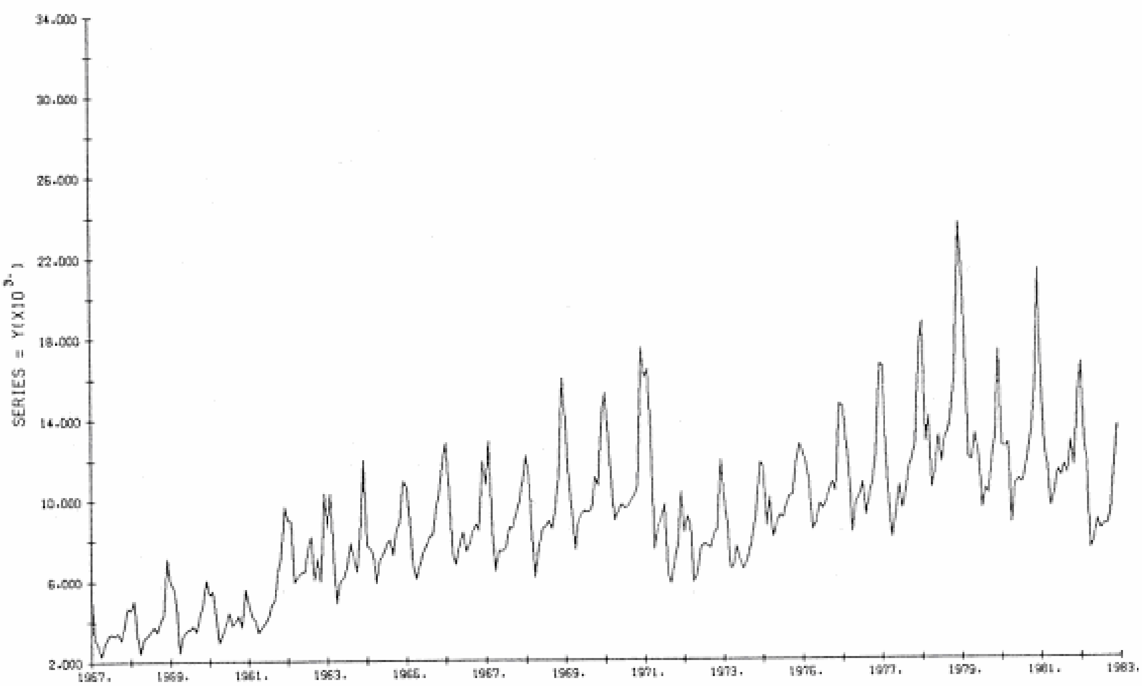
GROSS DIESEL SALES RECO.FOR ROAD USE (M.1).QUEBEC (LI)

(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

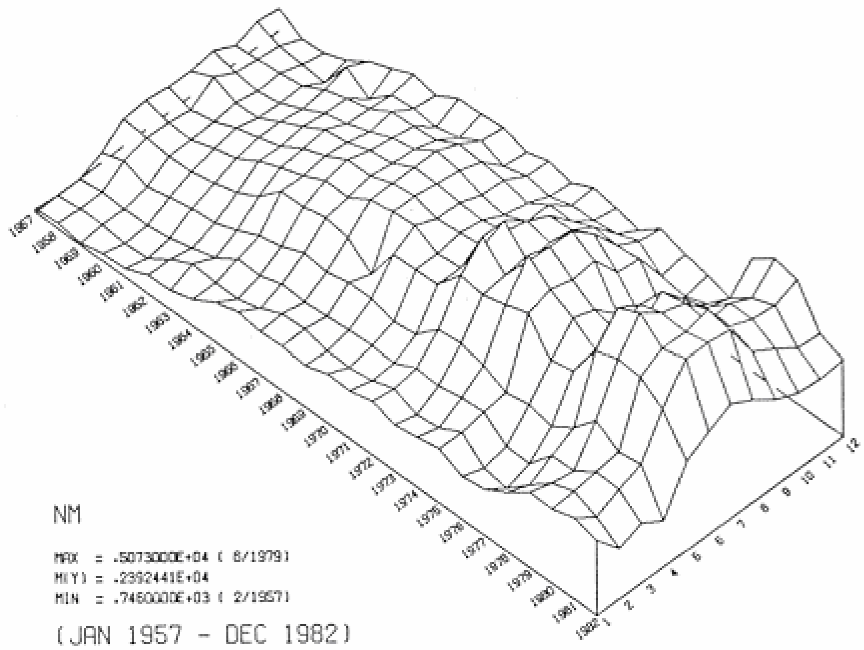
NUMBER OF ACCIDENTS WITH MATERIAL DAMAGES ONLY, QUEBEC



MA

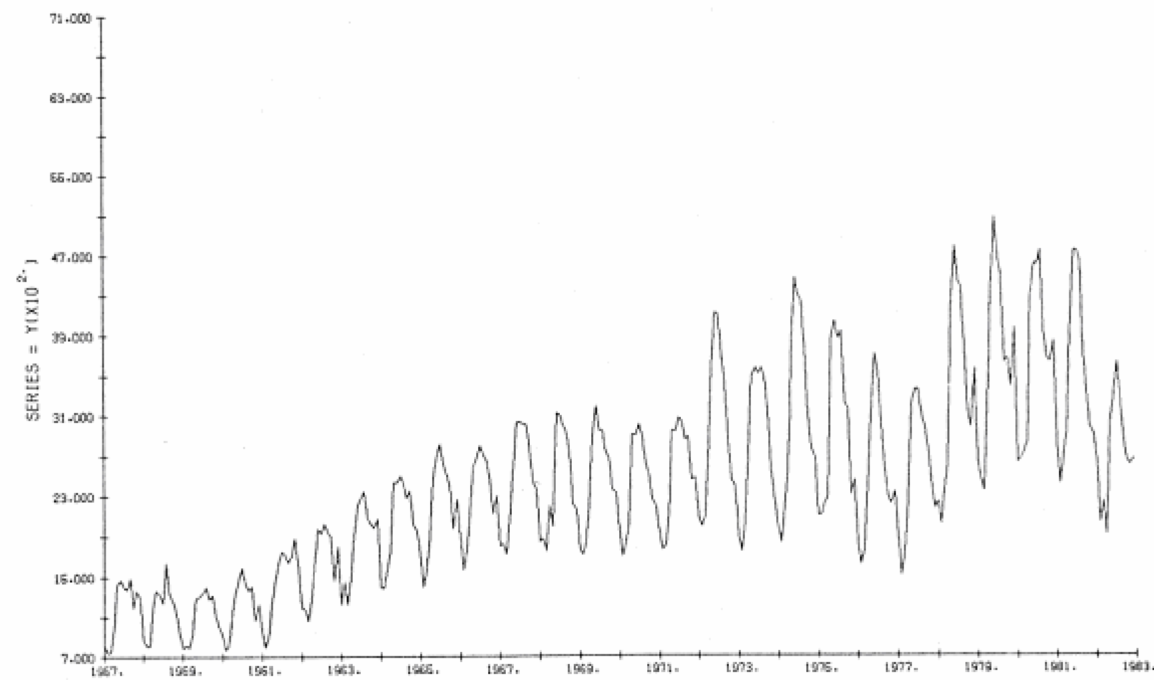
NUMBER OF ACCIDENTS WITH MATERIAL DAMAGES ONLY, QUEBEC

(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

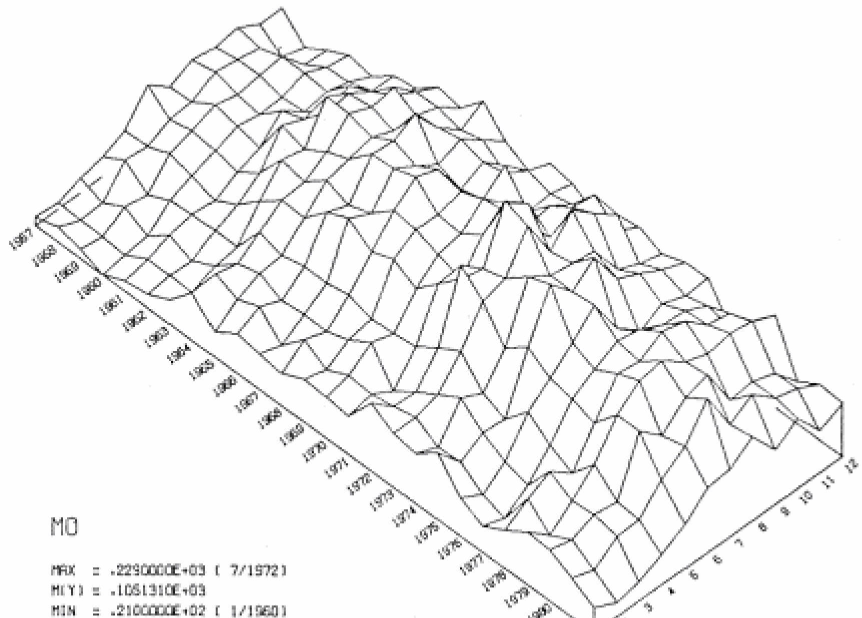
NUMBER OF NON MORTAL ACCID. (WITH PERSONS HURT),QUEBEC



NM

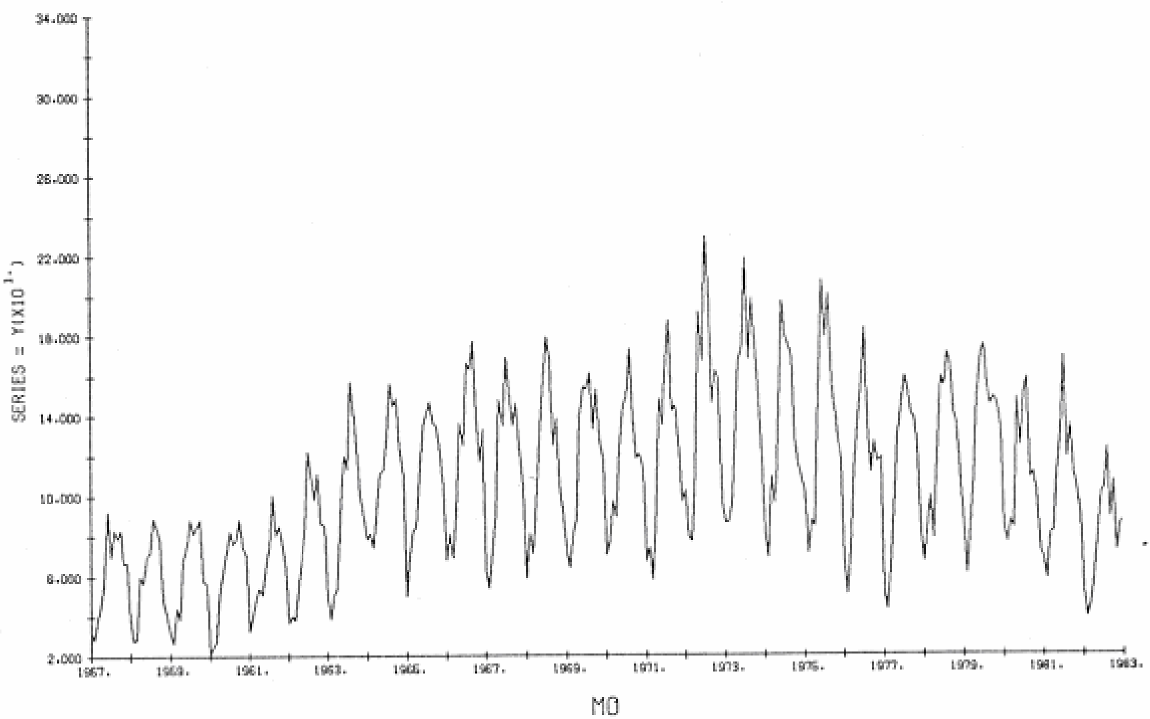
NUMBER OF NON MORTAL ACCID. (WITH PERSONS HURT),QUEBEC

(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

NUMBER OF MORTAL ACCID. (WITH PERSONS KILLED), QUEBEC



NUMBER OF MORTAL ACCID. (WITH PERSONS KILLED), QUEBEC

(JAN 1957 - DEC 1982)

As for the statistical power, the first three equations contain all the information we need on the number of accidents. Besides, later in layer 5, we will use only the results obtained on the components (P-3.2) and (P-3.3) in order to calculate the number of victims associated with each explanatory factor instead of using the less effective results of (P-3.4). However, we will show the results obtained for COR and ACC to help the reader understand the comparison with results of other researchers who would have explained sub-totals or the total instead of their components.

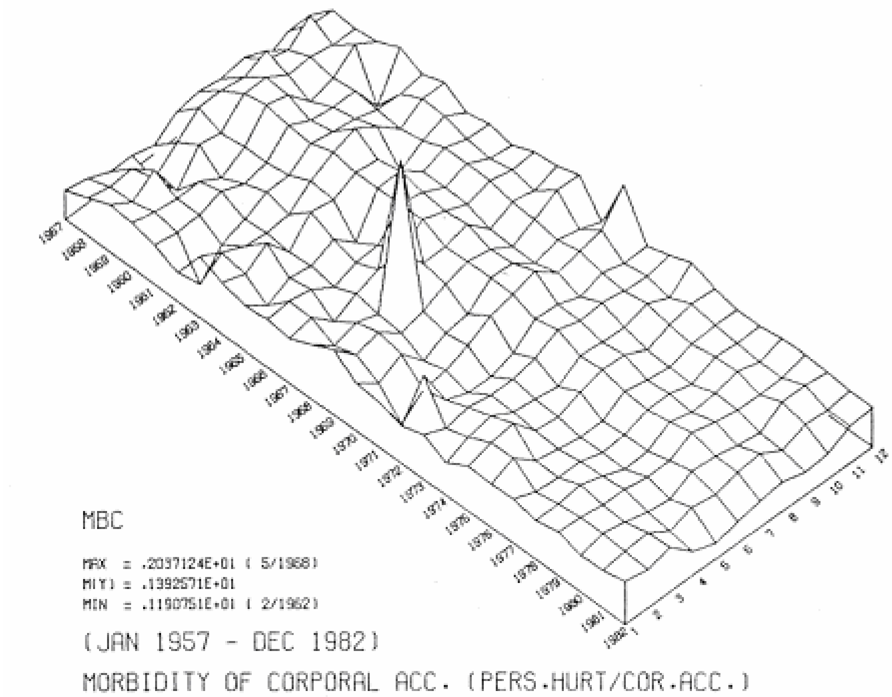
By looking at graphics MA, NM and MO we will see three completely different phenomena. So, we expect the stratification to be very beneficial. We will not be surprised, further on, to find out that some factors have very different effects on each type of accidents. We do not show the graphics COR and the graphics ACC because they are too similar to their dominant components, NM and ACC.

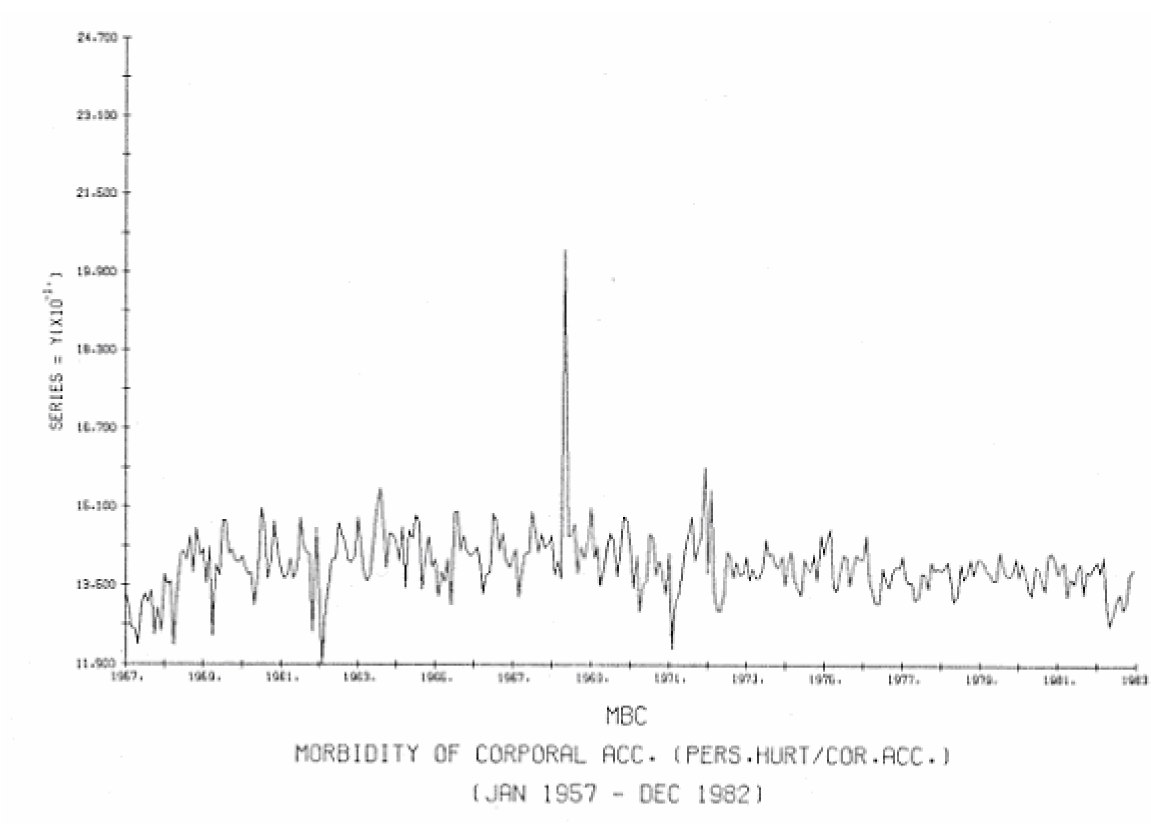
In the <u>fourth</u> layer, we explain two measurements of the accident severity GR:

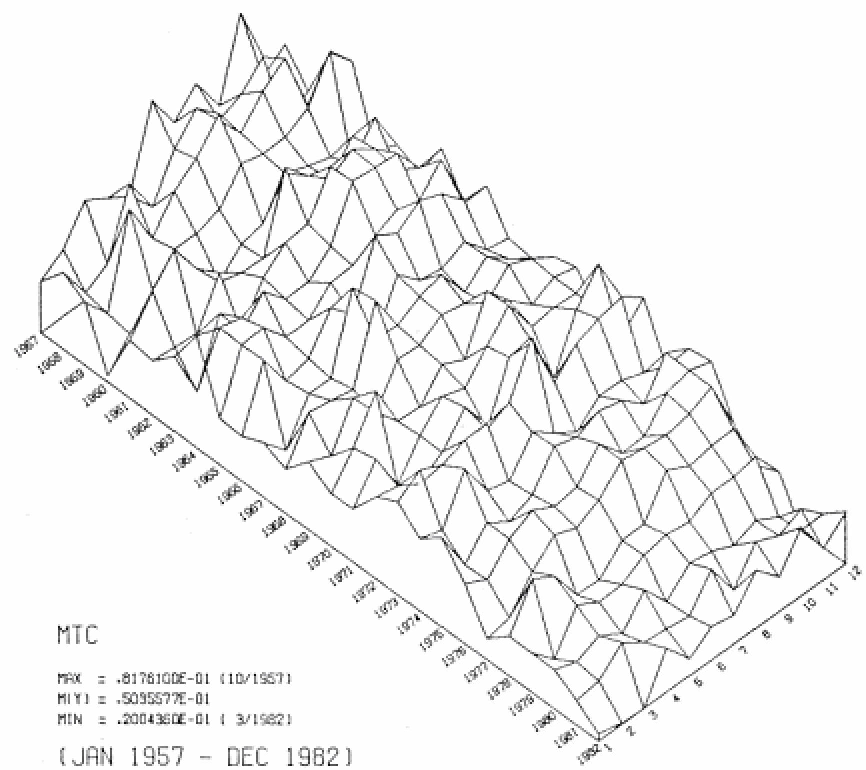
GR

- MBC = HT/COR morbidity of accidents or number of persons injured per accident with bodily injuries, (P-4.1)
- MTC = DE/COR mortality of accidents or number of persons killed per accident with bodily injuries. (P-4.2)

We observe on graphics MBC and MTC that there are different phenomena and that the breakdown must, here also, be useful. We could have defined other severity measurements by dividing the number of people injured or killed by the total number of fatal accidents. If we had used the total number of accidents as the denominator, there would have been errors in measurements of accidents with material damages only, which

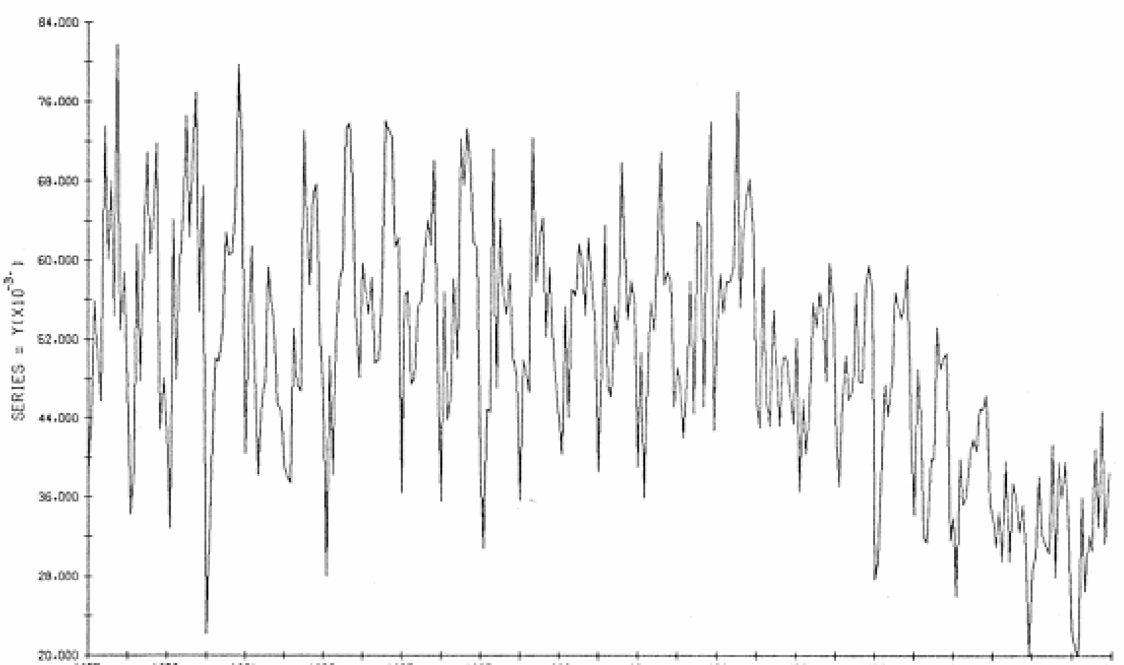

MBC
MAX = .2037124E+01 (5/1968)
M(Y) = .1392571E+01
MIN = .1190751E+01 (2/1962)
(JAN 1957 - DEC 1982)
MORBIDITY OF CORPORAL ACC. (PERS.HURT/COR.ACC.)


24.700
23.100
21.500
19.900
18.300
16.700
15.100
13.500
11.900
MBC
MORBIDITY OF CORPORAL ACC. (PERS.HURT/COR.ACC.)
(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)

MORTALITY OF CORPORAL ACC. (PERS.KILLED/COR.ACC.)



MTC

MORTALITY OF CORPORAL ACC. (PERS.KILLED/COR.ACC.)

(JAN 1957 - DEC 1982)

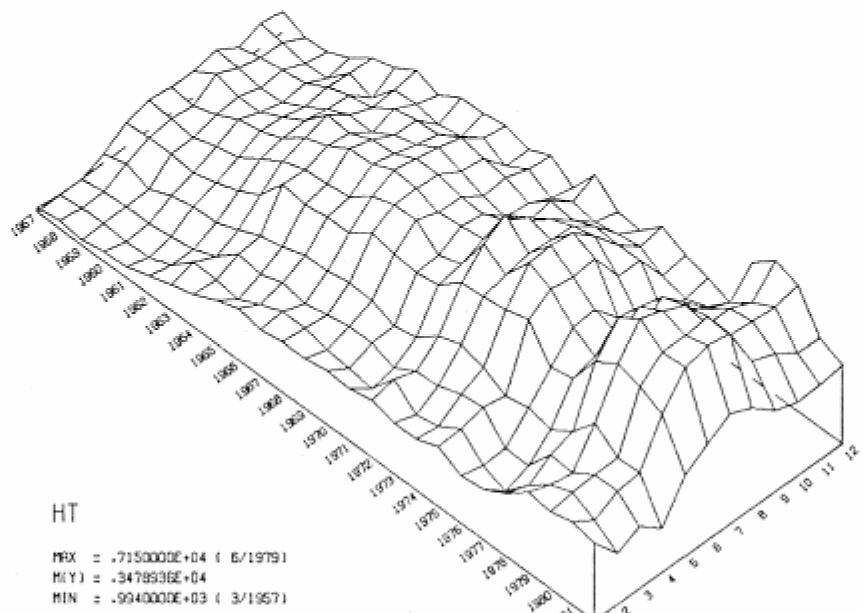
are more serious than those associated to accidents with bodily injuries. The use of the number of accidents as denominator also involves difficulties due to classification errors and because a fatal accident can also involve injured people: accidents with injured and dead persons are very close in the spectrum of real severity. It seemed a better solution to take the number of accidents with bodily injuries as denominator; we did estimations of both possibilities and a comparison of the results on a reference model, exposed below, confirmed this opinion.

We call REFERENCE MODEL the 9 equations of layers 2, 3 and 4.

In that reference model, the number of people injured HT, or the number of people killed DE, is *implicitly* explained as product of the number of accidents with bodily injuries (explained in layer 3) by the morbidity or mortality rates of these accidents (explained in layer 4). In fact, the total number of victims VI is computable in the fifth layer.

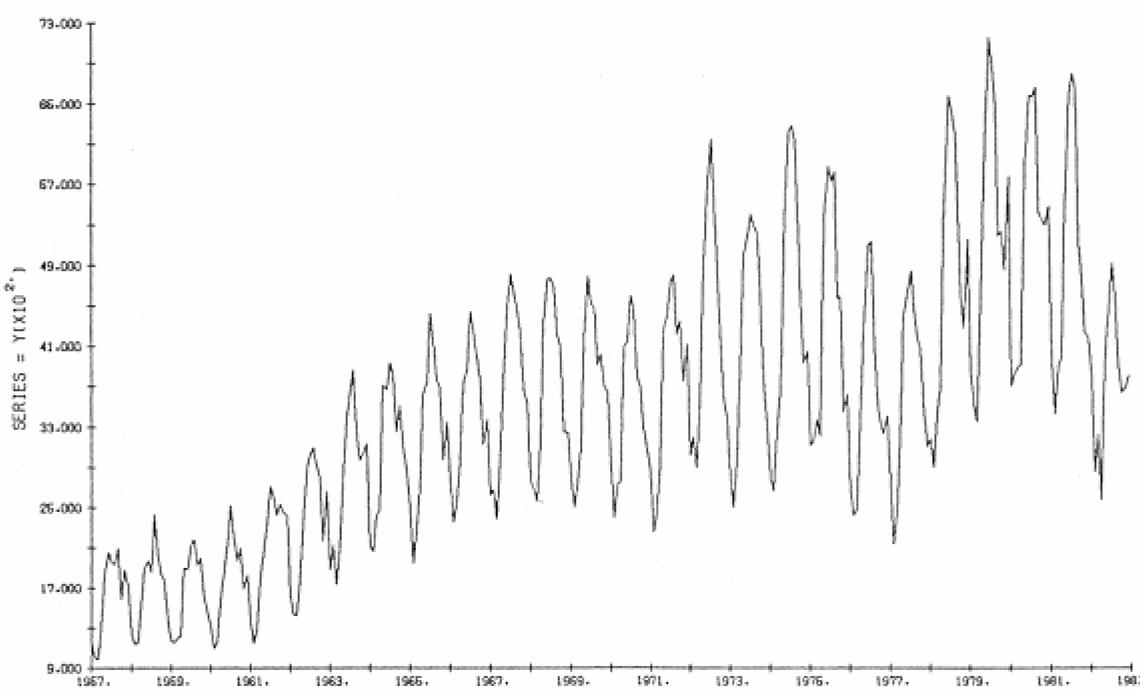
$$\text{VI} \quad \begin{cases} \text{HT} = (\text{NM} + \text{MO})\ \text{MBC}\ , & \text{(P - 5.1)} \\ \text{DE} = (\text{NM} + \text{MO})\ \text{MTC}\ , & \text{(P - 5.2)} \\ \text{VI}\ = \text{HT} + \text{DE}\ . & \text{(P - 5.3)} \end{cases}$$

We do not show the graphics VI because they are too similar to the graphics HT showing the number of people injured. Perhaps, we could have taken into account the identities (P-5.1) and (P-5.2) and estimated the parameters of layers 3 and 4 under constraints; the appropriate techniques to consider these constraints in the equations with Box and Cox transformations do not exist yet, to our knowledge, and it is not certain that the efficiency gains would justify a solution to the problems that would occur.



(JAN 1957 - DEC 1982)

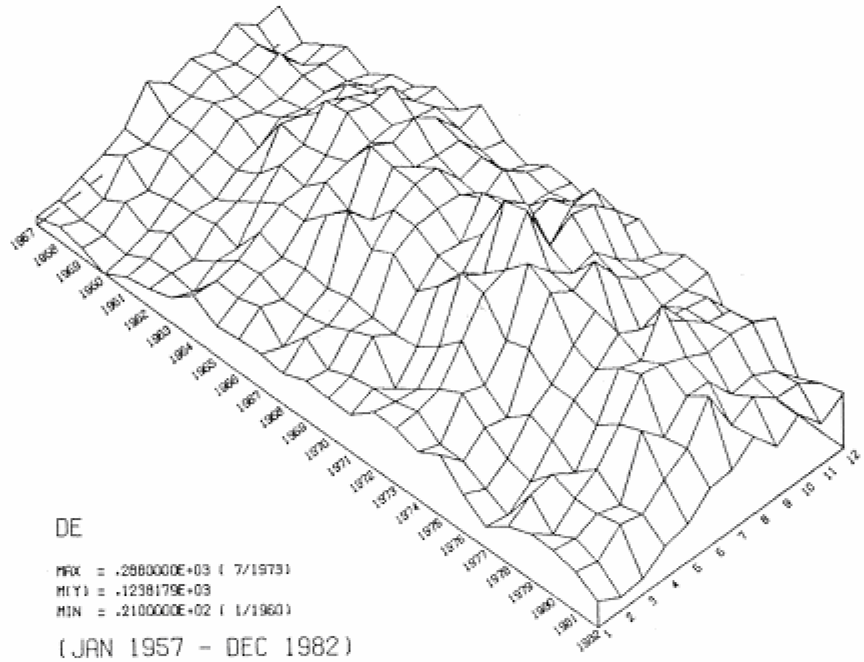
NUMBER OF PERSONS HURT ON QUEBEC ROADS



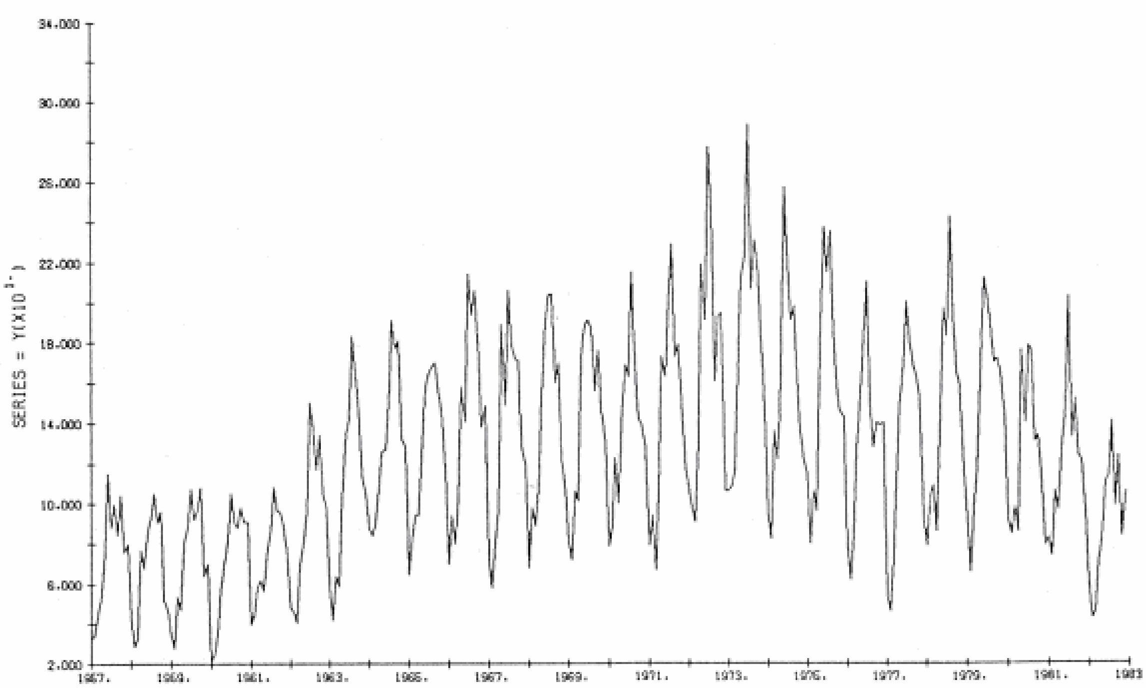
HT

NUMBER OF PERSONS HURT ON QUEBEC ROADS

(JAN 1957 - DEC 1982)



(JAN 1957 - DEC 1982)
NUMBER OF PERSONS KILLED ON QUEBEC ROADS



DE
NUMBER OF PERSONS KILLED ON QUEBEC ROADS
(JAN 1957 - DEC 1982)

3.2. Categories of independent variables

We can group in 7 large categories the explanatory variables that will be used in the stochastic equations of the first 4 layers – layer 5 contains only identities. Due to the relatively large number of explanatory factors, it is useful to allow sub-categories and to make a classification; the presentation of the results further on will follow the same classification.

These categories are:

1.	D		=	dependent
2.	P		=	price
3.	M	-Q	=	motorization - quantity
		-C	=	motorization - vehicles characteristics
4.	N	-L	=	networks - laws, regulations, police
		-T	=	networks - levels of services of transports modes
		-I	=	networks - infrastructure, climate
5.	Y	-G	=	consumers - general characteristics
		-A	=	consumers - age
		-S	=	consumers - sex
		-E	=	consumers - ebriety or vigilance
6.	A		=	final economical activities and intermediates
7.	ET	-AD	=	et cetera - administrative decisions that affect the measurement
		-AG	=	et cetera - aggregation: month composition
		-SC	=	et cetera - seasonal and constant

3.3. Economical formulation

How can we formulate the relation existing between the explanatory or the independent variables and the endogenous or dependent variables, up to now symbolised by $(\leftarrow)$? The procedures that we will use will be equations; we need to distinguish between the economical and econometrical formulations.

Two economical formulations will be considered:

$$(FRD) \leftarrow (\ - \ P, \ (M - Q/A_i, M - C), N, Y/A_i \ , \ (A_1/A_j, ..., A_{a-j}/A_j, A_j), \ ET), \qquad (DE)$$
$$(FRP) \leftarrow (DR, P, \ (\quad - \quad M - C), N, Y/A_i \ , \ (A_1/DR, ..., A_j/DR), \ ET), \qquad (PE)$$

keeping in mind that the dependent variable is one of a reduced form equation of the demand (FRD) or the one of a reduced form equation of the safety-performance (FRP). When reading the following brief justifications of the elements used, we have to keep in mind that the meaning of the explanatory variables is not the same at all layers where they can be found. Indeed, in (D-1) or (D-2), variables such as snow explain the use <u>level</u> of roads (« exposure » in several texts) whereas, in (P-3) and (P-4), they explain, to a *given road demand*, a change in the accident <u>probability</u> or in the accident severity per unit of demand. Therefore, the factor « employment » (or a function of employment) will explain the transport activity generated by work in (D-1) or (D-2) and will reflect, to a *given transportation demand* in (P-3) and (P-4), the elements (the driving, occupancy rate of vehicles) that have an impact on the accident probability or the accident severity per unit of demand.

Let's also observe that the X's of (P-3) and (P-4) respectively explain the probability of an <u>event</u> or of a <u>rate</u> per unit of demand. Consequently, when we will say that a variable has an effect "on the demand, the accidents and their severity" we will mean "on the level of road demand (of fuel), on the probability that an accident occurs to a given road demand and on the probability that an accident be serious to a given road demand".

To clearly understand the following comments, the reader should simultaneously consult table 5 where it is easy to notice if a particular explanatory variable is used or not in all the equations (the dependent variables are identified at the top of columns) of the reference model.

D: dependent variables

The measurements of road demand are used only in the performance equations (PE). They are presented in a level form. We could have inserted them in densities form (per km of road for example), but since the length of the road network seems to have gradually increased and not as fast as the fuel consumption during our period, the density would have been correlated with the demand level: the variables of fuel consumption and diesel consumption included in DR play both roles at the same time. Because of the large number of variables in the model, we did not insert any lagged dependent variables in the demand equations (DE) to verify the consumers' adjustment speed. The econometrical formulation will compensate by introducing these variables with the errors autocorrelation.

P: prices

The fuels prices, of the public transportation, the vehicles maintenance and the cost of living surely explain road use demand; insofar as they affect the speed, the state of vehicles or the driving, they will also influence the accidents and their severity. Some of the prices, which consider the price differences of the fuel between Quebec and Ontario, appear only in the equations (D-1).

M: motor vehicles

The number of motor vehicles of various categories M-Q and, for vehicles, some of their characteristics (size and availability of the seatbelt and shoulder belt) added when purchased M-C, are considered to be predetermined in our model. The availability rate of vehicles per activity unit (here A_i is the population or the number of adults) will influence the demand for fuels. The size characteristics and the availability of vehicles characteristics can have an effect on the distance travelled and on the speed: they appear in all functions (DE) and (PE) except for the proportion of small vehicles, which is excluded from the diesel fuel demand.

N: networks

The changes in the Highway Code and the police supervision N-L influence the speed and other elements of the driving. All components of N-L are used in all equations of the model. Also, variables that describe the levels of service of modes N-T are also used everywhere when strikes are concerned in the urban public transit and intercity public transport. The time spent waiting for public transport is used only to justify the gasoline demand. The physical characteristics of the infrastructures N-I are used in all functions because they have an impact on speed, and therefore on the demand for fuel, the probability of accidents and their severity.

Y: drivers' characteristics

The general characteristics of drivers Y-G, such as their frequency in the population and the important changes in the drivers' stock quality or their behaviour caused by the modifications in the road access regimes (by the law of automobile accident compensation in 1961 and the 1978 Automobile Insurance Act), also belong to all the functions of demand and performance. We can indeed think that the availability of the driving licences increases the transportation supply and changes the occupancy rate of the vehicles; we can suspect that important changes in the road access regimes will sufficiently modify the drivers' stock so to affect the demand, the accidents and their severity. A similar analysis concerning the drivers' age Y-A, their sex Y-S and their vigilance state Y-E deserves to be put to the test.

We can generally find these variables in a form of presence rate in the drivers' population. That is the meaning of ratio Y/A_i in (DE) and (PE). Of course, we do not know the real proportion of drivers who have taken alcohol or medications: we can assume it is the same as the population in general: the unknown factor of proportionality α is implicitly absorbed by the estimated coefficient $\hat{\beta}$ of regression ($\hat{\beta} = \beta\,(\text{real}) \cdot \alpha\,(\text{real})$) and cannot be identified because we only know the product estimation of the « real » coefficient β and of the proportionality factor α.

A: economical activities

In the demand equations, we have chosen a reference activity, employment, and expressed the other recurrent activities (not the special events such as Expo '67 or the 1976 Olympic Games) in relation with the latter ((A_a/A_i) = retail sales per employment, manufacture deliveries per employment). Some of the activities (agricultural, engineering construction and forestry) appear only in the equations (D-1) for the off-highway use.[4]

In the performance equations, we have established ratios A_a/DR to determine the effects of trip purposes. Fuel sales for highway use are used as denominator. The number of employment, the retail sales and the holidays are used as numerator of these three indexes of the probability that a trip be taken for a particular purpose. Of course, we do not know the transformation rate that would determine the real proportion of trips taken for each of the three considered purposes, but the regression coefficient is accordingly adjusted. Moreover, the estimated coefficients of these so-called portions must be interpreted in comparison to the coefficient of the residual portion, which is not represented, of trips done for other purposes (personal, social life, etc.).

ET: et cetera

The variables that have an impact on the measurement ET-AD contain the establishment of a standardised police accident report in 1978 and of the joint report of automobile accident plan in 1979. These two actions had an effect on the measured number of accidents with material damages (G) and the total of accidents. That is the case with the modifications of the criterion of minimum value applied to produce the official number of accidents with material damages. The aggregation variables ET-AG, which take into consideration the months length and incorporate adjustments linked to the dimensions of activities variables, as well as the constant ET-SC, are included everywhere.

We could have used everywhere, in the economical formulation (DE) and (PE), the level of the variables instead of defining availability rates of vehicles, rates of drivers' characteristics and economical activity rates. By doing so, we reduce multicollinearity problems. We also obtain a clear formulation where, in (DE), a reference activity defines a "basis" that is modified by all the rates. In (PE), it is the demand DR that defines the "basis". Of course, the qualitative variables play their usual role and detect level changes of the dependent variables.

3.4. Econometrical formulation

Which econometrical formulation should we adopt? Let's distinguish, for each considered equation, between the model that links the dependent variables and to the independent variables and the error model. The first one, which we called "fixed part", will be, for all t observation,

$$y_t^{(\lambda_y)} = \sum_{k=1}^{K} \beta_k \, X_{k_t}^{(\lambda_x)} + u_t \qquad \text{(E-1)}$$

where we do not precise for now the model of error u_t and where the Box and Cox transformation (1964) of the variables is defined as

$$y^{(\lambda)} = \begin{cases} \dfrac{y^{\lambda\text{-}1}}{\lambda} & , \quad \lambda \neq 0 \\ \ln y & , \quad \lambda \to 0 \end{cases} .$$

This transformation is commonly used in several fields when we do not have any ideas of the relation between variables or when we have precise prejudices we want to put to the test. Indeed, if $\lambda_y = \lambda_x = 1$ in (E-1), the function is equivalent (the constant excluded) to the linear regression; if $\lambda_y = \lambda_x = 0$, we have a linear model in the variables logarithms (therefore a multiplicative model). Moreover, since the opposite of the logarithm is the exponential, the values $\lambda_x = 0$ and $\lambda_x = 1$ are equivalent to $y = \exp(\sum_k \beta_k X_k)$. Often, there is evidently no reason to expect linearity instead of proportionality or any other value: square root ($\lambda = \frac{1}{2}$), power of two (λ = 2) etc. This transformation is used on transport demand functions since 1978 (Gaudry et Wills, 1978).

The error model, or "random part", is

$$u_t = \left[\exp(\delta_o + \sum_{m=1}^{M} \delta_m Z_{m_t}^{(\lambda_{zm})} \right]^{-1/2} v_t \quad , \tag{E-2}$$

$$v_t = \sum_{\ell=1}^{r} \rho_\ell \, v_{t-\ell} + w_t \quad . \tag{E-3}$$

This formulation has 2 goals:

- assure that the error variance is constant. As a matter of fact, the Box-Cox transformations in (E-1) affect the error variance. In order to obtain an error for which the variance is constant (homoscedastic), we need a model that can control the heteroscedasticity and we need not to confuse the form of the model and the variance of error: two instruments for two goals, following the strategy we have established (Gaudry and Dagenais, 1979) in a more general way than in (E-2)-(E-3). Notice that the formulation (E-2) has the advantage of including as a particular case the classic heteroscedasticity: if all the $\lambda_{zm} = 0$ and all the $\delta_m = 0$ except one that equals 2, we have $u_t = \left[\delta_o^* Z^2\right]^{1/2} v_t$;
- obtain residual errors that are not correlated in time ("white noise"). In reality, (E-3) is used to make, with a higher order autoregressive process, an approximation of a process that would contain an autoregressive schema and a part of moving average. The experiment revealed that this approximation was usually sufficient to get a random error.

The idea of this econometrical model is to balance the work on the fixed part and on the random part. In the fixed part, it is the data that decide of the functional form; in the error model, we will search for the systematic or modelisable information. These tasks are simultaneously accomplished by a maximisation of the likelihood logarithm of the $N-r$

observations that can be written, if we suppose that the w_t have a normal distribution and we disregard the r first observations:

$$L = -\frac{N-r}{2}\ln(2\pi\sigma^2) - \frac{1}{2}\sum_{t=1+r}^{N}\ln f(Ƶ_t)$$
$$-\frac{1}{2\sigma^2}\sum_{t=1+r}^{N}\left[\frac{u_t}{\sqrt{f(Ƶ_t)}} - \sum_{\ell=1}^{r}\rho_\ell\frac{u_{t-\ell}}{\sqrt{f(Ƶ_t)}}\right]^2 + (\lambda_y - 1)\sum_{t=1+r}^{N}\ln y_t \ , \qquad \text{(E-4)}$$

where $f(Ƶ_t)$ is defined as the square parenthesis content of $(E-2)$ and σ^2 is the variance of w_t that we find in the squared parenthesis. The algorithm used to maximise this function is described in details in Liem *et al.*, (1983). We have shown (Dagenais *et al.*, (1984) that, concerning the study of the CTCUM mass transit demand and the gasoline demand in Montreal, there were important benefits in estimating the parameters of the functional form of the "fixed part" of a model along with the parameters of heteroscedasticity and autocorrelation.

This equilibrium between part $(E-1)$, where we use variables from which we "understand" the dependent variable, and part $(E-2)-(E-3)$, where we try to describe the residual error u_t so to obtain w_t, a white noise at constant variance, combines two modelling tendencies. In the first perspective, we formulate a regression model and we neglect the work on the error model; if we cannot neglect it, we simply suppose that u_t is homoscedastic and does not suffer from autocorrelation. Moreover, we often estimate a linear model ($\lambda_y = \lambda_x = 1$) and a log-linear model ($\lambda_y = \lambda_x = 0$) and we publish the "best" results. In the second perspective, we are not interested in the explanatory variables: we only want to reproduce the dependent variable y_t by its lagged values and the lagged values of error w_t: we call this kind of analysis "time series analysis" or Box-

Jenkins analysis (1976). We use it to identify the structure $(E-3)$. Lately, we have been correcting the excess of this form of « curve fitting » by adding one or two explanatory variables, often binary ("dummy") variables which represent structural changes or "in steps" phenomena – such as the impact of a new law – that the smoothness of the autoregressive schemas poorly depicts. This Box-Jenkins modification, called "interventions analysis" or Box-Tiao analysis (1975), can also be used to identify effects that gradually increase or decrease. Wiorkowski and Heckard (1977) summarise these two methods very well. No matter what the statistical properties of the obtained estimations are, first trend models disregard the information usually existing in the errors u_t. Second trend models fairly reproduce the data, but by removing the essential elements of the understanding (except for some "interventions"): they generally cannot give answers on the future impact of an increase in prices or in use because they have deleted the causal structure of X_t. So, we try to combine the advantages of the non-linear regression analysis to the ones of the time series in order to properly use the information found in the errors.

3.5. Relation to literature

Having established where our model stands according to the two main trends of time series modelling, we have to establish its link to other precise models but without reviewing in details the literature. We are interested in the *multiple regression models* on national and regional *aggregates*; we will exclude the "interventions analysis" models which deal with only one variable and the models with an aggregation level which is too low (all the roads, individuals groups): we will use the information taken from the specific intervention analysis models and low level of aggregation models when commenting the specific variables in the next section. Since multiple regression models using aggregated data (in the sense previously defined) on the accident severity, do not exist, we will briefly comment some of those that deal with the other formulated layers in DRAG.

DR: fuel demand

The models of gasoline demand are fairly frequent and the ones of diesel fuel demand are relatively rare. We will be able to observe this fact by consulting the selected list of papers we consulted, list that was provided to us in addition to all the references mentioned in the text, and where only Preece *et al.* (1978) are considering diesel. The standard model of fuel demand explanation uses the real fuel price as explanatory variables, a measurement of the energy efficiency of vehicles, the size of vehicle fleet and one or two variables of income or activity: in total, five or six variables if we disregard the auxiliaries variables and the constants. This distribution of variables by category is indicated in table 1.A.

The adjustment mechanism is usually very simple: we first look at the demand elasticity on short term. Some models try to initiate the adjustment on long term with a lagged variable. Some models also add, in parallel, one or two relatively simple equations on the average rate of consumption of the stock of vehicles and the number of vehicles so to calculate the long term complete effect of the increase in prices of fuel. (Burright and Enns, 1975; Sweeny, 1979).

TABLE 2: Recent models of aggregated multiple regression

A: DR, fuels demand[1]

Source	DR	DR_{t-1}	P	M	N	Y	A	VAR	NOBS	λ_y, λ_x	ρ
1. Greene 1982	GA		1	4		5		10	561	$\hat{\lambda}_y, \hat{\lambda}_x$	-
2. Berzeg 1982	GA	1	2			1	1	5	960	$\lambda = 0$	-
3. Baltagi and Griffin 1983	$\frac{GA}{auto}$	1	2	2		1		6	342	$\lambda = 0$	-
4. Tishler 1983	GA		3	1		1		5	13	$\lambda = 1$	-
5. Greene 1984	$\frac{\$\ DI}{total\ \$}$		2	1		1		4	20	$\lambda_x = 1$, $\lambda_y = 0^2$	-

1. All models use annual series except for [2] where we find quarterly series. The number of observation for [1] – [3] is higher because of the use of data on several states at the same time, which is on 51, 49 and 18.
2. Applied to Deaton and Mullbauer's (1980) model AIDS.

B : AC et VI, les accidents et les victimes[1]

	AC, VI	DR	P	M	N	Y	A	VAR	NOBS	λ_y, λ_x	ρ_1
1. Crète 1982	$\frac{MATER.^2}{AUTO}$		2	1	2	5	1	11	33	$\lambda = 1$	-
2. Maag et al. 1982	$\frac{DE}{popul.}$	1		2				3	30	$\lambda = 0$	-
3. Partyka 1983	DE				1		4	5	22	$\lambda = 1$	-
4. Stein and Beauregard 1983	DE	1	1		1		2	5	26	$\lambda = 1$	-
5. Crandall 1984	DE	1		4	2	2	1	10	35	$\lambda = 0$	-
6. Graham 1984	$\frac{DE}{mi.}$		1	3	3	2	1	10	35	$\lambda = 1$	-
7. Hoxie et al. 1984	DE	1		1		2	2	6	72	$\Delta^3\lambda = 0$	ρ_1

1. All model use series except for [7] where we find monthly series.
2. Number of claims to the insurers per insured vehicle.
3. Logarithms differences.

The data used are almost always annual. In their revue on literature, which they did in 1975, Burright and Enns have 9 cases of annual series and 1 case of quarterly series. This proportion has not changed much since that date. However, Hartmann *et al.* (1982) mention several internal studies from the American department of energy that use monthly data. Among the recent models indicated in table 1.A, only one source uses quarterly data; all the other sources use annual ones.

According to the mathematical form of models and the formulation of random part, we can distinguish 3 periods. Before 1975, models (see Burright and Enns, 1975) are linear ($\lambda_y = \lambda_x = 1$) and we often correct the residual errors of the autocorrelation of first order, but not of superior orders. From 1975 to 1982, almost all models are log-linear ($\lambda_y = \lambda_x = 0$) and we do not make any correction of autocorrelation. Since 1982, we are starting to use the Box-Cox transformations (Greene, 1982; Rodekohr, quoted by Hartmann *et al.*, 1982) or other functional forms such as in Greene's (1984) model of diesel demand where the dependent variable is a ratio of diesel expense to the regional income. We have seen only one publication (Baltagi and Griffin, 1983) that took into account the presence of heteroscedasticity (classic) where Ƶ is time.

AC, VI: accidents and victims

Among the models available since 1982, we have found only one model, Crète's one (1982), that explains the number of accidents – in its case the number of claims for material damages presented to insurers. All other models of multiple regression use the number of deaths: besides, before 1982, only Peltzman (1975) explains, with the help of a log-linear model, the number of accidents with material damages only (per mile

(MA/mi.)) and the number of injured persons (per mil (HT/mi.)) *in addition* to explaining the number of traffic fatalities (per mil (DE/mi.)).

Models presented in table 1.B are divided almost equally between the linear and log-linear forms. We have not found any example of Box-Cox analysis or of heteroscedasticity corrections. Only Hoxie *et al.* (1984) consider the autocorrelation, but after using a first difference of the variables model, which assumes a value of $\rho = -1$ for the formulated model with their raw data.

Our model is different from the other known models in 5 aspects:

- the integration of levels of road use demand and of road safety in order to better determine the complete impact of each factor;
- the use of several components, for fuels as well as for accidents and victims;
- the use of monthly time series rich in usable information if we are ready to create a sufficient number of explanatory variables;
- an attempt to get an information on severity and frequency of accidents, which is different from the one we get if we are interested only in the number of victims;
- the use of flexible functional forms (Box-Cox) with simultaneous correction for the multiple autocorrelation and the heteroscedasticity of very general form.

4. RESULTS

4. RESULTS

DRAG model has a large number of components that would need particular attention: each demand equation or performance equation could be subjected to detailed comments. To be brief, we will instead, after a quick examination of a part of the results from layer 1, comment the results variable by variable for all of the equations of the reference model or of its variants. We will do so by pointing out only the most important aspects.

4.1. Meaning of the results

4.1.1. Calibration, estimation and robustness

There are two ways of understanding the numerical procedures that enable us to attribute parameters to variables of a model. In the first perspective, we do a *calibration* of the parameters and we want to know, in the case of a minimisation of the squared sum of errors for example, the sensitivity of the object (the squared sum of errors) to various modifications of the conditions: is the object sensitive to variations of the parameters? To the addition of a variable? To a change of functional form? In the second perspective, the one concerning the *estimation* of parameters, we pretend that the variable to be explained is really a random variable and we use the statistical theory to search for the sensitivity of the object (the likelihood of observing the sample, for example, for which the centre, as previously seen, is the squared errors sum affected with a negative sign) to various modifications of the conditions: is the likelihood significantly affected by a parameter variation? The addition of a variable? A change in the functional form? The significance measurements used to perform tests are all derived from numerical measurements of sensitivity to modifications of the parameters, of the list of variables or of the functional form: the standard errors, for example, come from a matrix inversion. The matrix is composed of partial derivatives; tests of likelihood ratios calculate the variation of following likelihood to the finished variation of a parameter …

In both cases, what we are really interested in is the *robustness* of the results, obtained with changes of the model formulation: addition or suppression of a variable, modification of the functional form, etc. Since robust econometrics procedures are just beginning to be used (see for example Belsley, 1983), we can measure the robustness only with pragmatic trials and by using the statistical tests as estimated indexes. We will try, in the results presentation, to summarise our experiment of numerical robustness, since we have made several trials with various formulations. We will also attempt to extract some information from the usual statistical tests.

4.1.2. **Likelihood ratio and Student t**

We will use the test of likelihood ratio to identify the functional form of the equations and the presence of heteroscedasticity. However, we will not use it to evaluate the contribution of the particular variables. Indeed, this test, as for Wald's (1943) test, requires a calculation for each hypothesis H_0 compared to the reference hypothesis H_1. There are some tests, such as the Lagrangian multiplier statistic suggested by Rao (1948), that do not require a re-evaluation of the parameters of the model every time. Though, these score tests generally have several asymptotically equivalent forms that were subjected only recently to analysis and comparisons with the likelihood ratio (Bera and McKenzie, 1984). This test consists in comparing the likelihood logarithm value, expressed in $(E-4)$, for a reference model to the one we obtain when arbitrarily attributing a particular value, such as 0 or 1, to one or several parameters of the model. Since this discrepancy multiplied by 2 has a distribution χ^2 with a number of degrees of freedom equal to the number of constraints imposed, we can see in table 3 the significance level reached by various discrepancies of the likelihood logarithm.

TABLE 3 : $\chi^2/2$ Distribution percentage

To reach the level		:	0,1	0,5	0,025	0,01
Required values with	1 degree of freedom	:	1,35	1,92	2,51	3,32
	2 degrees of freedom	:	2,30	3,00	3,69	4,61
	4 degrees of freedom	:	3,89	4,74	5,57	6,64

For the particular variables, we will use the Student t and find out if the considered coefficient is different from zero. In linear models, its classical interpretation, which required some restrictive assumptions, is essentially the following: if it is greater than 2 (whatever the sign might be), the corresponding coefficient is different from zero with a high probability level. Such a reading, though, does not really tell us much if the true value of the coefficient is close to zero. In that circumstance, the test has a lack of "power" and does not take into consideration:

- the fact that we sometimes expect a value of the coefficient close to zero or signed;
- the fact that, if we do not expect anything in particular, the coefficient obtained is nevertheless the most probable;
- the fact that a coefficient or significance can be extremely "robust", which means that it does not vary much in the case of important modifications of the other factors list.

On a statistical perspective, if we consider as linear a model that in reality is not, all parameters, Student t included, are biased and not convergent; we could calculate an upper limit to this non-convergence (Bera, 1984). Also, the use of t in the non-linear model causes the following problems:

- they are biased and are only asymptomatically convergent;
- when the explanatory X are raised to a variable power for which the parameters are estimated according to the entire model parameters, such as in the Box-Cox transformations, they are not invariant to the units of measurements because the ratio of the coefficients β to their standard deviations is not invariant (see Dagenais *and al.*, 1984 on the subject). This ratio is invariant when the transformation of X is fixed, such as in the log-linear models. We obtain in our problem t values that are conditional to the estimated values of λ of the transformations and to the units of measurement. We do not know if the lack of invariance is serious or not. We think that it is not too serious for the variables that are really significant: a quick comparison of the t obtained in the equations of road fuel demand implies that the shift of the linear to point $\hat{\lambda} \approx 1/2$ poorly affects the orders of magnitude of the t values despite the modification in the functional form. A special research would be required to study, to a given functional form on a particular model, the impact of units of measurement on the Student t;
- the algorithm we use here in order to calculate them, as explained in Liem *and al.* (1983), is an approximation resulting of the first derivatives of the likelihood function; this algorithm is not as precise as an algorithm that would use second derivatives.

We can use the Student t only with a great caution by handling them more as *relative* signification indexes between variables than as measurements of the *level* of signification of these same variables.

We will present two forms of Student t. When presenting the "regression results", we will inscribe in parenthesis the numerical value of the t associated to all the parameters. In the "tables of direct and indirect elasticities"

- the symbol * stands for an absolute value of the t between 0 and 1;
- the symbol ** stands for an absolute value of the t between 1 and 2;
- the symbol *** stands for an absolute value of the t between 2 and 3;
- the symbol /// stands for an absolute value of the t higher than 3,00

(C - 1)

4.1.3. Measurement of the elasticities

In an economical point of view, the coefficients and other estimated parameters are of limited interest. Even in a linear case they are useless if we do not know what the units of measurement of X are. Instead of presenting the coefficients, we will present the elasticities. Since the elasticities give the ratio of the effect in percentage on the dependent variable of a variation of a given factor and the variation in percentage of this factor, they give a clear number: if the elasticity of y in comparison to X_{10} is + 0,50, we can quickly judge if the underlying result expressed is reasonable. Lots of models would have never been published if we had demanded to have all the elasticities to evaluate the reasonableness of their results, instead of trusting only the usual statistics.

But how can we measure the elasticity? We can distinguish (see Dagenais *and al.*, 1984, for more details) between the case of the usual variables and the one of the auxiliary variables. Indeed, the elasticity in one point is obtained thanks to the expression of the left segment in

$$e_{y,X_k} = \frac{\partial\ E(y)}{\partial\ X_k} \cdot \frac{\overline{X}_k}{E(y)} \rightarrow \frac{\partial\ y}{\partial\ X_k} \cdot \frac{\overline{X}_k}{\overline{y}}$$

where E(y) means the mathematical expectation of the dependent variable. In the linear case, the expectations relate to the sample means. That is why the right segment of the equation also relates to the intuitive calculation of the elasticity "at an average point of the sample" instead of at any point. There is no significant difference between the strict measurement and the intuitive measurement in our results. We will therefore use the intuitive measurement in our tables. However, we are faced with two other measurement problems.

Some of the events or activities, for which their level varies in time, do not take place during the considered period. Instead of calculating the "average" influence of X_k on the average value of y, we can observe the influence of X_k on the average of y only if X_k occurs:

$$e_{y,X_k} = \frac{\partial\ y}{\partial\ X_k} \cdot \frac{\overline{X}_k}{\overline{y}}, \qquad X_{k_t} > 0 \qquad .$$

Moreover, the partial derivative used in these formulas does not exist in the case of binary auxiliary variables (equal to 0 or to a constant that is usually 1). Considering once again the original meaning of elasticity, we have to compare the level difference of y caused by the presence of an auxiliary variable or, indicating with $\hat{y}$ the explained value of the dependent variable,

$$\frac{\hat{y}\text{ (with an auxiliary variable) - }\hat{y}\text{ (without any auxiliary variable)}}{\bar{y}} .$$

Our tables distinguish between these three cases by presenting the code names of the variables used:

$$\left.\begin{array}{l}\text{- a code name that is not underlined, such as the proportion of small vehicles PPAS for example, means that the elasticity is calculated by averaging all the observations, positive or null, on this variable: it measures the influence of this variable "on average" on the dependent variable "on average";}\\ \text{- a code name underlined once, such as the strikes of the police officers of the Sûreté du Québec and the Communauté Urbaine de Montréal (Montreal Urban Community) }\underline{\text{GRPOL}}\text{, means that the elasticity is calculated by averaging the positive observations; it measures the influence of this variable « on average when occurring » on the dependent variable "on average".}\\ \text{- a code name underlined twice, such as the new highway code of April 1982 }\underline{\underline{\text{NCROUTO4}}}\text{, means that the elasticity measures the influence of this qualitative variable « on average when occurring » on the variable "on average".}\end{array}\right\}(C-2)$$

4.2. <u>Fuels demand (level 1): off-highway factors</u>

4.2.1. <u>Correction methodology</u>

In the level 1, the goal was to remove the off-highway use from the total sales of fuels. In order to succeed in doing this correction without any statistical bias, we need the explanatory factors of the off-highway demand, the X_i^{dnr} from $(D-1)$, to be different from the X_j^{dr}. We did not meet this condition here due to the two same variables: the constant used in each implicit underlying equation (one for the road use demand and the other one for the off-highway use demand) is necessarily similar to the sum of the two equations; in addition, we could not have discerned between the retailed prices (with taxes) and the tax free prices (for off-highway use) because of the correlation between these two series, in the case of the gasoline as well as in the case of diesel. The impossibility of considering the different prices alters more the correction done on the sales of diesel than the correction done on the sales of gasoline due to the more limited number of the gasoline free tax uses. The impossibility of considering different variables means that the correction done is incorrect *to within a constant*. In the rest of the model, using a measurement of the demand that neglects the effect of this constant will have no impact on the coefficient of the adjusted variables or on the other variables of the model, the constants (which are of no interest) excepted. Indeed, the correction is to draw from $(D-1)$

$$DR = DC - (\sum_{i \neq 0} \hat{\beta}_i \, X_i^{dnr} + \beta_o) \qquad \text{(R - 1)}$$

where β_o is unknown. If we use $(DR + \beta_o)$ as explanatory factor in one of the equation of safety-performance, we will implicitly do the second of these two regressions, instead of the first one

$$\begin{aligned} VI &= \gamma_o + ... + \gamma_{dr} \, (DR + \beta_o) \\ VI &= (\gamma_o + \gamma_{dr} \, \beta_o) + ... + \gamma_{dr} \, DR \end{aligned} \qquad \text{(R - 2)}$$

which means that the real constant of the performance equation, γ_o, will not be identifiable, but that $\hat{\gamma}_{dr}$ will not be biased. Nevertheless, the elasticity of the number of victims VI compared to the real road use demand $DR^* = DR + \beta_o$ will be unknown since that in the usual expression

$$ {}^{e}VI,DR^{*} = \hat{\gamma}_{dr} \frac{\overline{DR} + \beta_o}{\overline{VI}} \qquad \text{(R - 3)} $$

we will have implicitly put $\beta_o = 0$. The real *level* of the elasticity will be higher or lower than the calculated level, according to the unknown real value of the β_o neglected.

4.2.2. Correction variables

We will find in table 4 the estimations results of the demand functions $(D-1)$ for which the dependent variables are GA for gasoline and DIC for diesel. In addition to the presentation standard $(C-2)$ that we need to consider so to perfectly understand the *elasticities* that are inscribed with, in parenthesis, the statistics t of the coefficients $\hat{\beta}$ from which they are calculated, we need to take into account another presentation standard. Indeed, our estimation algorithm (Liem *and al.*, 1983) do not allow the Box-Cox transformations λ_y, λ_x or λ_z in $(E-1)$ or $(E-2)$ to be applied to variables X or Ƶ which have null observations, such as the variable EX7 (Expo 67). The values of this variable are positive only for a part of the observations and are null elsewhere: hence these variables are not transformable[6]. When they are transformable, we write under the Student t if this transformation is done with a fixed λ during the estimation or with an estimated λ. Since we can use different λ_x for various variables groups, we also indicate to which group the transformed variable belongs.

Under the Student t in brackets,

- the lack of indications means that the variable is not transformable, because it has null observations, or has not been transformed;
- the indication FL1 means that the λ associated to this variable is fixed to a particular value common to all variables of group 1 to which belongs this variable; fixed values for each group are indicated at the bottom of the table.
- the indication EL1 means that the λ associated to this variable is estimated and is common to all variables of group 1 to which belongs this variable; estimated values for each group are indicated at the bottom of the table.

(C – 3)

In table 4, the transformed variables all belong to “group 1” for which the fixed value was equal to 1; the fixed value of λ_y, as indicated at the bottom of the table, was also equal to 1. That means it is a linear case.

There are no significant differences between the list of explanatory variables of the *road* use demand included in table 4 and the ones that will be used again in the reference model presented later on [7]. We will comment the results of the variables that are common to both lists in the commentaries done further on the reference model and we will limit ourselves to commenting the results of explanatory variables of the off-highway demand. We will also present graphics of these variables.

- **<u>Prices and border impacts</u>**

The first impact we need to consider in order to adjust the fuel sales is the border impact of tax avoidance. It consists of filling up fuel where it is the less expensive. This situation is frequent at the border of Ontario, mostly for merchandise transportation [8]. So we constructed variables, PQPIGA and PQPID, which represent the theoretical part of Quebec price in the total price (“ interprovincial”) of a Quebec-Ontario trip. As we can

TABLE 4: Fuel demand: direct elasticities, autocorrelation parameters et t statistic

	CODE NO. =	41	22
	DEP.VAR. =	GA	DIC
P = PRICES		**GA**	**DIC**
REAL PRICE OF REG.GAS.PER KM	PGRPKM	-.114 (-1.20) FL1	
QUE.SHARE INTERPROV.PRICE REG.GAS.	POPIGA	-.104 (-.52) FL1	
IND.REAL PRICE TX+REB.DIESL QUE+ONT	IPDRQO		-.045 (-.19) FL1
QUE.SHARE INTERPROV.PRICE DIESEL	PQPID		-3.240 (-1.48) FL1
REAL PRICE VEH.MAINT.EXCL.GAS.PUR.	ENTRNMQC	.092 (.75) FL1	.160 (.38) FL1
REAL ADULT TRANSIT FARE, MONTREAL	FA0822	.143 (2.55) FL1	
CPI EXC.AUTO+MTL TRANSIT COMPONENTS	PCBNETT	-.065 (-.87) FL1	
M-Q = MOTOR VEHICLE - QUANTITY		**GA**	**DIC**
CARS PER PERSON	AUPPOP	.382 (1.19) FL1	
COMM.VEH.USING GASOLINE PER ADULT	VUTGAPAD	.103 (.85) FL1	
COM.VEH.USING DIESEL PER ADULT	VUTDIPAD		.367 (1.18) FL1
MOTORCYCLES + MOTORBIKES PER ADULT	MOCYPAD	.006 (1.15)	
M-C = MOTOR VEHICLE - CHARACTERISTICS		**GA**	**DIC**
PROPORTION OF SMALL CARS	PPAS	-.291 (-1.41) FL1	
PROP.CARS W.WAIST OR SHOULD.BELT	DISCEIN	.098 (.99)	.138 (.83)
N-L = NETWORK - LEGAL.REGULATION.POLICE		**GA**	**DIC**
SPEED LIM.+COMP.BELT 01-15/08/76	LVCEI	-.063 (-.71)	.281 (.74)
BREATHALYSER LAW(0.08) 01/12/69	PO8PC	-.007 (-.21)	.021 (.20)
DEMERIT POINT SYSTEM 01/03/73	PTDEM	.016 (.51)	.158 (1.66)

NEW HIGHWAY CODE 01/01/82	NCROUT ------	-.060 (-2.18)	-.115 (-1.26)
PATROL FREQUENCY,SURETE DU QUE.	SURSQ	-.059 (-.84) FL1	.139 (.74) FL1
STRIKES,SURETE DU QUEBEC	GRSQ ----	-.012 (-.37)	-.038 (-.31)
PATROL FREQ.,MTL.URB.COM.POLICE	SURCUM	-.136 (-3.78) FL1	-.078 (-.71) FL1
STRIKES,MTL.URB.COM.POLICE	GRPCUM ------	-.003 (-.09)	-.029 (-.31)

N-T = NETWORK - TIME,SERVICE LEVELS		GA	DIC
TRANSIT WAIT TIME,MONTREAL	TW822	.184 (2.63) FL1	
COMPLETE TRANSIT STRIKES,MONTREAL	STR813 ------	.014 (1.62)	.035 (.60)
PARTIAL TRANSIT STRIKES,MONTREAL	STRP ----	.050 (3.69)	.071 (.98)
COMPLETE TRANSIT STRIKES,QUE.CITY	STRCUQ ------	.002 (.20)	-.003 (-.08)
COMPL.INTRCITY BUS(VOYAGEUR)STRIKES	GRVOY -----	.003 (.22)	-.059 (-1.48)

N-I = NETWORK - INFRASTRUCTURE,WEATHER		GA	DIC
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.154 (2.50)	-.193 (-1.00)
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH ------	.017 (.52)	.029 (.22)
HOT OR COLD REL.TO 56 FAHRENHEIT	TLK822	.021 (2.38)	.035 (1.05)
RAINFALL PER DAY,DORVAL AIRPORT	RFK822	-.008 (-1.56)	.009 (.65)
SNOWFALL PER DAY,DORVAL AIRPORT	SFK822	.004 (1.09)	-.009 (-.75)
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMR822	-.018 (-3.39)	.040 (2.48)

		GA	DIC
COMPL.INTRCITY BUS(VOYAGEUR)STRIKES	GRVOY -----	.003 (.22)	-.059 (-1.48)
N-I = NETWORK - INFRASTRUCTURE,WEATHER		**GA**	**DIC**
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.154 (2.50)	-.193 (-1.00)
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH ------	.017 (.52)	.029 (.22)
HOT OR COLD REL.TO 56 FAHRENHEIT	TLKB22	.021 (2.38)	.035 (1.05)
RAINFALL PER DAY,DORVAL AIRPORT	RFKB22	-.008 (-1.56)	.009 (.65)
SNOWFALL PER DAY,DORVAL AIRPORT	SFKB22	.004 (1.09)	-.009 (-.75)
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMRB22	-.018 (-3.39)	.040 (2.48)
Y-G = CONSUMERS - GENERAL CHARACTERISTICS		**GA**	**DIC**
N.OF DRIVER'S LICENSES PER CAR	PERPA	.205 (.96) FL1	
UNEMPLOYED PER DRIVER	CHOMPP	-.053 (-2.79) FL1	
ROAD VICT.INDEMN.ACT 01/07/61	LOIIND61 ========	.022 (.82)	.039 (.31)
AUTOMOBILE INSURANCE ACT 01/03/78	LOIAS =====	.030 (1.06)	-.006 (-.06)
Y-A = CONSUMERS - AGE		**GA**	**DIC**
18 TO 16 LOW.MIN.DRIV.AGE 01/07/62	MOP62 =====	-.001 (-.05)	.134 (2.08)
17 TO 18 DRIV.LESSONS 08/09/76	MOP76 =====	.025 (.32)	-.012 (-.03)
Y-S = CONSUMERS - SEX		**GA**	**DIC**
PREGNANT WOMEN PER FEM.DRIV..LIC.	FEVMPP	.037 (.56) FL1	
Y-E = CONSUMERS - EBRIETY OR VIGILANCE		**GA**	**DIC**
DRUGS PER DRIVER'S LICENSE	MEDPP	-.007 (-.17) FL1	
TOTAL ALCOHOL PER DRIVER'S LICENSE	ALTOTPP	-.007 (-.20) FL1	-.034 (-.32) FL1

A = ACTIVITY FINAL AND INTERMEDIATE		GA	DIC
EMPLOYMENT PRESENCE INDEX	EIQP	.138 (1.09) FL1	
REAL RETAIL SALES INDEX	RSIDPQ		.246 (1.81) FL1
REAL RETAIL SALES PER EMPL.PERSON	RSIDPQPE	.205 (4.37) FL1	
VACATION INDEX	VWMD	.016 (1.96)	
EXPO 1967	EX7 ---	.023 (.57)	
OLYMPIC GAMES 1976	JO --	-.009 (-.18)	
REAL MANUFACT.SECTOR DELIVERIES	LIVMAD		.516 (2.50) FL1
REAL MANU.SECT.DELIV.PER EMPL.PERS.	LIVMADPE	.121 (1.26) FL1	
BUSHOURS,MTL.TRANSIT COMMISSION	VEHSF		.163 (.68) FL1

ET-AD = ET CETERA - ADMINISTRATIVE		GA	DIC
BEF.BLUE HT.OIL+AGR.TX.RB.01/07/73	NCOLHC ======		-.048 (-.47)
BEF.TX.REMOVED ON HEAT.OIL 28/04/61	NDTXHC ======		.095 (.52)
RED COLOR IN HEATING OIL 01/11/81	COLRHC ======		.133 (.86)
ON SITE FOREST INDUSTRY ACTIVITY	ACFOR		.215 (3.58) FL1
ON SITE LARGE CONSTRUCT.PROJ.ACTIV.	TRGEN		.087 (.62) FL1
ON SITE AGRICULTURAL ACTIVITY	ACVEAG	.047 (9.34)	.053 (2.93)

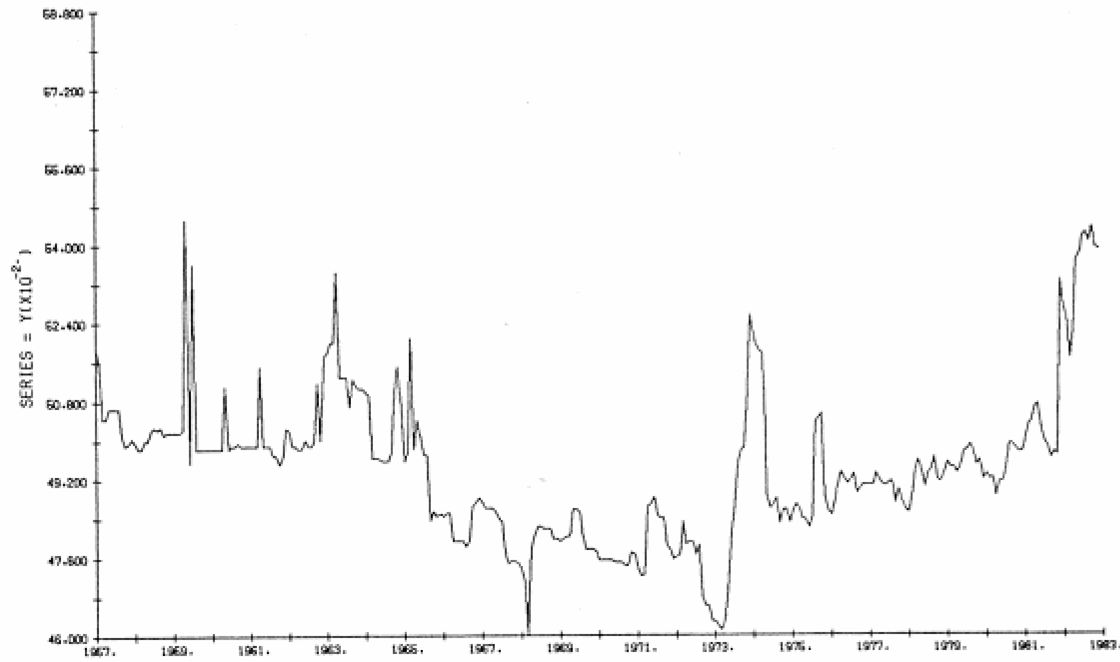
ET-AG = ET CETERA - AGGREGATION		GA	DIC
WORKDAYS PER MONTH	WD	.123 (1.34) FL1	-.475 (-1.51) FL1
SATURDAYS PER MONTH	SAT	-.030 (-1.00) FL1	-.110 (-1.37) FL1
SUNDAYS AND HOLIDAYS PER MONTH	SHD	-.063 (-2.12) FL1	-.105 (-1.25) FL1

ET-SC = ET CETERA - SEASONALITY,CONSTANT		GA	DIC
REGRESSION CONSTANT	CONSTANT	-.185 (-.09)	-3.130 (-1.38)

	CODE NO. =	41	22
	DEP.VAR. =	GA	DIC
AUTOCORRELATION			
	RHO 1		.379 (6.88)
	RHO 3	.161 (2.20)	.111 (1.71)
	RHO 7		-.181 (-2.94)
	RHO 8		.138 (2.17)
	RHO 9		.110 (1.79)
	RHO 10	-.212 (-2.49)	
	RHO 12		.202 (3.50)
BOX-COX TRANSFORMATIONS			
FIXED LAMBDA(X) - GROUP I	FL1	1.000	1.000
FIXED LAMBDA(Y)	FLY	1.000	1.000
LOG-LIKELIHOOD		94.394	-327.472
PSEUDO-(L)-R2		.988	.973
NUMBER OF OBSERVATIONS		301	301
ESTIMATION PERIOD		13-313	13-313
NUMBER OF INDEPENDENT VARIABLES		49	41

see in graphics PQPIGA and PQPID, these parts have changed and prices have not always been higher in Quebec than in Ontario: equal prices involve a part of Quebec price equal to 0,5.

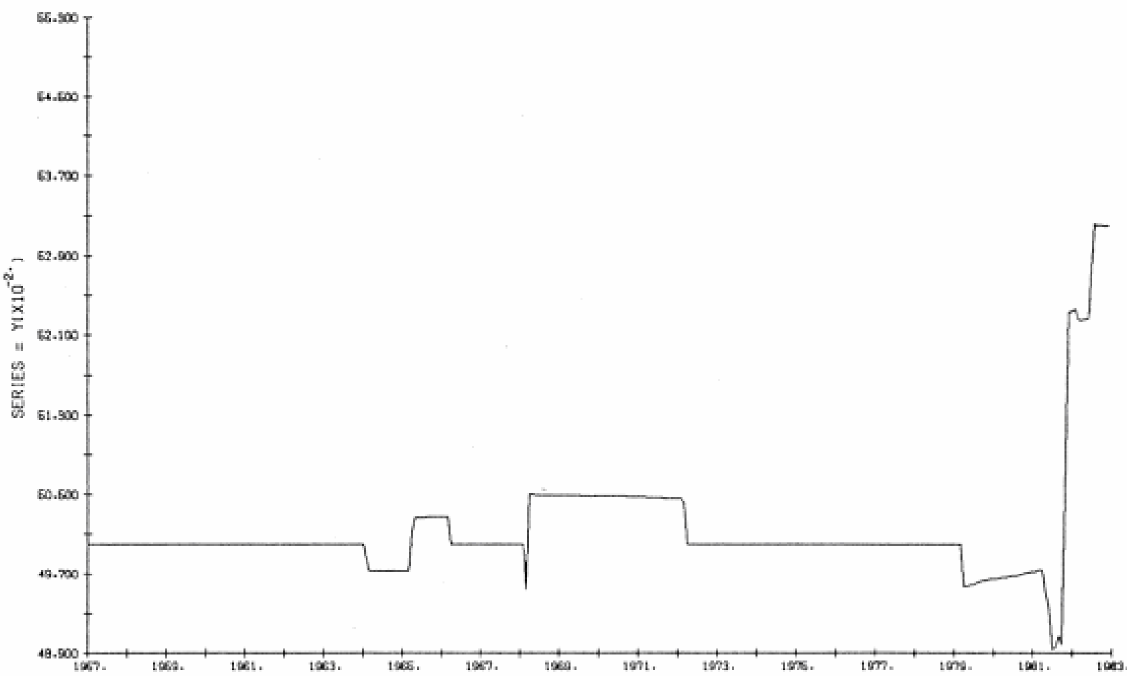
Gasoline market, as indicated by elasticities - 0,10 and - 3,24, is less affected by the price differences than the diesel market. These numbers mean that the change from equal prices to Quebec prices 10 % higher than the Ontario prices reduces[9] the gasoline demand from 0,005 % and the diesel demand of 15,42 % (9,85 % in 1982). The first result is understandable since few drivers live near the border and the interurban flow of cars and utility vehicles running on gasoline represent a small part of the total kilometrage. The second result requires another mechanism in order to be achievable: law demands that tax be paid by truck drivers according to the kilometrage they travel in each province or American state. In order to get around the law, we "adjust" the consumption levels[10] per kilometre declared on forms or to inspectors. Until very recently (beginning of 1983, I believe) the financial practices of the fiscal authorities in Quebec complicated this mechanism since the net fiscal benefits of the enterprises were null at the end of the year; therefore, some enterprises may have been declaring higher kilometrages than the actual ones in order to use up all this balance. We did not explicitly take into account these calculable effects but it is possible that the structure of some of the seasonal variables and the structure of autocorrelation implicitly consider them. To adjust the border factor, we have *added*, to the sales in Quebec, the appropriate quantities when the price in Quebec was higher than the price in Ontario and we have *subtracted* the required quantities in the opposite case: we are looking for a measurement of the actual road use demand that is independent from the source of fuel supply.



PQPIGA

QUEBEC SHARE OF INTERPROVIN. PRICE OF REGULAR GASOLINE

(JAN 1957 - DEC 1982)



PQPID

QUEBEC SHARE OF INTERPROVINCIAL PRICE OF DIESEL

(JAN 1957 - DEC 1982)

- **Tax evasion**

We took into account three sources of tax evasion considering the fact that heating oil can be used instead of diesel fuel in truck motors, agricultural tractors etc. Indeed:

- tax removal on heating oil of April 27 1961 has reduced the fuel sales by 9,5 % as indicated by the elasticity of variable NDTXHC;
- by introducing a blue colouring into the heating oil in June 1973 we have reduced this fraud; the simultaneous suppression of an agricultural tax removal on diesel fuel has undoubtedly reduced the diesel demand; the net impact, measured by the elasticity of the variable NCOLHC, is an increase of 4,8 % of the sales of diesel; this means that a large part of the fraud was not affected by the addition of the blue colouring since the suppression of the tax removal could have difficulty reduced the sales of diesel by 5 %;
- this impression was confirmed by the large impact of the red colouring that was added to the diesel when refined, since November 1981. The short-lived experiment (the variable COLRHC existed during the last 14 months of the sample) implies an increase of 13,3 % in the sales of diesel.

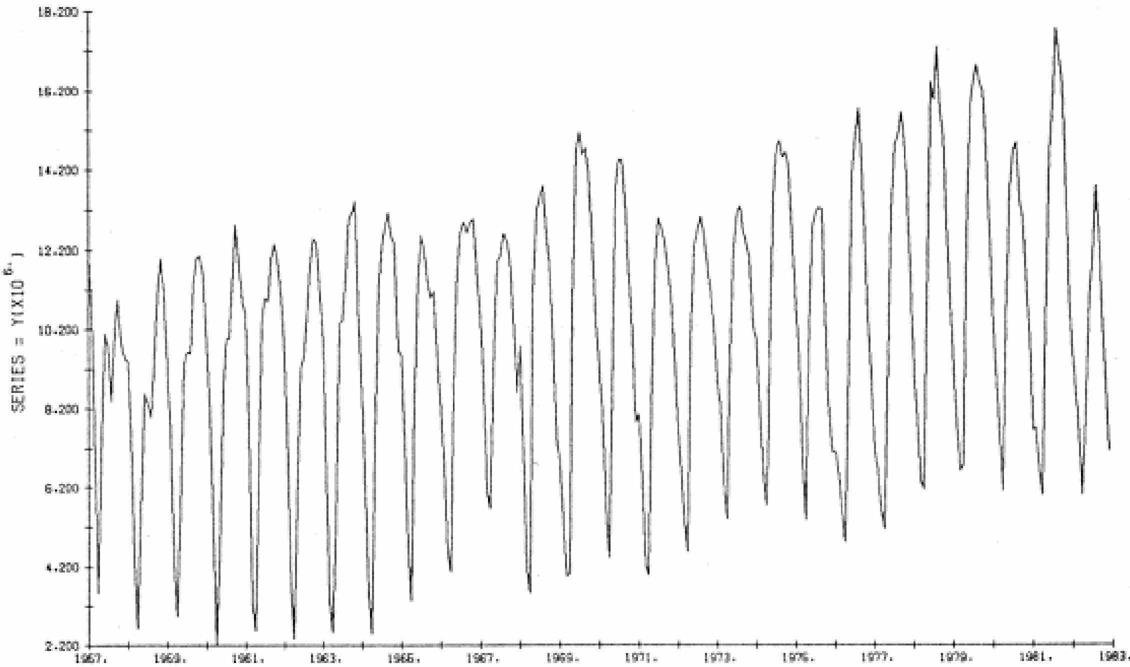
The order by sizes of these impacts is robust to changes in the list of explanatory variables or to other changes. With all the usual precautions, we can conclude that the major part of this fraud, which represented from 5 to 15 % of the sales, disappeared by the end of 1981. In order to get our measurement of the road use demand, DICR1, we have considered these frauds and have *added* to the official sales of diesel DIC the amounts of heating oil consumed on roads.

- **<u>Accounting procedures</u>**

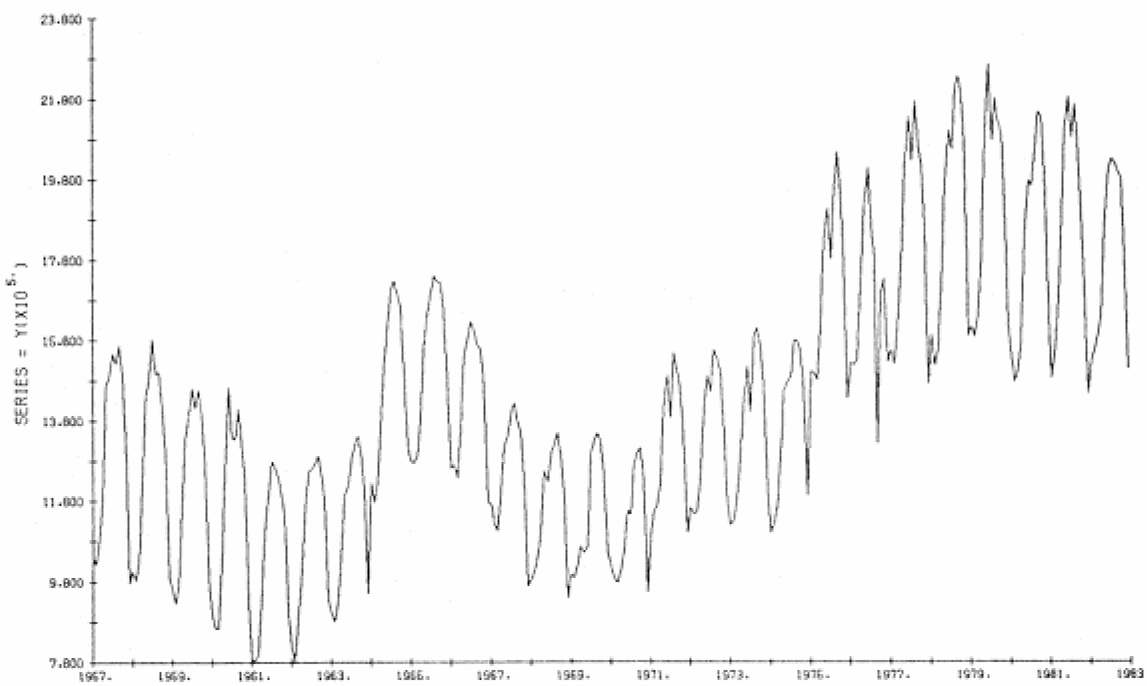
Our measurement of fuel sales, DIC, differs from the data given by Statistics Canada because we used the sources of the *ministère du Revenu* (Ministry of Revenue) who does not always send their adjusted data to Statistics Canada. Without going into all the details, (given in Gaudry *and al.*, 1984) we also adjusted “to the source” the gross data to remove the consumption of the railways CN and CP and other elements. We also tried to adjust DIC to consider several off-highway uses of diesel, which are regrouped in the total for administrative uses. The main off-highway uses are the following:

- the forestry activity, for which we see a small upward trend on graphic ACFOR, has a perceptive impact on the sales of diesel: the elasticity of 0,21 means that if we double the forestry activity in Quebec the sales of diesel will increase an average of 42 %;
- the important engineering works, for which we notice the plateaux on graphic TRGEN, relate to the construction of large dams and have proportionally not as much influence on the sales of diesel: the elasticity is 0,08;
- agricultural activity, represented on graphic ACVEAG where we notice its considerable increase and its seasonal characteristic, has a proportionally lower influence (0,05) on diesel; the sensibility of the gasoline sales to these variations is of the same size order and very significant.

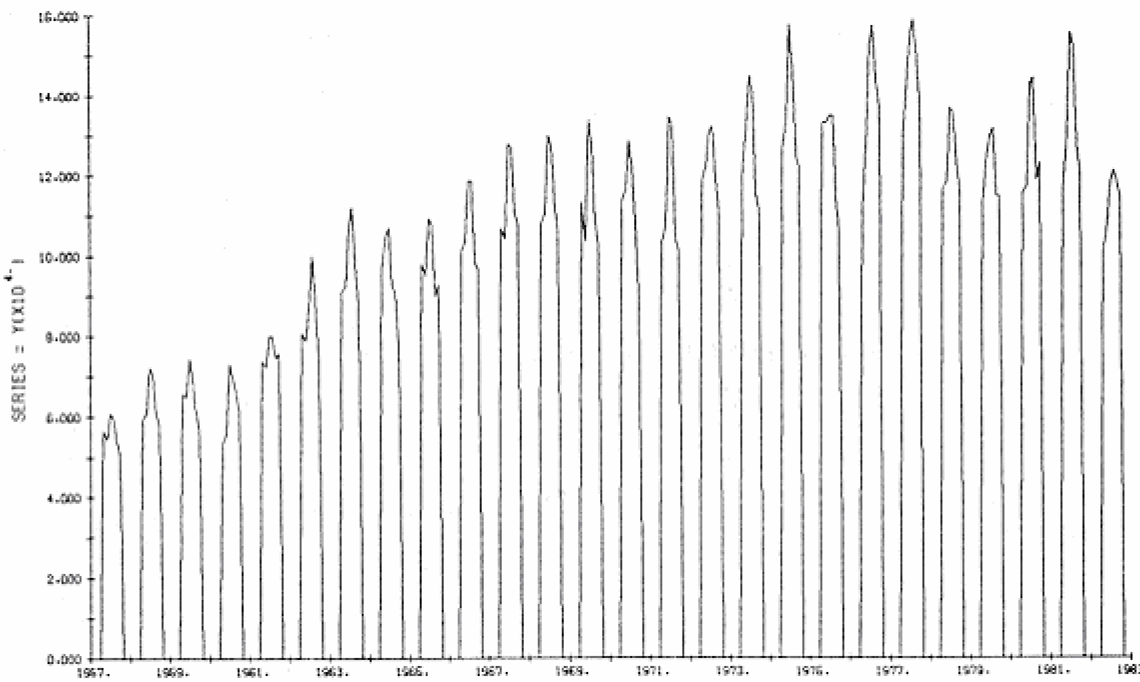
We have to remember that all these results are valid *all other things being equal*: to a constant number of utility vehicles VUTDIPAD, for example. Of course we have subtracted the appropriate amounts of the first three elements to obtain the variable DICR1, and the last one to obtain GAR1. These measurements of road use demand still include some off-highway elements that we could not have taken into consideration:



ACFOR
ON SITE FOREST INDUSTRY ACTIVITY (CUNITS)
(JAN 1957 - DEC 1982)



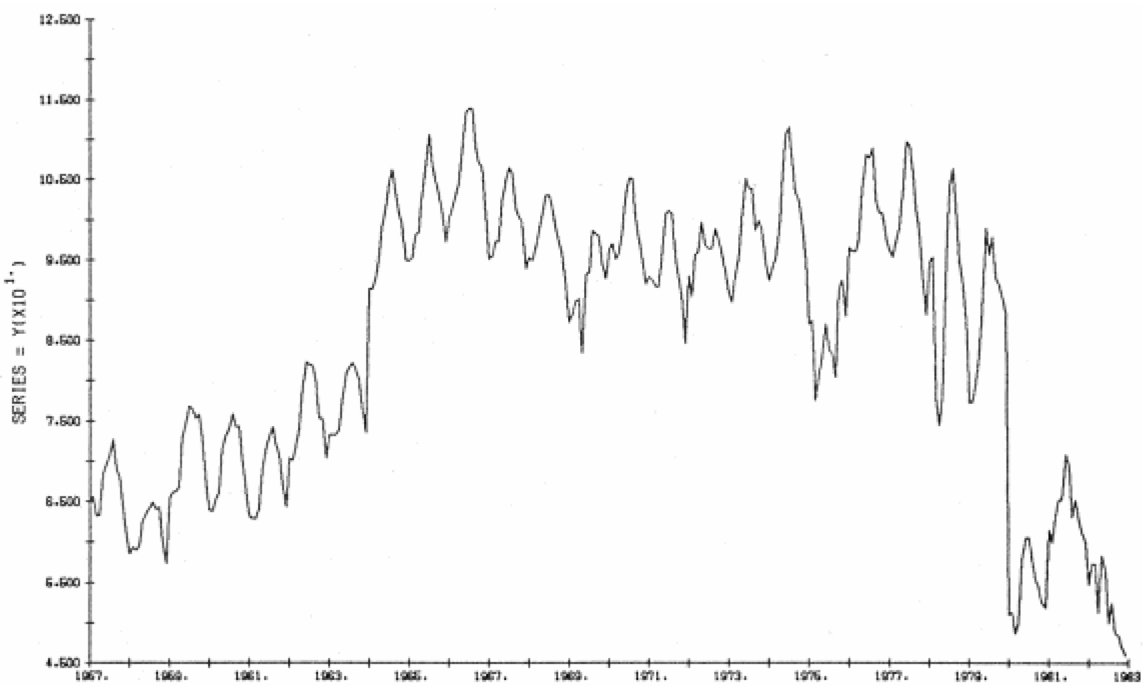
TRGEN
ON SITE LARGE CONSTRUCTION PROJECT ACTIVITY(THOU.OF $)
(JAN 1957 - DEC 1982)



ACVEAG

ON SITE AGRICULTURAL ACTIVITY (AGRICULTURAL VEHICLES)

(JAN 1957 - DEC 1982)



ACMIN

ON SITE MINING INDUSTRY ACTIVITY IN QUEBEC (1967=100)

(JAN 1957 - DEC 1982)

snowmobiles use fuel and Hydro-Quebec own a few stationary generators* that use diesel; American locomotives in transit also use a bit of diesel. It may be possible that some of the climatic variables consider these sales but we are incapable of adjusting GA and DIC so to deduct their influence and get road measurements GAR1 and DICR1 that would be perfect. We tried, for example, to consider the use of diesel in mines and we constructed a variable ACMIN to serve this purpose. We can see its important variance on the graphic: its coefficient was always null and we disregarded it. The sequence on the gross sales of diesel also includes at least one observation, the one of March 1963, where speculative purchasing was done before the budget. Attempts in modelling, using simple methods, the phenomena of speculative storage associated to the budget have not given any useful results. No doubt we should simultaneously represent the "fiscal" storage of truckers at the end of the year, as mentioned earlier.

4.3. Reference model and variants

4.3.1. Reference model (levels 2-3-4): general comments

Since we got the corrections of the sales of fuel from the functions $(D-1)$, we estimate the functions of road use demand $(D-2)$, accidents $(P\text{-}3)$ and accidents severity $(P\text{-}4)$ by allowing the use of variable functional forms, according to $(E-1)$, at the same time as the multiple correlation, according to $(E-3)$. We will only have a general discussion on the statistical results, presented in table 5, and keep the comments of the results variable by variable for the next section.

* We know that those generators consumption is not included in our DIC label from July 1970 to July 1976. We are not sure for the rest of the sample.

- **<u>Autocorrelation, multicollinearity and heteroscedasticity</u>**

In table 5, each function has its own autocorrelation schema. These schemas, effective when they allow us to get a residual error with values in time that are independent from one another, would have been different in some cases from the ones presented if the model would have been linear or log-linear. Indeed, the examination of a former version of the reference model (the minor differences are described in appendix 1) has shown that, for the 4 equations MA, NM, COR and ACC, the significant elements (identified by the t) of the autocorrelation schema varied following the functional form used.

The structures of multiple autocorrelation used have an important advantage on the simple structures. In addition "to getting the remaining information in the errors", their use also transforms the explanatory variables in a way that usually reduces the correlation observed between gross variables. Frequent and detailed examination of the correlation between distinct pairs of transformed variables (there are 465 of them in the equation DICR1, 946 in equation GAR1 and an intermediate number in the other equations) as well as sensitivity tests of the results to modifications in the list of variables of all equations, leads us to believe that the model has no negative multicollinearity case. This means that some signs would be unstable or some elasticities would be excessive due to a too large correlation between one or more variables or combination of transformed variables.

The results found in table 5 imply that the residual error is homoscedastic or to a constant variance $(u_t = k^{1/2}\ v_t, k = \text{a constant, dans (E-2)})$. The tests that are presented in appendix 1 and are used to identify demand variables (in the performance equations) that could produce a heteroscedasticity, suggest that only equations DICR1 and MIC could be improved in that sense by using the manufacturing deliveries (LIVMAD) in the first case and a measurement of road demand (KMPARR1 or DICR1) in the second. We did not use this information in the reference model in part due to presentation homogeneity and also in part due to effects that are still unknown concerning the multicollinearity of the very general form of heteroscedasticity $(E-2)$ used.

- **Functional form**

We can also notice at the bottom of table 5 that only one Box-Cox transformation is used in 8 of the 9 equations: the λ_y associated to the dependent variable has to be everywhere equal to the λ_x used on all the transformable variables, following the standard $(C-3)$, except for the function MBC where λ_y and λ_x have distinct values[11]. The first Student t written under the estimated values is a difference test according to 0 and the second test is one according to 1.

The analysis of the t and the tests of the likelihood ratio done on the results presented in appendix 1 demonstrate that *none* of the functions is linear or log-linear. The results of appendix 1 also indicate that, for several functions, more gains could have been realised by allowing $\hat{\lambda}_y$ to differ from $\hat{\lambda}_x$ but there could never have been any gains in allowing the λ_x to be different for the various groups of expected explanatory variables. Our reference model is "conservative" because we use the smaller common denominator and we insist that the functional form used improve *all* of the 9 functions considered in the model in order to use it. The less conservative model that would necessitate analysis, is

TABLE 5: Reference model: direct elasticities, autocorrelation or functional form parameters and t statistic

		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
	CODE NO. =	51	11	30	30	30	31	29	45	30
	DEP.VAR. =	GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
D = DEPENDENT OR DEMAND		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
GR.GAS.SALES F.ROADS WTD=GAR1*KM/LI	KMPARR1			.869 (3.41) EL1	.482 (1.90) EL1	.588 (1.46) EL1	.491 (2.09) EL1	1.010 (3.89) EL1	.067 (.78) EL1	.753 (1.36) EL1
GR.DIESEL SALES REC.F.ROADS(M.R.1)	DICR1			.054 (1.71) EL1	.032 (1.03) EL1	.045 (.68) EL1	.036 (1.18) EL1	.043 (1.58) EL1	-.015 (-.95) EL1	-.016 (-.20) EL1
P = PRICES		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
REAL PRICE OF REG.GAS.PER KM	PGRPKM	-.106 (-1.17) EL1		.042 (.25) EL1	-.383 (-2.06) EL1	-.076 (-.30) EL1	-.352 (-1.88) EL1	.021 (.16) EL1	.001 (.02) EL1	.278 (1.10) EL1
IND.REAL PRICE TX+REB.DIESL QUE+ONT	IPDROO		-.317 (-1.13) EL1							
REAL PRICE OF TAXED DIESEL	PDRO			-.822 (-3.00) EL1	-.028 (-.13) EL1	-1.740 (-4.88) EL1	-.104 (-.45) EL1	-.622 (-2.84) EL1	-.067 (-.60) EL1	-1.330 (-2.80) EL1
REAL PRICE VEH.MAINT.EXCL.GAS.PUR.	ENTRNMDC	.205 (1.95) EL1	.273 (.68) EL1	-.629 (-3.03) EL1	-.728 (-3.77) EL1	-1.010 (-3.20) EL1	-.706 (-3.66) EL1	-.618 (-2.98) EL1	-.057 (-.47) EL1	-.278 (-.82) EL1
REAL ADULT TRANSIT FARE, MONTREAL	FAD822	.129 (2.00) EL1								
CPI EXC.AUTO+MTL TRANSIT COMPONENTS	PCBNETT	.040 (.33) EL1								
M-Q = MOTOR VEHICLE - QUANTITY		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
CARS PER PERSON	AUPPOP	.259 (1.12) EL1								
COMM.VEH.USING GASOLINE PER ADULT	VUTGAPAD	.127 (1.28) EL1								
COM.VEH.USING DIESEL PER ADULT	VUTDIPAD		.315 .84) EL1							
MOTORCYCLES + MOTORBIKES PER ADULT	MOCYPAD	-.000 (-.01)								
M-C = MOTOR VEHICLE - CHARACTERISTICS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
PROPORTION OF SMALL CARS	PPAS	-.526 (-1.96) EL1		1.070 (2.33) EL1	.487 (1.29) EL1	1.500 (2.69) EL1	.596 (1.46) EL1	.834 (2.73) EL1	.304 (.69) EL1	.830 (1.41) EL1
PROP.CARS W.WAIST OR SHOULD.BELT	DISCEIN	.151 (2.31)	.265 (1.46)	.346 (3.27)	.222 (3.10)	.042 (.46)	.201 (2.58)	.278 (3.86)	.003 (.10)	-.225 (-2.59)
N-L = NETWORK - LEGAL,REGULATION,POLICE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
SPEED LIM.+COMP.BELT 01-15/08/76	LVCEI =====	-.003 (-.13)	.224 (1.98)	.056 (1.45)	-.057 (-1.59)	-.046 (-.98)	-.062 (-1.53)	.025 (.65)	.008 (.43)	.028 (.44)
BREATHALYSER LAW(0.08) 01/12/69	POBPC =====	.003 (.12)	.045 (.36)	.013 (.28)	-.023 (-.44)	-.009 (-.14)	-.020 (-.38)	.029 (.72)	-.010 (-.58)	.029 (.41)
DEMERIT POINT SYSTEM 01/03/73	PTDEM =====	-.006 (-.18)	.159 (1.54)	-.250 (-3.84)	-.093 (-1.67)	-.095 (-1.27)	-.094 (-1.53)	-.218 (-6.14)	-.016 (-.65)	.074 (.97)
NEW HIGHWAY CODE 01/04/82	NCROUT04 ========	-.052 (-1.33)	-.162 (-1.22)	-.137 (-1.72)	-.183 (-3.04)	-.049 (-.51)	-.179 (-3.04)	-.111 (-1.67)	-.030 (-1.01)	.112 (1.05)
PATROL FREQ.,S.Q.AND MTL.U.C.POL.	SURPOL	-.154 (-3.75) EL1	-.102 (-.75) EL1	.205 (1.88) EL1	.173 (1.98) EL1	-.397 (-2.25) EL1	.167 (2.03) EL1	.154 (1.42) EL1	.033 (.47) EL1	-.465 (-1.57) EL1
STRIKES,S.Q.AND MTL.U.C.POL.	GRPOL =====	-.001 (-.08)	-.021 (-.32)	-.017 (-.50)	.009 (.57)	-.005 (-.12)	.010 (.56)	.003 (.15)	.005 (.07)	.020 (.17)

N-T = NETWORK - TIME,SERVICE LEVELS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
TRANSIT WAIT TIME,MONTREAL	TWB22	.213 (2.84) EL1								
COMPLETE TRANSIT STRIKES,MONTREAL	STR813	.012 (1.41)	.048 (.67)	.009 (.43)	.028 (1.44)	.051 (1.33)	.024 (1.40)	.007 (.32)	-.007 (-.93)	.007 (.14)
PARTIAL TRANSIT STRIKES,MONTREAL	STRP	.044 (2.54)	.082 (1.09)	.040 (.78)	-.006 (-.12)	-.044 (-.71)	-.007 (-.14)	.036 (.79)	-.002 (-.07)	-.127 (-1.17)
COMPLETE TRANSIT STRIKES,QUE.CITY	STRCUQ	.003 (.27)	-.027 (-.52)	-.033 (-1.19)	-.033 (-1.28)	-.073 (-1.86)	-.034 (-1.28)	-.037 (-1.53)	.011 (.59)	-.054 (-1.08)
COMPL.INTRCITY BUS(VOYAGEUR)STRIKES	GRVOY	.004 (.27)	-.068 (-1.33)	-.031 (-.59)	.000 (.02)	-.013 (-.30)	.002 (.08)	-.011 (-.29)	-.015 (-.73)	-.033 (-.49)

N-I = NETWORK - INFRASTRUCTURE,WEATHER		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.077 (1.34)	-.139 (-.61)	-.409 (-3.27)	-.035 (-.32)	.049 (.33)	-.042 (-.35)	-.294 (-3.39)	-.072 (-1.63)	-.095 (-.59)
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH	.020 (.50)	.025 (.14)	-.005 (-.14)	.052 (1.01)	-.037 (-.49)	.053 (1.05)	.024 (.77)	.004 (.21)	-.021 (-.26)
HOT OR COLD REL.TO 56 FAHRENHEIT	TLK822	.023 (2.57)	.016 (.54)	.184 (4.61)	.027 (.93)	-.148 (-5.27)	.016 (.55)	.105 (5.53)	.022 (2.96)	-.070 (-2.09)
RAINFALL PER DAY,DORVAL AIRPORT	RFK822	-.008 (-1.67)	.012 (.86)	.034 (3.12)	.000 (.05)	-.000 (-.01)	.001 (.06)	.025 (2.84)	.009 (1.60)	-.000 (0.00)
SNOWFALL PER DAY,DORVAL AIRPORT	SFK822	.004 (1.06)	-.012 (-1.03)	.038 (3.51)	.004 (.54)	.020 (1.53)	.003 (.44)	.030 (4.54)	-.000 (-.10)	-.012 (-.88)
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMR822	-.016 (-2.62)	.058 (4.26)	.025 (2.26)	-.023 (-1.90)	-.109 (-5.51)	-.021 (-1.77)	.020 (1.84)	.003 (.82)	-.006 (-.38)

Y-G = CONSUMERS - GENERAL CHARACTERISTICS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
N.OF DRIVER'S LICENSES PER CAR	PERPA	.073 (.38) EL1		-.371 (-1.71) EL1	-.089 (-.45) EL1	.604 (1.95) EL1	-.133 (-.63) EL1	-.374 (-2.22) EL1	-.253 (-1.87) EL1	.317 (1.05) EL1
PROB.THAT A DRIVER BE UNEMPLOYED	PRCHOM	-.094 (-2.92) EL1		-.272 (-3.11) EL1	-.110 (-1.83) EL1	-.202 (-2.30) EL1	-.100 (-1.64) EL1	-.245 (-4.82) EL1	-.053 (-1.14) EL1	-.072 (-.83) EL1
ROAD VICT.INDEMN.ACT 01/07/61	LOIIND61	.034 (1.33)	.124 (1.56)	.249 (4.50)	.131 (3.50)	-.037 (-.62)	.124 (3.13)	.220 (6.45)	-.065 (-3.53)	-.215 (-3.72)
AUTOMOBILE INSURANCE ACT 01/03/78	LOIAS	.026 (.73)	.050 (.42)	.085 (1.04)	.263 (5.94)	.033 (.58)	.238 (5.14)	.147 (2.37)	-.005 (-.23)	-.217 (-2.73)

Y-A = CONSUMERS - AGE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
18 TO 16 LOW.MIN.DRIV.AGE 01/07/62	MOP62	.010 (.43)	.307 (4.24)	.123 (2.68)	.067 (1.95)	.450 (7.24)	.082 (2.07)	.097 (2.65)	.037 (2.22)	.334 (4.05)

Y-S = CONSUMERS - SEX		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
PROB.THAT A DRIVER BE A PREG.WOMAN	PRFEVM	-.198 (-1.61) EL1		.211 (1.18) EL1	-.175 (-1.00) EL1	-.211 (-.93) EL1	-.157 (-.82) EL1	.136 (.99) EL1	.057 (.60) EL1	-.289 (-1.17) EL1

Y-E = CONSUMERS - EBRIETY OR VIGILANCE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
AVER.WEEKLY HOURS WORKED IN MANUF.	HEUHM			-.889 (-2.02) EL1	.101 (.25) EL1	.613 (.73) EL1	.118 (.30) EL1	-.579 (-1.51) EL1	.136 (.64) EL1	.444 (.56) EL1
PROB.DRIV.HAS TAKEN DRUGS($/ADULT)	PRMED	-.018 (-.45) EL1		.061 (.57) EL1	.278 (2.92) EL1	.116 (.71) EL1	.234 (2.59) EL1	.095 (1.09) EL1	.008 (.20) EL1	-.093 (-.61) EL1
PROB.DRIV.HAS TAKEN ALCOH.(LI/AD.)	PRALT	-.020 (-.51) EL1	-.190 (-1.68) EL1	.033 (.30) EL1	-.012 (-.12) EL1	-.257 (-1.61) EL1	-.030 (-.32) EL1	-.034 (-.33) EL1	.035 (.83) EL1	-.394 (-2.49) EL1

A = ACTIVITY FINAL AND INTERMEDIATE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
EMPLOYMENT PRESENCE INDEX	EIOP	.163 (1.27) EL1								
PROB.OF WORK TRIP(MEASURE R.1)	PRNTRAR1			.448 (2.24) EL1	.265 (1.44) EL1	.246 (.95) EL1	.253 (1.45) EL1	.488 (2.72) EL1	.046 (.51) EL1	.074 (.21) EL1
REAL RETAIL SALES INDEX	RSIOPQ		.492 (2.75) EL1							
REAL RETAIL SALES PER EMPL.PERSON	RSIOPQPE	.240 (3.74) EL1								
PROB.OF SHOPPING TRIP(MEASURE R.1)	PRMNAGR1			.211 (1.42) EL1	.160 (1.02) EL1	.447 (2.16) EL1	.183 (1.21) EL1	.273 (1.97) EL1	-.076 (-.61) EL1	.694 (2.67) EL1
VACATION INDEX	VWMD	.018 (1.90)								
PROB.OF VACATION TRIP(MEASURE R.1)	PRMVACR1			.029 (2.13)	.012 (.83)	.058 (3.20)	.012 (.92)	.034 (2.42)	.005 (.91)	.028 (1.27)
EXPO 1967	EX7 ---	.020 (.70)								
OLYMPIC GAMES 1976	JO --	-.002 (-.05)								
REAL MANUFACT.SECTOR DELIVERIES	LIVMAD		.228 (.97)							
REAL MANU.SECT.DELIV.PER EMPL.PERS.	LIVMADPE	.094 (.87) EL1								
BUSHOURS.MTL.TRANSIT COMMISSION	VEHSF		.192 (.73) EL1							

ET-AD = ET CETERA - ADMINISTRATIVE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
EXISTENCE STAND.ACC.REPORT IN 1978	DUM78RAU ========			.029 (.30)				-.020 (-.26)		
UNDEREST.DUE TO STD.ACC.REP.IN 1978	SED78RAU --------			-.024 (-.39)				.022 (.42)		
REAL MIN.MAT.DMAGE REPORT.CRITERION	DMSR			-.818 (-12.81) EL1				-.607 (-4.00) EL1		
ACC.WITHOUT POL.REP.REQUIR.01/06/79	CONSTA ======			-.073 (-.99)				-.085 (-1.57)		

ET-AG = ET CETERA - AGGREGATION		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
WORKDAYS PER MONTH	WD	.154 (1.77) EL1	-.515 (-1.53) EL1	.425 (2.24) EL1	.183 (1.22) EL1	-.076 (-.19) EL1	.169 (1.11) EL1	.351 (1.95) EL1	.120 (1.08) EL1	-.052 (-.15) EL1
SATURDAYS PER MONTH	SAT	-.032 (-1.05) EL1	-.147 (-1.70) EL1	.148 (2.52) EL1	.160 (2.94) EL1	-.049 (-.37) EL1	.151 (3.01) EL1	.131 (2.41) EL1	.060 (.82) EL1	-.187 (-1.36) EL1
SUNDAYS AND HOLIDAYS PER MONTH	SHD	-.049 (-1.69) EL1	-.130 (-1.60) EL1	.156 (2.97) EL1	.095 (1.98) EL1	-.008 (-.08) EL1	.095 (1.97) EL1	.160 (2.58) EL1	.058 (.78) EL1	-.038 (-.39) EL1

ET-SC = ET CETERA - SEASONALITY,CONSTANT		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
REGRESSION CONSTANT	CONSTANT	-2.150 (-1.49)	-.186 (-.31)	6.490 (3.97)	.119 (.09)	4.100 (1.85)	.629 (.46)	3.620 (2.97)	.779 (1.00)	4.370 (1.44)
	CODE NO. =	51	11	30	30	30	31	29	45	30
	DEP.VAR. =	GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC

AUTOCORRELATION

	RHO 1		.455 (8.43)	.275 (4.02)	.377 (6.48)		.368 (6.11)	.263 (4.00)		
	RHO 2			-.166 (-2.54)		-.050 (-.81)	.065 (.85)	-.255 (-3.75)		
	RHO 3	.212 (2.84)	.106 (1.61)	-.065 (-.92)	-.204 (-2.95)	-.009 (-.13)	-.219 (-3.10)	-.131 (-1.71)		
	RHO 4			.063 (.92)	-.062 (-.88)	-.193 (-2.89)	-.054 (-.78)	.038 (.51)	-.078 (-1.20)	-.234 (-3.04)
	RHO 5			-.203 (-3.07)	-.075 (-.97)	-.052 (-.71)	-.038 (-.51)	-.221 (-3.20)		-.085 (-1.35)
	RHO 6			-.120 (-1.62)	-.030 (-.43)				-.113 (-1.51)	-.072 (-1.14)
	RHO 7		-.233 (-4.05)		-.132 (-1.92)	-.140 (-2.05)	-.090 (-1.34)	-.126 (-1.79)		-.221 (-3.28)
	RHO 8		.260 (4.33)	-.019 (-.28)	-.064 (-.83)	-.147 (-1.99)	-.068 (-.89)			-.135 (-1.95)
	RHO 9		.063 (1.13)		-.118 (-1.56)		-.136 (-1.72)	-.120 (-2.06)		
	RHO 10	-.224 (-2.88)		-.182 (-2.75)			.117 (1.43)	-.136 (-2.05)	-.072 (-1.08)	-.064 (-1.11)
	RHO 11				.215 (3.12)	-.089 (-1.18)	.189 (2.49)			-.037 (-.58)
	RHO 12		.149 (2.70)	.251 (3.89)	.227 (3.71)	.167 (2.56)	.230 (3.75)	.317 (4.69)		.052 (.79)
	RHO 13				-.028 (-.40)	-.137 (-2.16)	-.012 (-.17)			
BOX-COX TRANSFORMATIONS										
ESTIMATED LAMBDA(X) - GROUP 1	EL1	.555 (6.31) (-3.32)	.579 (10.42) (-7.57)	.189 (2.14) (-9.14)	.272 (2.54) (-6.78)	.264 (3.26) (-9.09)	.227 (2.07) (-7.06)	.223 (2.07) (-7.22)	-.063 (-.09) (-1.46)	.628 (3.22) (-1.91)
ESTIMATED LAMBDA(Y)	ELY	.555 (6.31) (-3.32)	.579 (10.42) (-7.57)	.189 (2.14) (-9.14)	.272 (2.54) (-6.78)	.264 (3.26) (-9.09)	.227 (2.07) (-7.06)	.223 (2.07) (-7.22)	-3.588 (-7.27) (-9.29)	.628 (3.22) (-1.91)
LOG-LIKELIHOOD		103.149	-303.353	-303.891	109.909	186.672	104.318	341.339	523.672	381.724
PSEUDO-(L)-R2		.907	.972	.963	.968	.906	.969	.962	.577	.699
NUMBER OF OBSERVATIONS		300	300	300	300	300	300	300	300	300
ESTIMATION PERIOD		14-313	14-313	14-313	14-313	14-313	14-313	14-313	14-313	14-313
NUMBER OF INDEPENDENT VARIABLES		44	31	43	39	39	39	43	39	39

the one that would have a λ_y and a λ_x distinct in 6 or 7 functions. We will not do this analysis.

- **Adjustment to the observations**

For a non linear model, we have described (Dagenais *and al.*, 1980) the following adjustment measurements between the observed values and the values "predicted" by the model:

$$\cdot \text{Pseudo-(L)-R}^2 = 1 - \exp\left\{\frac{2}{N}(L_o - L)\right\} \quad , \qquad \text{(R - 4)}$$

where L_o is the value of the likelihood logarithm by assuming that the model is linear, that the results are homoscedastic and independent in time and that all the β_k, except the constant, are null. L is the value of the maximum likelihood of the considered model. The other measurement is

$$\cdot \text{Pseudo-(E)-R}^2 = 1 - \sum_{t=1+r}^{N}\left[y_t - E(y_t)\right]^2 / \sum_{t=1+r}^{N}(y_t - \overline{y})^2 \quad , \qquad \text{(R - 5)}$$

where $E(y_t)$ is the mathematical expectation of y_t.

From these two measurements, which both match with the ordinary R^2 in the case of the classic linear model, only the first measurement is included between 0 and 1. Its values are written at the end of table 5 where we see that the equations of accident severity MBC and MTC have an adjustment that is not as good as the others'. That is also true if we use the measurement (R - 5) for which the values appear in table 6.

TABLE 6: Values of the pseudo-(E)-R^2 of the reference model

code	:	51	11	30	30	30	31	29	45	30
dep. Var.	:	GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC
Pseudo-(E)-R2	:	.987	.966	.957	.964	.897	.964	.957	.363	.693

This measurement is perhaps closer to the intuitive notion of R^2 than the measurement of $(R-4)$ because it uses the squared sum of errors as denominator, where the errors are seen as difference between the observed values and the "predicted" values (mathematical expectation) by the model; we generally cannot isolate the calculated variable, in linear regression, because the transformation (λ_y) in $(E-1)$ sometimes has no real inverse (for example if the model is $1/y^2 = \ldots$). We have used this measurement in order to compare the implicit adjustment, done by the reference model, to the real number of persons injured or killed, which is only indirectly analysed. To do so, we have supposed that, for each observation, the mathematical expectations of the numbers of fatal or non-fatal accidents were independent of morbidity and mortality rates[12]. We compared these results to the ones we obtained when directly doing a regression of the number of persons injured HT and the number of persons killed DE (without bringing any change to the list of explanatory variables and imposing the constraint $\lambda_y = \lambda_x$). We also modified the reference model so to use, instead of MTC (persons killed/non-fatal+ fatal` accidents), MTMO (persons killed/fatal accidents). The results presented in table 7 show that the reference model appropriately explains the number of persons injured and killed. They also show that we cannot change the definition of mortality rate used and that a "direct" three-step model instead of a five-step one (a model that would explain the number of victims without decomposing it in a product of a number of accidents by a severity level) gives a slightly poorer adjustment, in addition to losing the comprehension element given by the decomposition.

TABLE 7: Pseudo-(E)-R^2 of various calculated models for the injured (HT) and the dead (DE) persons

	HT	DE
Chosen reference model (with MTC)	.9644	.8941
Modified reference model (with MTMO)*	_	.8870
Direct model with 3 levels instead of 5*	.9630	.8877

*The # of code of regressions are MTMO-30, HT-30 and DE-30.

- **Role of the equations on casualty and total accidents**

Table 5 contains two equations of explanation of sub-totals: accidents with bodily damages COR are the sum of non-fatal NM and fatal accidents MO; the total of the accidents ACC includes the accidents with material damages only as well as the casualty accidents. If we look at the average values of the dependent variables in table 8, we will immediately note that the results for equation COR will look like the ones of the equation NM since there are relatively few fatal accidents. Indeed, in table 5, all signs of the variables are identical in the two equations and the orders of size of the elasticities of COR resemble the ones of NM. In the same way, the results of ACC will look like the ones of MA since there are relatively few casualty accidents. In table 5, 3 variables do not have the same sign in these 2 equations: the variable of residual effect of the police officers' strike GRPOL, the variable representing the strike of the maintenance of the streets in Montreal GRMUMH and the alcohol consumption per adult PRALT.

TABLE 8: Values of the dependent variables from January 1957 to December 1982

	GA *(li)*	DIC *(li)*	GAR1*(li)*	DICR1*(li)*
Maximum	827 239 000	177 741 900	771 966 000	155 865 800
Average	509 662 100	66 845 400	485 041 800	59 402 410
Minimum	184 382 300	2 806 223	186 065 600	6 091 788

	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
Maximum	23 554	5 073	229	5 243	27 223	2,04	0,082	7 150	288	7 361
Average	8 988	2 392	105	2 497	11 488	1,39	0,050	3 478	123	3 602
Minimum	2 304	746	21	775	3 334	1,19	0,020	994	21	1 038

- **Elasticities and components**

In the direct and indirect tables of elasticities we will soon use, the elasticities for the sub-totals will be calculated from their components. Since the elasticity of a total equals the sum of the elasticities of each of the weighted parts by their portion of the total – we use the average portions – we have:

$$e_{COR} = e_{NM}\,(NM/COR) + e_{MO}\,(MO/COR) \quad . \qquad (R-6)$$

This aggregation allows the use of the regression results on the components to also calculate the implicit elasticities of the number of the persons injured or killed. Since the elasticity of a product is equal to the sum of the elasticities of its components, we can write

$$\left.\begin{aligned} e_{HT} &= e_{COR} + e_{NM} \\ e_{DE} &= e_{COR} + e_{MO} \end{aligned}\right\} \qquad (R-7)$$

and we can get the elasticity of the total number of victims VI when changing any explanatory variable by calculating

$$e_{VI} = e_{HT}\,(HT/VI) + e_{DE}\,(DE/VI) \quad . \qquad (R-8)$$

Those calculations will be done for all variables, whether they are direct or indirect elasticities. We will not be using anymore the results shown in table 5 for the aggregates COR and ACC. In tables of direct and indirect elasticities, the elasticities of COR, ACC, HT, DE and VI are obtained by applying the formulas $(R-6)$, $(R-7)$ and $(R-8)$. Their differences with the correspondent values of table 4 are weak.

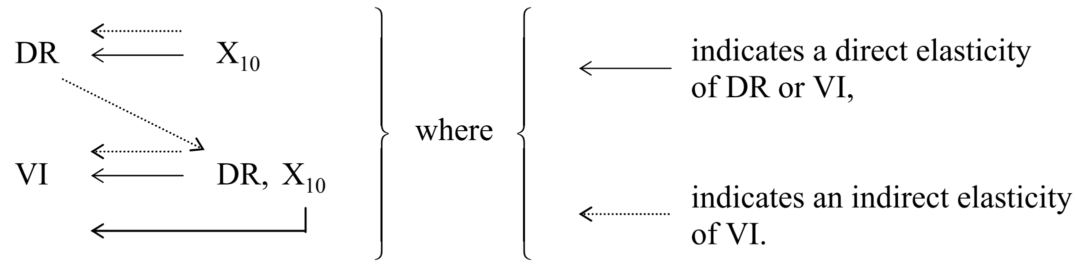
4.3.2. Direct and indirect elasticities (levels 2-3-4-5) : reference and variants

It is now the time to analyse, variable by variable, the results of the REFERENCE MODEL and its VARIANTS: in a variant, we do only one modification of the model for a particular reason.

To each variable, for which the code name is a reminder of the meaning of the elasticity defined by the convention (C-2), we associate

- on the same line, a *direct* elasticity that measures its impact on road use demand, accidents, their severity and the number of victims;
- on the following line, an *indirect* elasticity to take into account its “indirect” influence on the accidents, their severity and the number of victims, through the road use demand.

Schematically, we have, when using the simplified structure:



The indirect elasticity is calculated by multiplying the direct elasticities. In this schema, the indirect elasticity of the number of victims to a variation of X_{10} is

$$E_{VI, X_{10}} = e_{VI, DR} \cdot e_{DR, X_{10}} \quad . \qquad (R-9)$$

We could add up these two elasticities to get the total impact, in the model of a percentage variation of each factor on each dependent variables considered. We will write the two elasticities on distinctive lines.

The Student t associated with the regression coefficient used to calculate the direct elasticity is printed following the convention $(C-1)$ under indirect elasticity. The absence of one of the four visual symbols of the t in the third line means that the result is calculated using other results, following $(R-6)$, $(R-7)$ or $(R-8)$: for example, the numbers shown in column COR derive from a weighted sum of the numbers shown in columns NM and MO, following $(R-6)$.

Before presenting the detailed results, lets verify our comprehension of the 3 elements of information presented following the standards (C-1) and (C-2) in sections of table 9 of the results. Let's chose the variable of police surveillance SURPOL which is part of the variables of category N-L « networks-laws, regulations, police ». We will be able to read, later on, the following results taken from the reference model

N-L		MBC	MTC
⋮		⋮	⋮
Police surveillance SQ and CUM	SURPOL……	,033	−,465
		−,009	−,114
		*	**

and understand that a 10 % increase in the surveillance of police officers decreases the mortality by 4,65 % and raises the morbidity by 0,33 %. The first impact is the most important one. To these direct impacts (measured at a given fuel consumption) is added the indirect impacts due to a reduction in fuel consumption (respectively - 1,14 and - ,09 %) and indicated at the second line. Since the code name SURPOL is not underlined, these impacts are calculated on the average of all the observations.

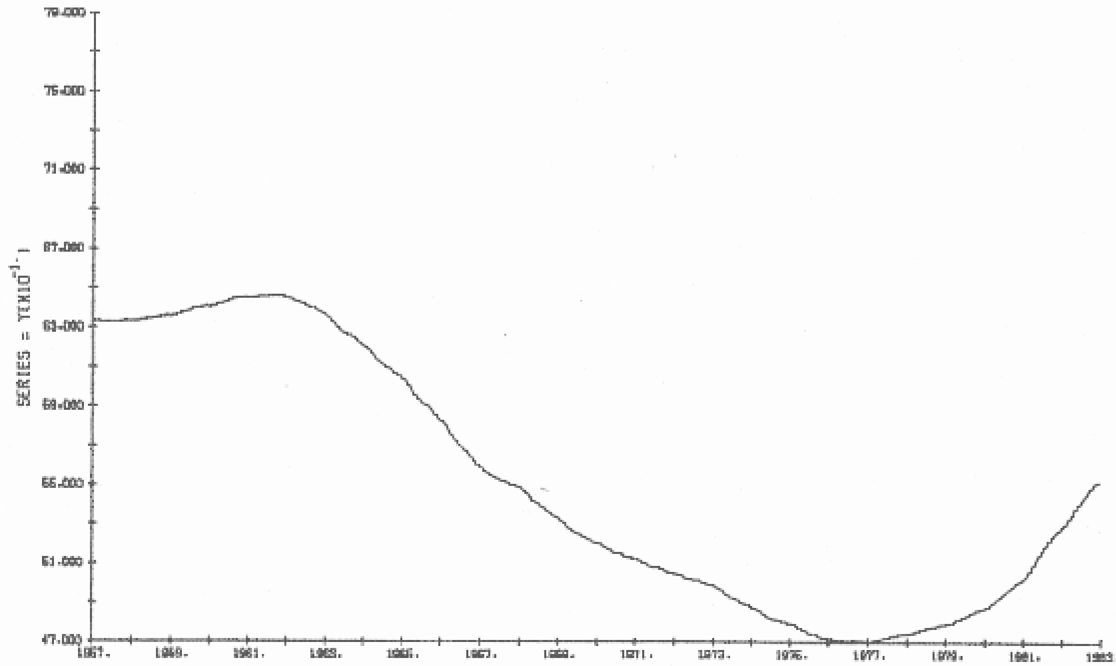
In order to comment, we will follow the sequence of categories and sub-categories of variables used in sections 3.2 and 3.3 of this study. We will consider all variables used. This comment supposes that the reader consults the table of direct and indirect elasticities at the beginning of the comment of each variable and it may be divided in three main parts: a description of the data, a brief reading of the signs and direct or indirect elasticities with an explanation; comparisons with relevant results obtained elsewhere and a sentence on the sensitivity of the results of the reference model to the chosen functional form. All sections in table 9, as well as the variants, are based on the optimal $\hat{\lambda}_y$ and $\hat{\lambda}_x$ but it is interesting, when considering the robustness, to briefly compare them with other results, for which the corresponding tables will not be presented. These results are obtained when assuming that the reference model or its variants are linear or log-linear.

- **<u>D = road use demand</u>**

KMPARR1

The number of kilometres travelled is obtained by multiplying the gasoline demand for highway use GAR1 by par the average energy efficiency of the stock of cars represented in graphic COAUT. This efficiency, which the average is approximately 5,5 km/li (14,5 mi/imperial gallon), shows that it is not independent from the real price of the gasoline per litre as seen in graphic PGRMDSI. The transformation of fuel sales for highway use GAR1 in travelled kilometrage KMPARR1 does not change the shape of the curve: we can clearly see though, an important drop in 1981 and 1982.

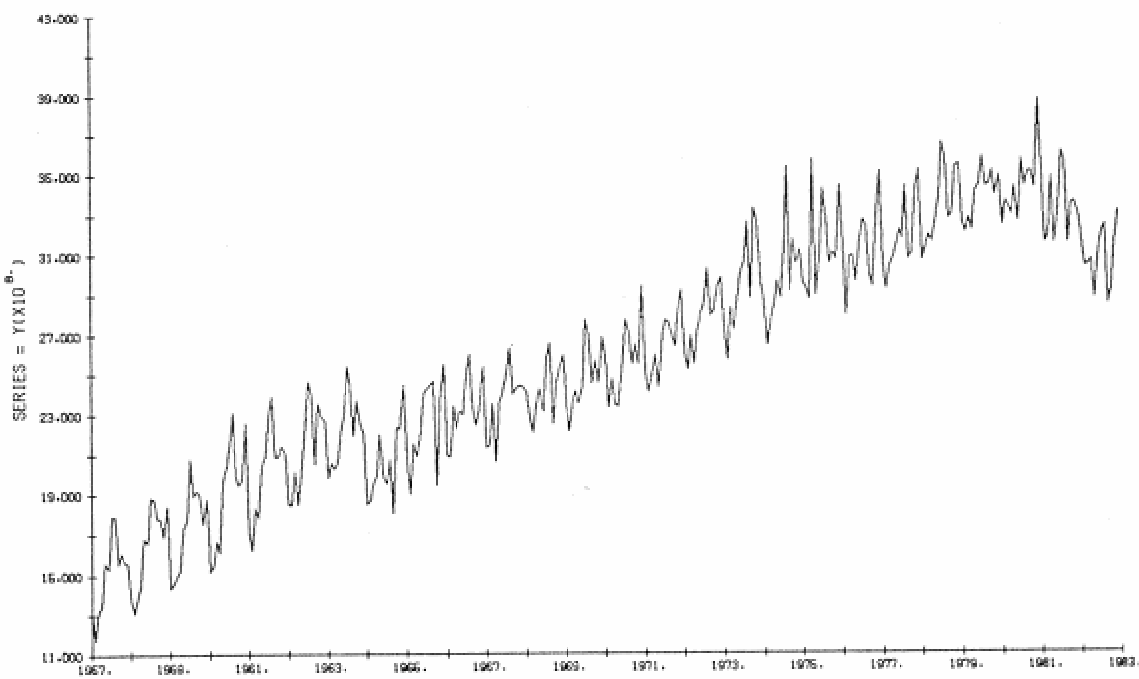
One can notice in table 9.1 that an increase in the demand raises the accidents, their severity, and consequently the victims. The direct elasticities are interesting: the accidents with material damages increase proportionally more than the other categories; the morbidity is barely affected but the mortality increases almost proportionally; the persons killed increase more than proportionally and the injured persons increase a lot less. The elasticities of the number of traffic fatalities would have been of 1,48 with a linear model and of 0,80 with a logarithmic model: the intermediate result of 1,23 obtained with the optimal form implies that our results are slightly different from Peltzman's (1975) who, in an argument with Joksch (1976), had shown (Peltzman, 1976) that the number of persons killed increases proportionally with the distance travelled. Here the number of fatalities increases more than proportionally. Since our measurement of the kilometrage is also representative of the influence of speed on gasoline consumption, the difference between the two results can be explained by the fact that Peltzman could have used a speed index in his model.



COAUT

AVERAGE CAR FUEL EFFICIENCY IN QUEBEC (KM/LI)

(JAN 1957 - DEC 1982)



KMPARR1

GROSS GAS.SALES (M.R.1) WEIGHTED BY KM/LI VEH.EFFI.(KM)

(JAN 1957 - DEC 1982)

TABLE 9.1: Direct elasticities, D = road use demand

D = DEPENDENT OR DEMAND		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
GR.GAS.SALES F.ROADS WTD-GAR1*KM/LI	KMPARR1			.869	.482	.588	.486	.786	.067	.753	.554	1.239	.577
				///	**	**			*	**			
GR.DIESEL SALES REC.F.ROADS(M.R.1)	DICR1			.054	.032	.045	.032	.049	-.015	-.016	.017	.016	.017
				**	**	*			*	*			

There is no doubt that the considerable reduction of kilometrage travelled by cars and utility vehicles running on gasoline in 1981 and 1982 contributed to a drop in the number of victims observed during that period.

DICR1

We did not change the diesel consumption into kilometrage because the average energy efficiency of the stock of trucks and utility vehicles using diesel has increased less than the one of the cars. In the case of the C.T.C.U.M.'s 2000 buses, for example, the consumption per kilometre has practically not changed in the last 15 years. New engines on trucks have improved in that last 15 years though (apparently from slightly more than 3mi/gallon to a little less than 6/mi/gallon) but the consequences of these improvements are slowly being felt due to the average life of engines that has increased from 300 000 mi. to 500 000 mi. on the same period[13].

We observe in table 9.1 that the rises in diesel consumption increase accidents, especially material damages ones, reduce their severity and increase, in total, the injured and dead persons of similar percentages. Since the rate of diesel consumption per kilometre of vehicle using it is 4 times higher than the one of vehicles running on gasoline, and that KMPARR1 is 8 times higher than DICR1, we can multiply the elasticities of the table by 32 in order to get an idea of the danger of heavyweight trucks compared to other vehicles to *equal total kilometrage*: we then obtain 0,51 for HT and 0,55 for DE, which means that with heavyweight trucks there is as much injuries per kilometre than with other vehicles but there is 55 % less persons killed[*]. We think that the interurban characteristic of the major part of the kilometre travelled by heavyweight trucks and the fact that the driver is relatively well-protected help in explaining some of the results. Indeed, heavyweight trucks are responsible for, by kilometre, more non-fatal and fatal accidents than other vehicles [(0.032 x 32 =) 1,02 and (0,045 x 32 =) 1,44 compared to 0,48 and 0,58], but these accidents are less severe: they kill more often but less persons at a time than other vehicles. These results are located between the ones that would have been given by a linear model where trucks are proportionally responsible for more victims than other vehicles, and a log-linear model, where trucks are proportionally responsible for fewer victims per kilometre than vehicles running on gasoline.

- **<u>P = Prices</u>**

PGRPKM

The real price of gasoline per kilometre can be obtained by dividing the real price per litre by the average efficiency of the stock of cars, variables that we see in graphics PGRMDSI and COAUT. This transformation allows to take into account the adjustment of consumers to the increases in gasoline prices by purchasing more effective vehicles[15] and using COAUT as explanatory variable of gasoline demand[16].

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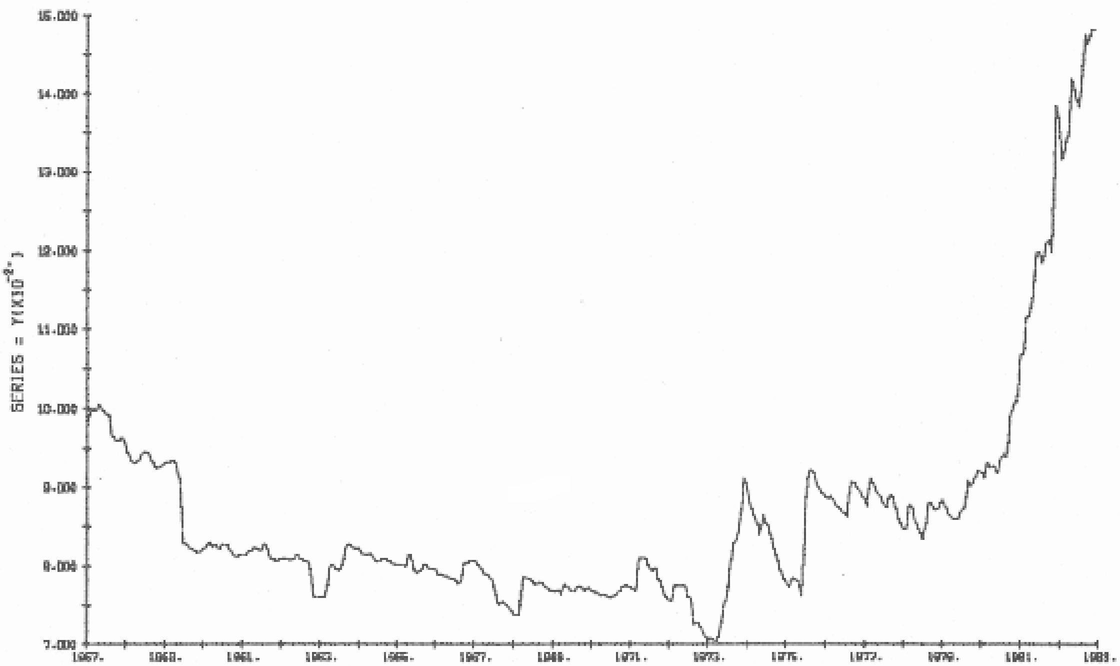
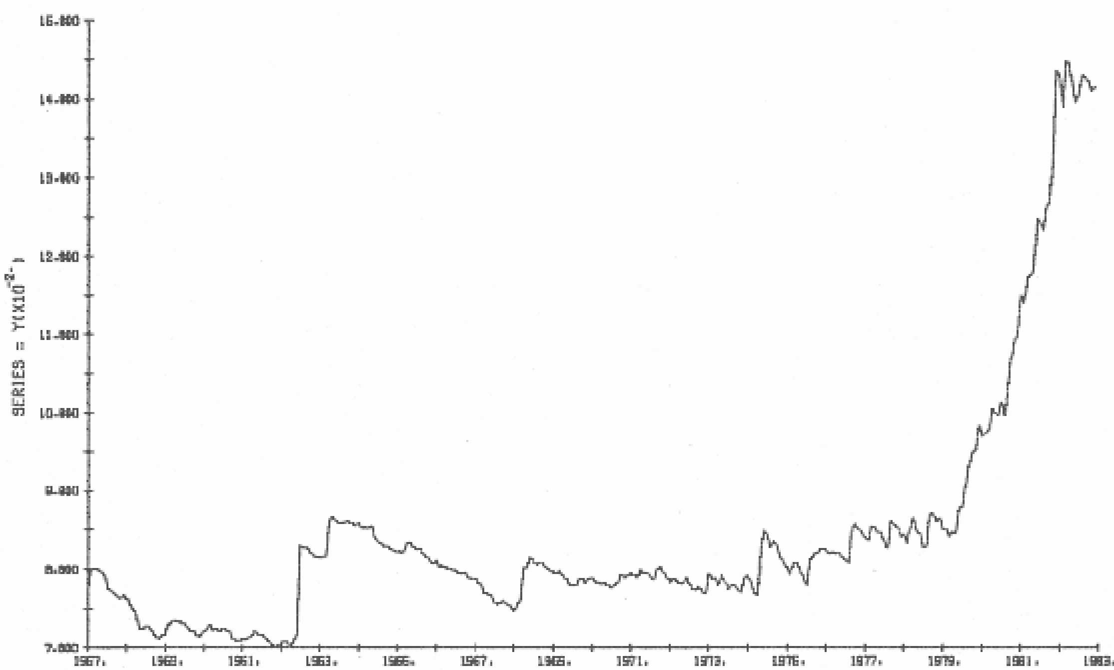
[*] because (0,55/1,23) x 100 = 45%.



PGRMDSI

REAL PRICE OF REGULAR GASOLINE IN MONTREAL ($/LI)

(JAN 1957 - DEC 1982)



PDRQ

REAL PRICE OF TAXED DIESEL IN QUEBEC ($/LI)

(JAN 1957 - DEC 1982)

In table 9.2 we can see that elasticity-price of the demand is - 0,10 and that the rise of the price increases the material accidents, decreases the casualty accidents, and despite an increase of the severity, decreases the victims. Short-term elasticities estimated elsewhere are usually very low (Burright and Enns, 1975, Hartman *and al.*, 1982) and of this order of size. The direct elasticity of the number of victims (- 0,35) is far more important than the direct elasticity of the gasoline demand. This implies that the increases in prices have an important effect on speed. The raise of the "price of speed" reduces its demand. It is a drop in the price of autoprotection compared to the autoinsurance one, or a change from point 2 to point 1 on figure 1.a of table 1. We can realise this reduction in open country rather than in urban zone: in total, the fuel demand slightly falls but the reduction of speed, on roads where it is realisable, has a considerable effect. We can get an idea of this effect if we consider that the fuel consumption increases rapidly at more than 55 km per hour. The improvement in engines reduces the consumption at every speed levels but does not change the minimum of the U curve which links speed (on the horizontal axis) to consumption level (on the vertical axis)[*]. Using the Labiale's data (1982), we can calculate that a drop in speed from 120 to 100 km/h. involves an average elasticity of the level of consumption of - 1,27. If the accident probability also decreases more than proportionally to the speed, it is not surprising that an increase in prices reduces the total number of road victims by - 0,35.

[*] The motor power required to reach a certain speed is the product of the speed by the aerodynamic friction (air resistance). Because that friction is proportional to the square of the speed, the power required increases according to the third power of the speed.

TABLE 9.2: Direct and indirect elasticities, P = price

P = PRICES		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
REAL PRICE OF REG.GAS.PER KM	PGRPKM	-.106 **		.042 -.092 *	-.383 -.051 ***	-.076 -.062 *	-.370 -.052	-.048 -.083	.001 -.007 *	.278 -.080 **	-.369 -.059	-.092 -.131	-.359 -.061
IND.REAL PRICE TX+REB.DIESL QUE+ONT	IPDRQO		-.317 **	-.017	-.010	-.014	-.010	-.016	.005	.005	-.005	-.005	-.005
REAL PRICE OF TAXED DIESEL	PDRQ			-.822 ***	-.028 *	-1.740 ///	-.100	-.665	-.067 *	-1.330 ***	-.167	-1.430	-.210
REAL PRICE VEH.MAINT.EXCL.GAS.PUR.	ENTRNMOC	.205 **	.273 *	-.629 .193 ///	-.728 .107 ///	-1.010 .133 ///	-.740 .108	-.653 .174	-.067 .010 *	-.278 .150 *	-.797 .118	-1.018 .258	-.804 .123
REAL ADULT TRANSIT FARE, MONTREAL	FAD822	.129 **		.112	.062	.076	.063	.101	.009	.097	.071	.160	.074
CPI EXC.AUTO+MTL TRANSIT COMPONENTS	PCBNETT	.040 *		.035	.019	.024	.020	.032	.003	.030	.022	.050	.023

If we add to the direct elasticities the effect of the indirect elasticities, we obtain the following total elasticities: HT: - 0,42, DE: - 0,22. The corresponding values are (- 0,48, - 0,32) and (- 0,38, - 0,04) with the linear and log-linear models.

IPDRQO and PDRQ

While the real price of gasoline PGRMDSI has increased by only 50 % since 1956, the real price of diesel has increased by 75 %, as we can see in graphic PDRQ. We use a combined index Quebec-Ontario to explain the road demand due to its significant interprovincial characteristic. However, the price in Quebec is relevant in explaining the drivers' behaviour on roads.

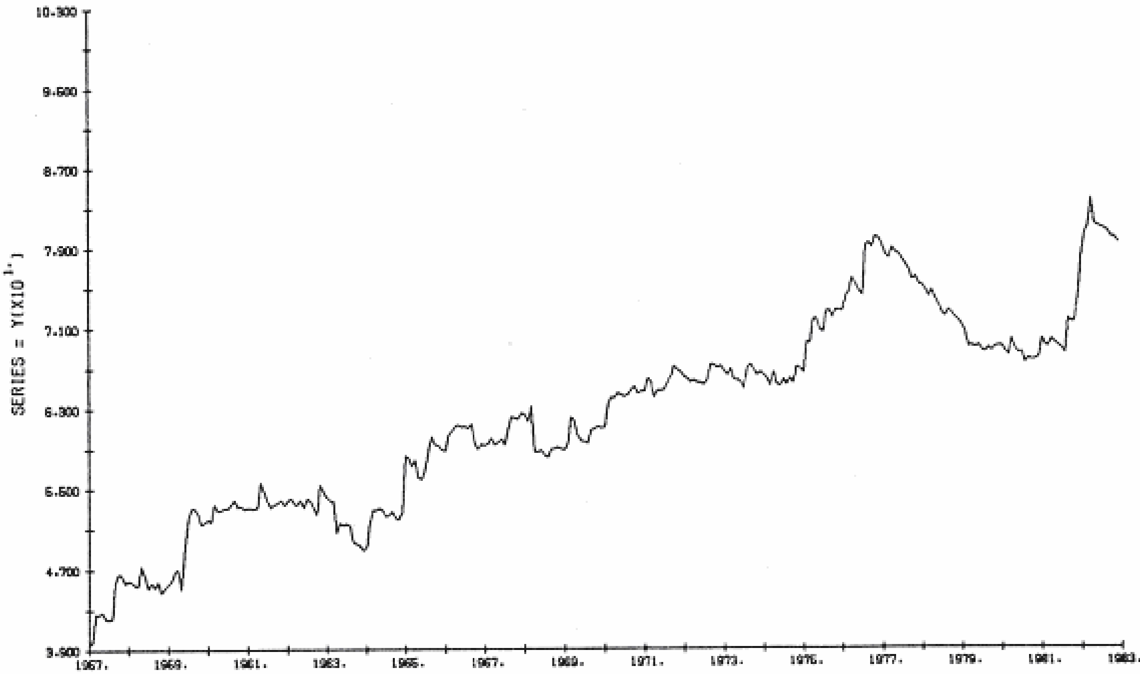
In table 9.2 we observe that the price-elasticity of the demand is - 0,31 and that the increases in the price PDRQ significantly lower all accident categories and their severity, and consequently, the victims. We will notice the size and the high statistical meaning of the reductions of fatal accidents and mortality.

The price-elasticity being smaller than the one of the gasoline can be due to a larger competition from other transportation modes in merchandise transportation than in people transportation[17]. It can also be due to the fact that the consumption level of vehicles can be modified when truck drivers change their differential disk (this is easy to do during the maintenance) or when they change the level by lowering the gear, which is more expensive.

The effects of the price on the accidents and their severity involve that a reduction in speed decreases the accident probability and severity (to others) proportionally more than for cars. It is interesting to notice that reductions of speed do not result in more serious accidents than for other types of vehicles. Engines are made to achieve road speeds of approximately 105 km/h. (65 mi./h) and the rises in prices force the truckers to maintain this speed. The elasticity of the number of victims (- 0,21) is very high. It would have been lower (- 0,02) with a linear model and even lower (- 0,19) with a log-linear model.

ENTRNMDC

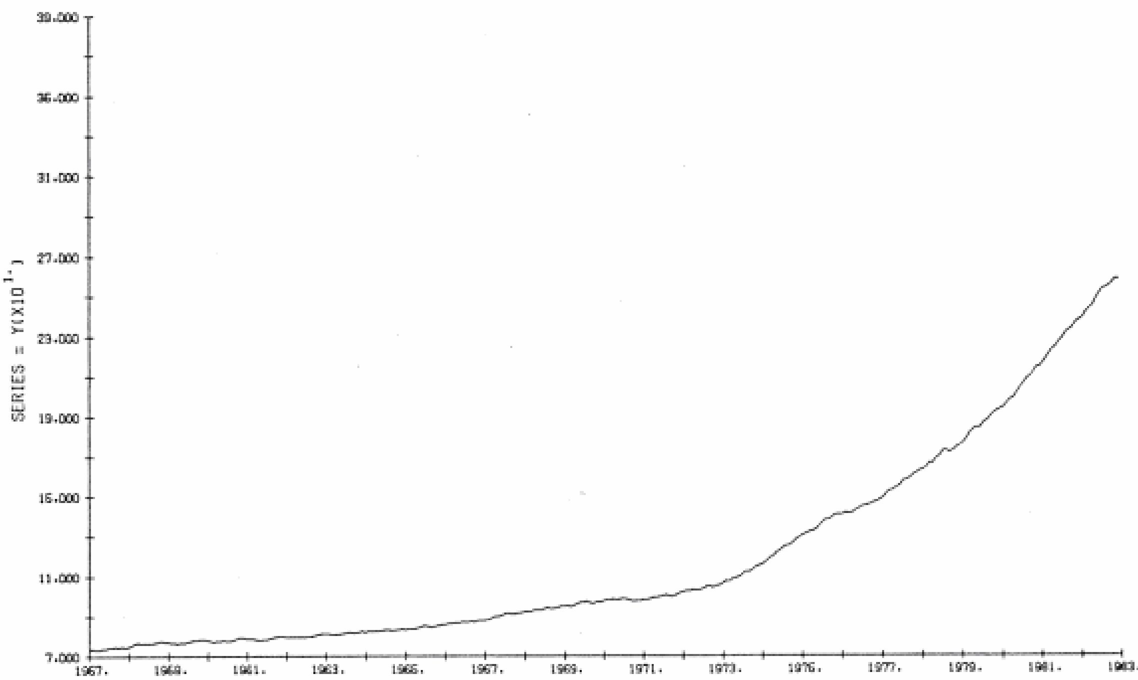
One of the most visible characteristics of the actual maintenance cost of a vehicle, which we can see on graphic ENTRNMDC, is the “bump” in the middle of years 1970. If we compare it to the one of its two components, maintenance and insurance, illustrated on graphics ENTRNAS and PRASA of appendix 2, we observe that they have played different roles in the total cost of maintenance.



ENTRNMDC

REAL PRICE OF VEH.MAINTENANCE EXC.GAS.PURCH.(1956=39.6)

(JAN 1957 - DEC 1982)



PCBNETT

CPI EXCLUD. AUTO AND MTL TRANSIT COMPONENTS (1971=100)

(JAN 1957 - DEC 1982)

An increase of the real cost in vehicle maintenance ENTRNMDC creates a rise in fuel consumption and a drop in all categories of accidents, their severity and the victims. The impacts on all accident categories show a high sensitivity that is significant in a statistical perspective.

We expect that an increase of the maintenance costs will lead to a change in the choice of fuel. Why is there such a high drop in the accidents and their severity? It might be related to drivers, who feel that the risk of severe accidents might increase when driving an older vehicle that is in poorer condition, drive more carefully and try to reduce the probability and the average severity, as predicted in our theory. The augmentation of risk, without any change in perceived trade-offs between speed, probability and severity of accidents, include a shift from point 1 to point 2 on figure 5 of table 1. We do not pay any attention to the indirect effect that only proves the poor maintenance state of the engines and do not have anything to do with accidents. These results are not truly affected by the use of a log-linear or linear model.

FAD822 and PCBNETT

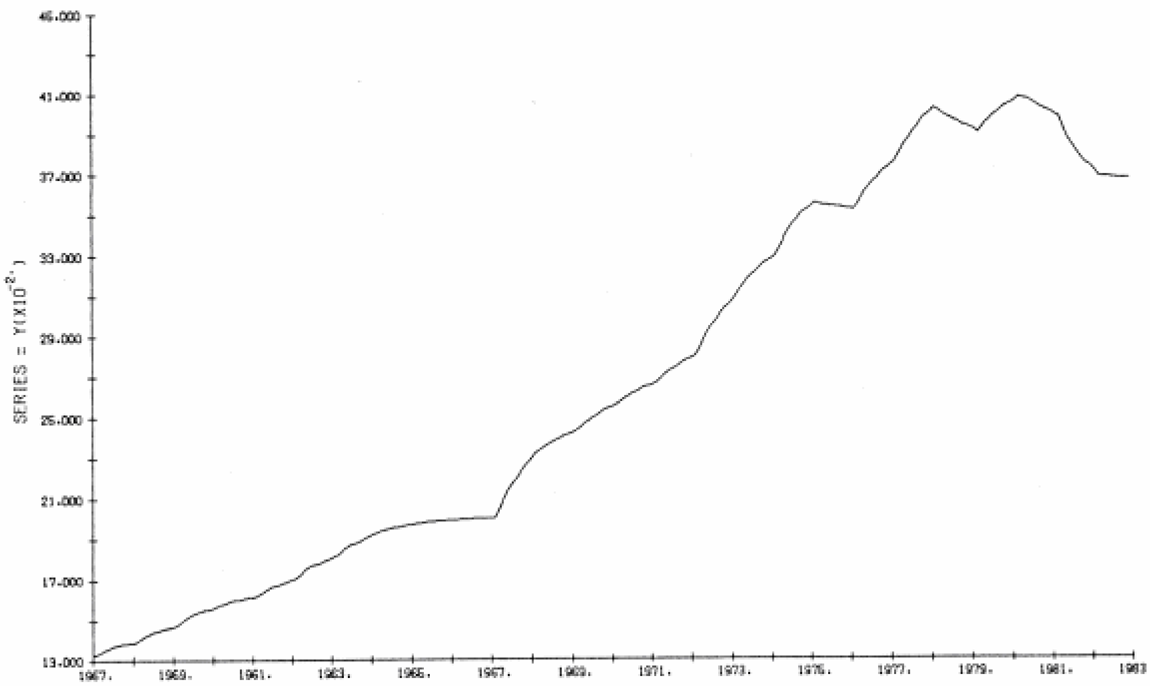
The fare of public transit in Montreal FAD822 seems to us having a too big effect on fuel demand. We can understand why, with its high correlation with fares of other public transit enterprises, it becomes an provincial index; we can also imagine that the impact on road congestion might be considerable. However we have found, in a deeper study on Montreal conducted until 1971 (Gaudry, 1980), an elasticity of 0,07 that seems more likely. Allsop and Turner (1984) have also found, as we did, a significant impact of the increase in the public transport fares of London on the accidents, especially among drivers and cyclists.

The other goods, such as the cost, on graphic PCBNETT that looks typical, are substitutes of gasoline. An increase of the cost of these goods slightly raises the number of victims with the indirect elasticity.

- **<u>M = motorization, quantity and characteristics</u>**

AUPPOP

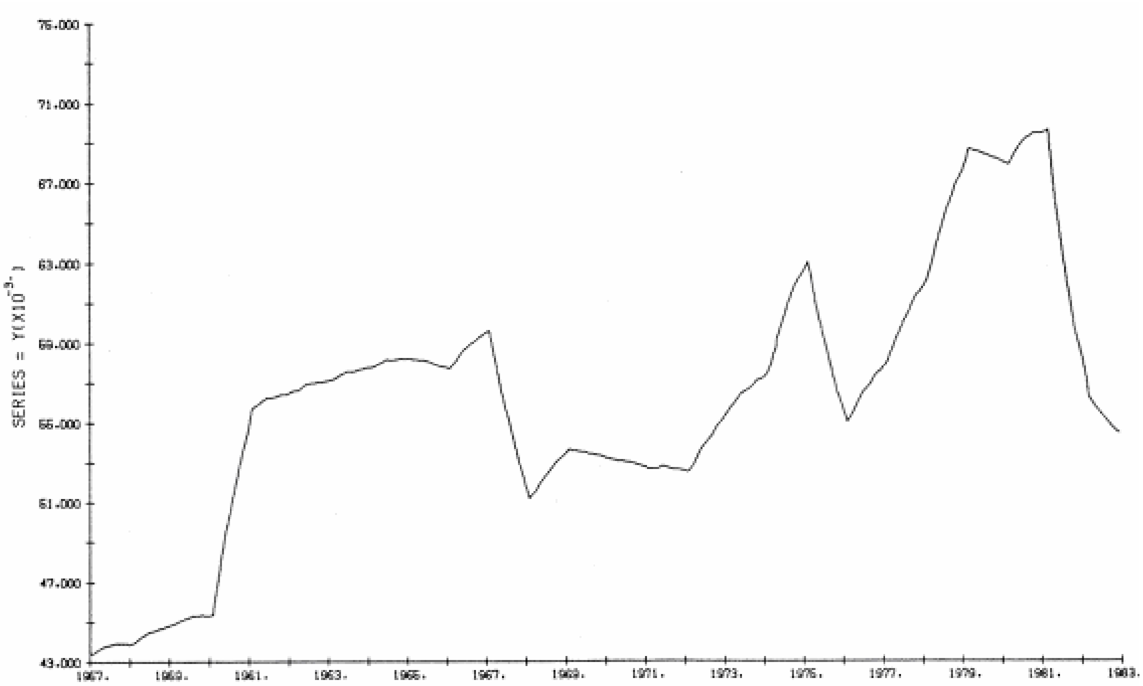
The number of cars per adult has significantly decreased in Quebec in 1977, in 1978-79 and in 1981-82. The tendency, which was upward during the first twenty years of our sample, is downward since 1978. We will try to find some of the factors that will explain the interruption of the tendency, visible on graphic AUPPOP, in a very simple auxiliary model with results that will be presented in appendix 2. The elasticity of the gasoline demand to the cars availability, indicated in table 9.3, is 0,26. A linear model would have given 0,34 and a log-linear model, 0,13. Lets remember that all the results have a meaning only if *all else being equal*: the use, prices etc. This result thus means that, in order to execute the same activities, employment, shopping, etc., additional particular cars do not proportionally increase the fuel demand. Since we have considered the level of energy efficiency of the stock by using a price per km instead of a price per litre, we have to come to the conclusion that the additional cars are, on average, less used than the ones already in use. Of course, a deeper analysis, which would distinguish between first and second cars, would help us understand the meaning of this elasticity.



AUPPOP

NUMBER OF CARS PER PERSON IN QUEBEC

(JAN 1957 - DEC 1982)



VUTGAPAD

COMMERCIAL VEHICLES USING GASOLINE PER ADULT IN QUEBEC

(JAN 1957 - DEC 1982)

TABLE 9.3 : Direct and indirect elasticities,
M = motorisation, quantities and characteristics

M-Q = MOTOR VEHICLE - QUANTITY		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
CARS PER PERSON	AUPPOP	.269 **		.234	.130	.158	.131	.211	.018	.203	.109	.225	.113
COMM.VEH.USING GASOLINE PER ADULT	VUTGAPAD	.127 **		.110	.061	.075	.062	.100	.009	.096	.051	.106	.053
COM.VEH.USING DIESEL PER ADULT	VUTDIPAD		.315	.017	.010	.014	.010	.015	-.005	-.005	-.002	.006	-.002
MOTORCYCLES + MOTORBIKES PER ADULT	MOCYPAD	-.000 *		-.000	-.000	-.000	-.000	-.000	-.000	-.000	-.000	-.000	-.000

M-C = MOTOR VEHICLE - CHARACTERISTICS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
PROPORTION OF SMALL CARS	PPAS	-.526 **		1.070 -.457 ***	.487 -.254 **	1.500 -.309 ***	.530 -.256	.953 -.413	.304 -.035 *	.830 -.396 **	.573 -.213 **	1.360 -.441 ***	.600 -.220
PROP.CARS W.WAIST OR SHOULD.BELT	DISCEIN	.151 ***	.265 **	.346 .145 ///	.222 .081 ///	.042 .101 *	.214 .082	.317 .132	.003 .006 *	-.225 .109 ***	.207 .059 ***	.012 .132 *	.200 .062

VUTGAPAD

Most of the new trucks run on gasoline. Presently, less than 14 % of new trucks run on diesel. We will observe on graphic VUTGAPAD how the truck stock is influenced by the recessions of 1968, 1976 and 1981-82. Since there are 4,75 times more cars than utility vehicles, the elasticity similar to the cars' one would be 0,60 and not 0,12. Additional utility vehicles are therefore 2 times more used than the utility cars*, ceteris paribus*…. Consequently, their influence on accident, their severity and victims is 2 times the one of cars *per vehicle*. If we had chosen a linear model, we would have found the same influences, as the log-linear model would have involved 8 times more accidents per vehicles.

VUTDIPAD

Utility vehicles running on diesel (their graphic, which is not presented, looks a lot like the one of VUTGAPAD), increase the diesel demand in a non-proportionally way because the elasticity is 0,315. The measurements of indirect elasticities show that *per vehicle* (there is 7,8 times more utility vehicles running on gasoline), they are responsible for half the number of injured persons (0,005 x 7,828 = 0,039) and the quarter of the number of fatalities caused by additional utility vehicles running on gasoline. If we compare to cars, these proportions are respectively the quarter and the eight. In a linear model, utility vehicles running on diesel would cause more victims than the utility vehicles running on gasoline; in a log-linear model, the fractions would be even smaller than the ones of the reference model.

MOCYPAD

Our data concerning the motorcycles and the powercycles are not very effective since the monthly number is not available and we had to use annual "plateaux" separated by null level "negative curvatures" during winter. Our results suggest a trivial decrease of fuel consumption, as if less cars were driven when motorcycles and powercycles can be used. We have also made experiments by adding this quasi-qualitative variable in the equations of accidents and their severity, with or without an auxiliary variable representing the mandatory use of helmets for motorists. Results show a reduction of accidents, their severity and victims when there is a rise in the availability of motorcycles and powercycles (would the drivers have killed or injured *more* persons if they had been driving a car?) and a significant augmentation of the number of people killed since the use of helmets is mandatory. Our data are not reliable enough to consider this variant and give any credibility to these results (which are not shown). Therefore in conclusion, we have not succeeded in incorporating the impact of motorcycles and powercycles in the model.

PPAS

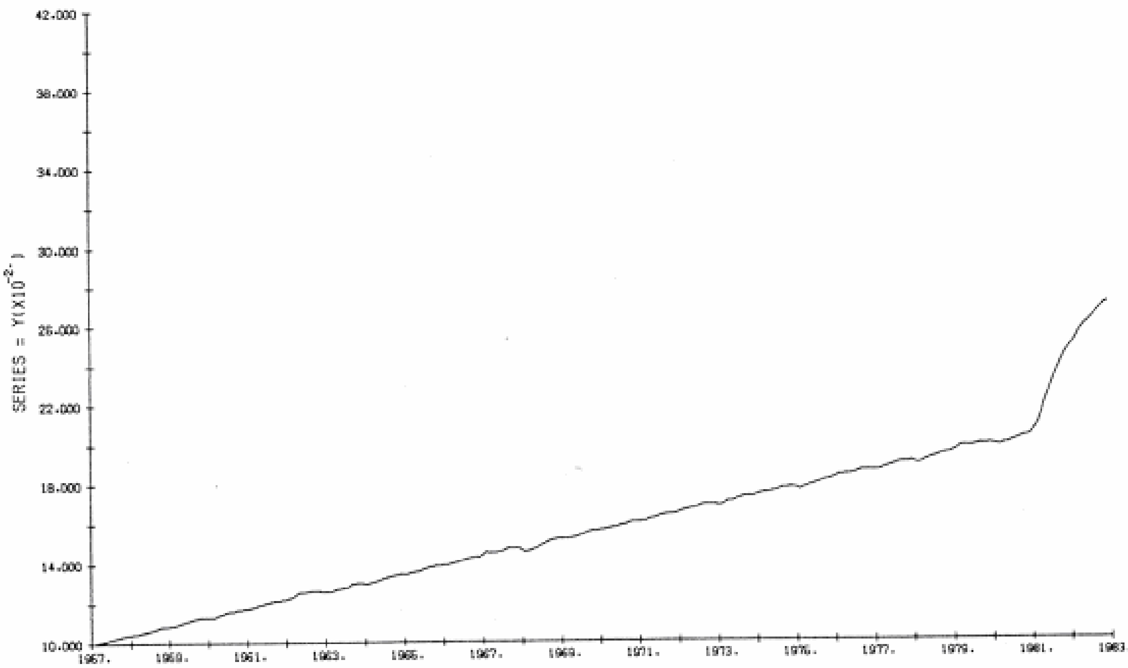
The proportion of small cars goes from 10 to a bit more than 20 % in 26 years on graphic PPAS. We will notice in table 9.3 that an increase of PPAS reduces the gasoline consumption (to a given price per *kilometre*…) and increases all categories of accidents, their severity and the number of victims. The increase in fatal accidents and mortality are particularly important and significant in a statistical perspective.

How can we understand this phenomenon? The force applied on a passenger of vehicle 1 during an accident is proportional to the deceleration during the collision. The latter, ΔV_1, can be estimated from the masses W_1 and W_2, the angle between the speed vector after the impact and the initial direction of the vehicle 1, α, and the speed of the vehicles, V_1 and V_2, following Carlson's formula (1979)

$$\Delta V_1 = \frac{W_2}{W_1 + W_2} \sqrt{(V_1^2 + V_2^2 + 2 \cos \alpha)} \qquad , \qquad \text{(R - 10)}$$

where the "protection effect" that offers the structure of the vehicle is represented by its weight and the other factors illustrate the "hostility effect". We can observe from (R-10) that ΔV depends on the *relative* weights of the vehicles, but also that the light vehicle is mostly affected by the effects of the speed *independently of the relative speeds of the vehicles*. It is therefore impossible to reduce, with a lower speed, the relative anticipated severity and the relative risk of small cars; on average, we expect more victims than with bigger cars if only 15 % of the cars circulating are small. These results* are compatible with the ones of Moffet and Groleau (1982) on a sample of accidents in Quebec involving more than one vehicle; they have found that the severity of accidents, measured

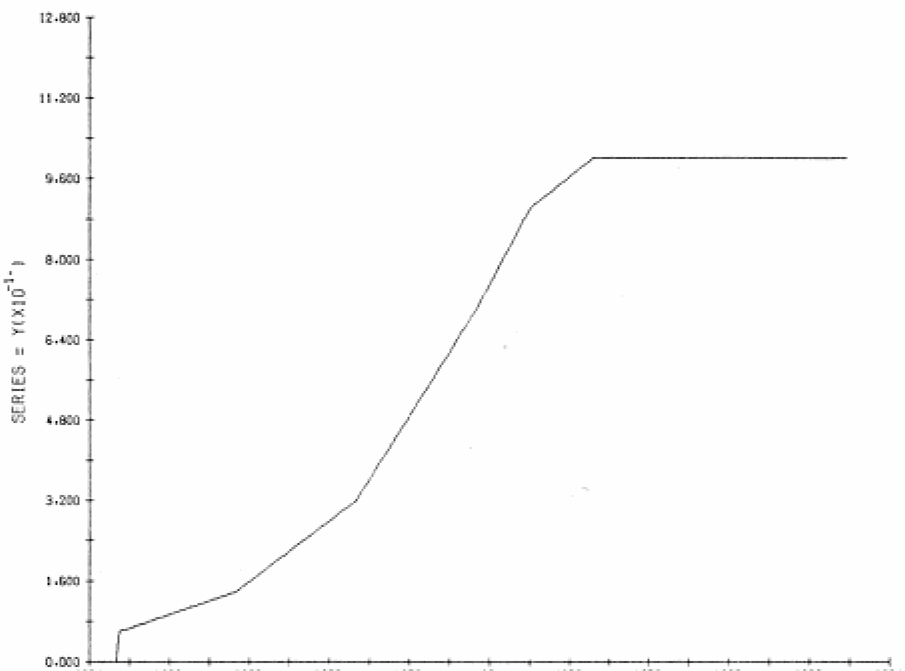
* Let's add that the smaller cars have an insurance price higher per dollar than the bigger cars.



PPAS

PROPORTION OF SMALL CARS IN QUEBEC

(JAN 1957 - DEC 1982)



DISCEIN

PROPORTION OF CARS WITH WAIST OR SHOULDER BELT.QUEBEC

(JAN 1964 - DEC 1982)

by the number of fatalities per passengers, was diminishing with the weight of crashed cars.

Let's notice that, according to the gasoline demand, small cars added to the vehicle fleet travel 2 times less than the bigger cars. The indirect elasticities are therefore important and negative, but in total, despite this moderating element, an increase of 10 % in the proportion of small cars augments by 5,2 % the injured persons and by 7,1 % the dead ones. These effects would have been of the same size range with a linear model and a log-linear model. Due to the high non-linearity of (R-10), we are expecting that the effects lessen as the proportion of small cars increases, and people who drive them become more representative of all the drivers, if they are not already.

DISCEIN

Availability of the belt and the shoulder belt, as illustrated in graphic DISCEIN, increases the consumption of fuels, all categories of accidents, morbidity and the total number of victims: only the mortality and the number of fatalities diminish slightly; if we calculate the direct elasticities of the victims in 1982 instead of using all the sample, we would get 0,46 for the injured and - 0,19 for the persons killed. These numbers are compatible with the Peltzman's ones (1975), who has calculated that in Canada the cars equipped with "security systems" had 25 % more accidents than cars of the *same make and year* without this equipment. When we add the indirect effects to these direct effects, we obtain an increase of the injured *and the dead* individuals because of the positive effect of the seatbelt on the gasoline consumption. This effect can come from a kilometrage and a higher speed. The total effects obtained with a linear or log-linear model are *identical*.

In his analysis on the effect of security equipment, Peltzman had also obtained the following results for the United States: (a) the number of persons killed per mile has slightly increased after its introduction and the proportion of persons killed who were pedestrians has increased advantaging the passengers; (b) the number of injured persons and accidents with material damages per mile have increased, especially the second one. Our results are the same. Peltzman considers the speed but not the kilometrage. Ours results take into account a mix of kilometrage + speed (the effect on gasoline consumption) and it is consequently not surprising to find identical results for the material accidents and slightly more important (meaning a significant rise) for both categories of victims.

A drop in the perceived severity of accidents leads to an increase in their number, exactly as in graphic 1.a of table 1: if we take a close look at the total elasticities (direct + indirect) in 1982 instead of in the entire sample, we get for MBC 0,01 and for MTC - 0,33 (instead of 0,01 and 0,05 in table 9.3).

- **N-L = networks – laws, regulation, police**

In this study, the auxiliary variables (for which the code name is underlined twice) have, by deduction, a standardised effect in time. We would have to undergo other studies in order to evaluate the evolution of the effects in time and to upgrade them with additional information or specific hypothesis.

LVCEI

The impact of the law concerning the mandatory use of a seatbelt and the law on reduction of speed limit, passed within a 15-day interval in August 1976, cannot be separately evaluated.

We find in table 9.4.A., a major rise of the diesel consumption, an increase of the material accidents and a drop of the casualty accidents for which the severity does not increase enough to increase the number of people injured and killed. The increase of diesel sales is surprising, as well as the low diminution of the number of victims (4,8 %). A linear model would have produced a direct drop of 8,3 % and a log-linear model a drop of 4,4 %.

If the increase of the diesel sales does not result from a misleading correlation, meaning from another unknown variable (building sites activities of the Bay James that are wrongly illustrated in our index TRGEN of table 4?), it can illustrate in part the effect of the interaction between the cars and the trucks: if cars are travelling slower and slower (as the drop in gasoline consumption indicates), heavy trucks can therefore travel on average faster in open country; in the city they can travel too slow to be effective. We neglect the indirect elasticities (for which the effect is very low) due to the uncertain characteristic of this result.

TABLE 9.4: Direct and indirect elasticities,
N-L = networks – laws, regulations, police

A. Reference model

N-L = NETWORK - LEGAL,REGULATION,POLICE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
SPEED LIM.+COMP.BELT 01-15/08/76	LVCEI	-.003 * 	.224 **	.055 .009 **	-.057 .005 **	-.046 .008 *	-.056 .006	.030 .008	.008 -.004 *	.028 -.006 *	-.053 -.003 **	-.029 .001 *	-.052 -.003
BREATHALYSER LAW(0.08) 01/12/69	POBPC	.003 *	.045 *	.013 .005 *	-.023 .003 *	-.009 .004 *	-.022 .003	.006 .005	-.010 -.000 *	.029 .002 *	-.027 .001 *	-.011 .004 *	-.026 .001
DEMERIT POINT SYSTEM 01/03/73	PTDEM	-.006 *	.159 **	-.250 .003 ///	-.093 .002 **	-.095 .004 **	-.093 .002	-.216 .003	-.016 -.003 *	.07[illegible] -.007 *	-.[illegible]74 -.003 **	-.018 -.002 *	-.072 -.003
NEW HIGHWAY CODE 01/04/82	NCROUT04	-.052 **	-.162 **	-.137 -.054 **	-.183 -.030 ///	-.049 -.038 *	-.177 -.030	-.146 -.049	-.030 -.001 **	.112 -.036 **	-.218 -.020 ///	-.031 -.046 *	-.212 -.021
PATROL FREQ.,S.Q.AND MTL.U.C.POL.	SURPOL	-.154 ///	-.102 *	.205 -.139 **	.173 -.077 **	-.397 -.095 ***	.149 -.078	.193 -.126	.033 -.009 *	-.465 -.114 **	.160 -.062 **	-.497 -.131 ***	.138 -.064
STRIKES,S.Q.AND MTL.U.C.POL.	GRPOL	-.001 *	-.021 *	-.017 -.002 *	.009 -.001 *	-.005 -.002 *	.009 -.001	-.011 -.002	.005 .000 *	.020 -.000 *	.016 -.000 *	.004 -.001 *	.015 -.000

B. Variant: stratification of the police patrol

N-L = NETWORK - LEGAL,REGULATION,POLICE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
SPEED LIM.+COMP.BELT 01-15/08/76	LVCEI	-.006 *	.230 ***	.055 .008 **	-.076 .005 ***	-.106 .007 **	-.077 .005	.027 .007	.003 -.004 *	-.005 -.006 *	-.073 .002	-.082 -.000	-.074 .002
BREATHALYSER LAW(0.08) 01/12/69	POBPC	.007 *	.035 *	.025 .008 *	.002 .005 *	.063 .007 *	.004 .005	.020 .007	-.008 -.000 *	.052 .006 *	-.003 .005	.056 .011	-.001 .005
DEMERIT POINT SYSTEM 01/03/73	PTDEM	-.001 *	.156 **	-.246 .008 ///	-.081 .005 **	-.052 .007 *	-.080 .005	-.210 .007	-.013 -.002 *	.079 -.001 **	-.093 .003	-.001 .004	-.090 .003
NEW HIGHWAY CODE 01/04/82	NCROUT04	-.050 **	-.163 **	-.135 -.051 **	-.177 -.031 ///	-.050 -.044 *	-.172 -.031	-.143 -.045	-.029 -.001 *	.131 -.044 **	-.200 -.032	-.040 -.075	-.195 -.034
PATROL FREQUENCY,SURETE DU QUE.	SURSQ	-.069 *	.117 *	.001 -.051 *	-.183 -.030 **	-.584 -.043 ///	-.200 -.030	-.043 -.047	-.035 -.007 *	-.323 -.061 **	-.235 -.037	-.523 -.091	-.245 -.039
STRIKES,SURETE DU QUEBEC	GRSQ	-.004 *	-.053 *	-.057 -.006 *	.018 -.004 *	-.013 -.006 *	.017 -.004	-.041 -.006	.015 .000 *	.063 -.004 *	.032 -.004	.080 -.008	.033 -.004
PATROL FREQ.,MTL.URB.COM.POLICE	SURCUM	-.136 ///	-.082 *	.201 -.119 **	.164 -.071 ***	-.445 -.102 ///	.129 -.072	.186 -.109	.028 -.009 *	-.424 -.120 ***	.157 -.081	-.295 -.192	.142 -.084
STRIKES.MTL.URB.COM.POLICE	GRPCUM	.001 *	-.021 *	.046 -.000 *	.024 -.000 *	.041 -.000 *	.025 -.000	.042 -.000	-.003 .000 *	-.014 .001 *	.022 .000	.011 .001	.022 .000

The substitution from material accidents to casualty accidents, and the augmentation of the average severity of accidents are compatible effects with our predictions on the effects of these two measurements taken together. The reduction of the speed limits increases the price of the speed: we therefore expect an increase of the number of accidents and a decrease of the severity (shift from point 1 to point 2 on figure

1.a in table 1). Simultaneously, the mandatory use of the seatbelt reduces the price of the use of the shoulder belt (increases the penalties when not worn), and resulting in the opposite effect. The two measurements reduce the risk (the variance of the severity) and incite in increasing the accident probability and the average severity of accidents. We thus observe a net effect that is lower than what we might have first expected.

Following an "analysis of interventions" on the same data, Chenail (1984) concluded to decreases of about 13 % in the number of injured persons and of about 25 % in the number of persons killed from 1976 to the end of 1979. Since the method used does not consider the others factors that could have contributed to this drop (drop in the accessibility of car, the large increase of the price of fuels and vehicles maintenance) or that would go in an opposite direction (Automobile Insurance Act of March 1st 1978), the higher results are comparable to ours because they evaluate a net effect of all the changes. In Ontario, where a combination of similar laws was implanted in January 1976, the net effect determined by Abraham (1983) from 1976 to the end of 1980 was of 19 people dead per month, compared with 108 per month before the intervention; Abraham has not estimated any net effect on injured people. In France, the simultaneous obligation to wear the seatbelt in open country and to respect the speed limits in 1973 seems to have reversed the upward trend of the number of people injured or killed (Vallin and Chenais, 1975).

The results found when analysing one *or* the other of the implanted measures vary considerably. In their excellent analysis on the impact of limiting speed in Texas, Wiorkowski and Heckard (1977) obtain a reduction of the mileage and the number of persons killed per mile, an increase of the number of fatal and non fatal accidents per mile and of the number of injured persons per mile; however, the severity, measured by the number of people killed per injured person, has not changed! Studies on the obligation of wearing the seatbelt propose a drop of 46 % of the number of fatalities in Queensland (Bhattacharyya and Layton, 1979) and a raise of 15 % in New Zealand (Palmer and Toomath, 1974).

P∅8PC

We evaluate the effect of the law concerning the breathalyser in two ways: (i) by its effect on the total alcohol consumption, which has a direct and indirect influence on accidents; (ii) by the residual effect that can stay, considering the alcohol consumption (or in order to correct an heterogeneity in the sequence on alcohol consumption put into effect by this law) and is measured by the variable P∅8PC in table 9.4.

(ii) We can notice, in table A.2 of the auxiliary models, that the law on breathalyser has *increased* the intake of alcohol by 4 %. This effect is possible if publicity concerning the permitted level, or “safe” level of consumption, encourages a large number of people to drink more; if this effect is important, it can easily compensate the hypothetical reductions of consumption of « heavy drinkers » who represent a small part of the population proportion.

As we see in table 5 and as we will discuss later in detail when commenting on tables 9.10.A and 9.10.C, an increase of the *global* alcohol consumption decreases the number of persons killed and increases the number of persons injured; if we consider the indirect effects, the consumption does not affect the number of persons injured in total; the number of dead persons decreases more. This effect is possible if the alcohol consumption in small quantities slightly reduces the accident probability among a large number of people and considerably increases among a very small number; it is possible if, on average people, "overcompensate".

The product of these two effects is:

	Alcohol effect	HT		DE	
	Direct (0,04) x	(0,013) = 0,00052		(0,04) x (-0,416)	= -0,01664
	Indirect (0,04) x	(-0,014) = -0,00056		(0,04) x (0,028)	= 0,00112
T-1 :	Total	-0,00004			-0,01776

(ii) Considering this effect by the average alcohol consumption, the law seems to have an *additional* residual effect of increasing the number of dead persons and reducing the number of injured persons. The increase of the alcohol consumption produced by the law must be corrected. This correction is:

	Residual effect	HT	DE
	Direct	-0,032	0,007
	Indirect	0,003	0,005
T-2:	Total	-0,029	0,012

The fact that this correction, not very significant, has to be done implies that the law has changed the habits of alcohol consumption. The signs of the direct elasticities of residual variable $P\emptyset 8PC$, interpreted with the results on the variable of alcohol consumption, mean that people who drink more (see auxiliary model of PRALT in table A.2) on average (which reduces the number of deaths and increases the number of injuries) do not drink the additional quantities the same way as the one that follows the constant increase of consumption tendancy: new drinkers, who drink the "safe" amount of alcohol before driving, drink more than the new drinkers of the trend and this increases the number of deaths and reduces the number of injuries. According to the trend, there is a slight movement above 30 mg in the graphic « Index of accident probabilities according to the alcohol level in the driver's blood » of section Y - E .

The total effect of the law on breathalyser, obtained when adding up T-1 and T-2, is a reduction of 2,9 % of the number of injured persons and a barely observable drop of 0,5 % in the number of persons killed. These results are identical to the conclusions of Carr *and al.*, (1976) according to which the law concerning breathalyser of December 1st 1969 had no effect on fatal accidents in Canada, conclusion based in part on the observation that the blood alcohol concentration of the drivers who died in an accident in 1970 were equivalent to the ones of 1969.

PTDEM

The demerits plan of March 1st 1973 had the following effects:

- a small diminution of the gasoline consumption but an important increase of the diesel consumption. This increase, such as the one caused by the speed limits, might be due to the interaction between cars and heavy trucks: reductions of the speed of heavy trucks in urban zone and an increase in open country?

- a reduction of all categories of accidents, of severity (except for mortality) and of victims but more of injured persons (-10,9 %) than persons killed (-1,9 %); the indirect effects slightly increase the values to 11 % and 2,4 %. A linear model would have given a “direct” raise of the number of deaths and a log-linear model a reduction of 10 % of the two categories of victims.

NCROUT04

The new Highway Code of April 1st 1982 has

- reduced considerably the fuel consumption: 5,2 % for gasoline and 16,2 % for diesel;
- reduced all categories of accidents, of severity (except for mortality) and the number of victims. The raise of mortality due to the demerits plan and to the new Highway Code insinuates that consumers who reduce the accident probability and the severity expectation decide, because of the decrease of risk (variance of severity) to take more risks and it causes more serious accidents. However these accidents are not numerous enough to increase the number of people killed.

The sum of direct and indirect effects of the new Highway Code indicates drops of 23,8 % in the number of injured people and of 13,2 % of the number of people killed. The corresponding numbers would be 26,2 % and 20,0 % for the linear model; 22,1 % and 1,1 % for the log-linear model.

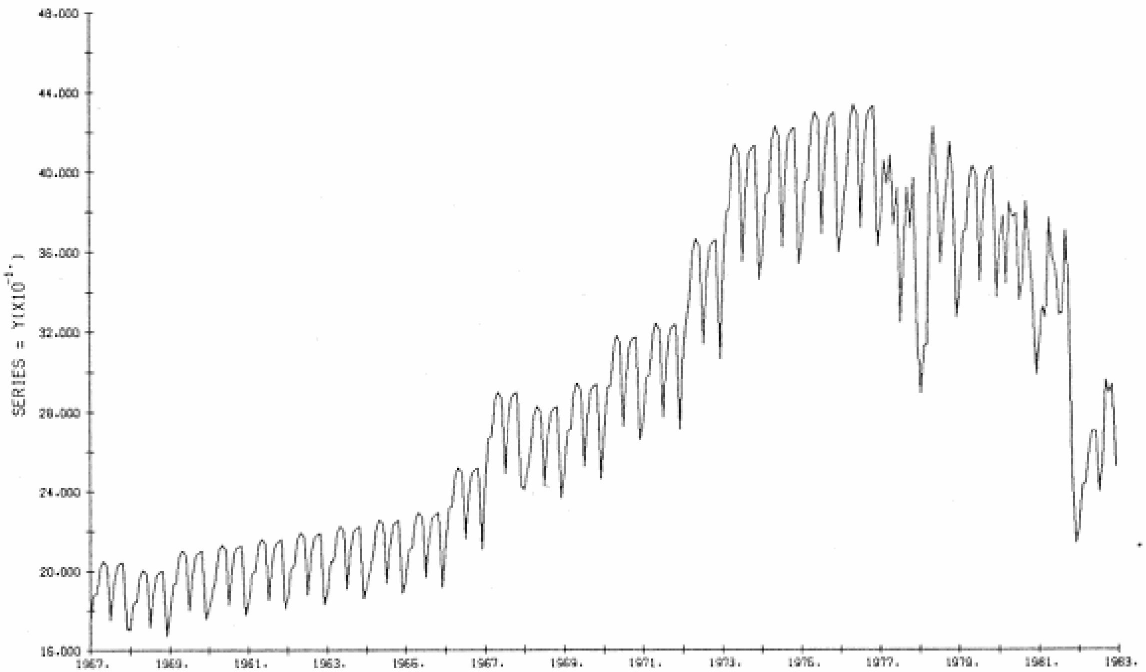
SURPOL and GRPOL

The index of police surveillance SURPOL is an aggregation of the surveillance indexes of the *Sûreté du Québec* SURSQ* and of the *police de la Communauté Urbaine de Montréal* (Montreal urban community police) SURCUM. We clearly see on graphic SURSQ the progressive effect of the twinning of police patrols (2 police officers per car, 2 slots succession on 3) in 1977 and the other reductions of service following the budget cuts of November 1981. On graphic SURCUM, we see the reduction of nearly 10 % of service caused by the merge of 28 police forces of the municipalities of Montreal Island to the service of the city of Montreal in early 1972 as well as the impacts of the recent budget cuts. In some cases, we can detect the effect of the strikes. Our indexes of strikes are residual indexes that measure, if any are left, effects in addition to those caused by the reduction of service or effects of another nature. The aggregated index therefore represent close to two third of the police services in Quebec; insofar as the other police forces services are correlated with it, its coefficient (or those of the indexes used separately) take it into consideration.

We will note, when reading the direct elasticities in table 9.4.A, that the police surveillance

- reduces the fuel consumption, especially of cars; Hauer (1982) has shown that the surveillance reduces the average speed and its variance….;
- from the statistical point of view, reduces the fatal accidents, the mortality and the number of persons killed in an important and significant way but increases the other accident categories, the morbidity, and the number of injured people;

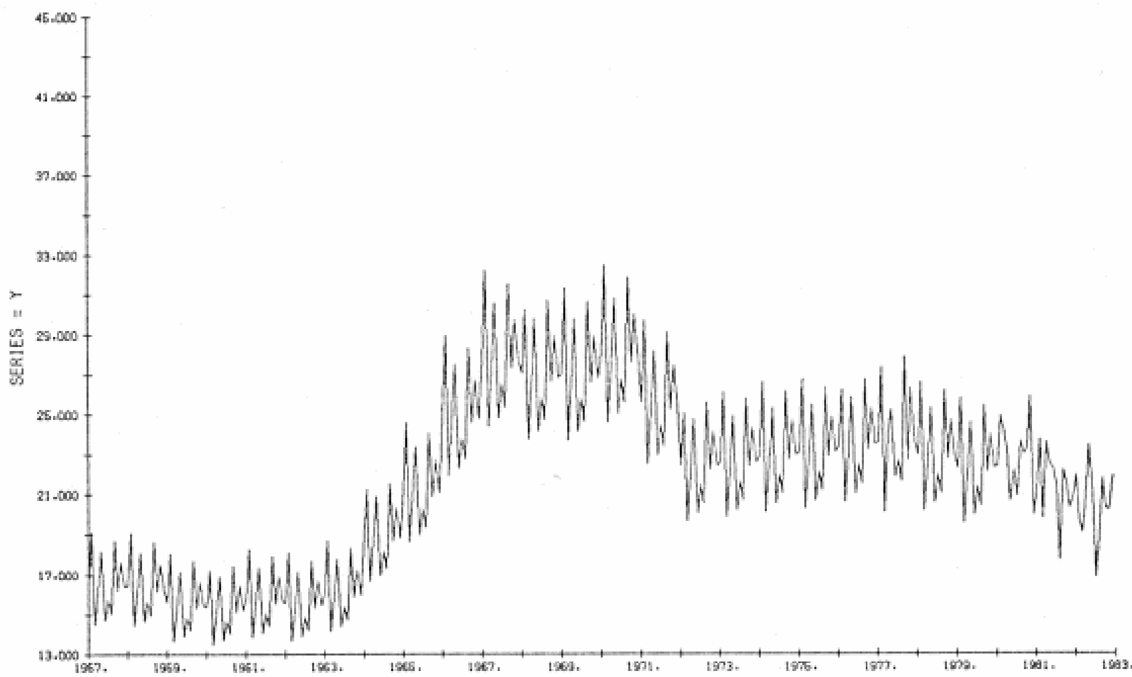
* The index, which represents a frequency of shift in an random point of the network, does not consider the implementation of the bidirectional radar or of a different impact per kilometre travelled associated with static patrols. We could consider improving it.



SURSQ

PATROL FREQUENCY, SURETE DU QUEBEC (TOURS/DAY)

(JAN 1957 - DEC 1982)



SURCUM

PATROL FREQUENCY, MTL URB.COM.POLICE (TOURS/DAY)

(JAN 1957 - DEC 1982)

- because of the relative importance of the components, the surveillance increases the total number of accidents and victims. This result means that the consumers substitute accidents that are more numerous and less serious to accidents that are less numerous but more serious;
- the indirect effects lead to a total elasticity of 0,09 for the injured persons and - 0,50 for the dead ones. The corresponding values in a linear model are 0,16 and - 0,45; in a log-linear model, 0,12 and - 0,44.

The residual variable of strike GRPOL presents an effect of strike per day of 1,4 % more injured persons and 2,9 % more dead persons than what the average drop of service, during the concerned month, explains.

The desegregation of the aggregated index in desegregated index in table 9.4.B indicates the following *differences* in comparison with the ones of the aggregated index:

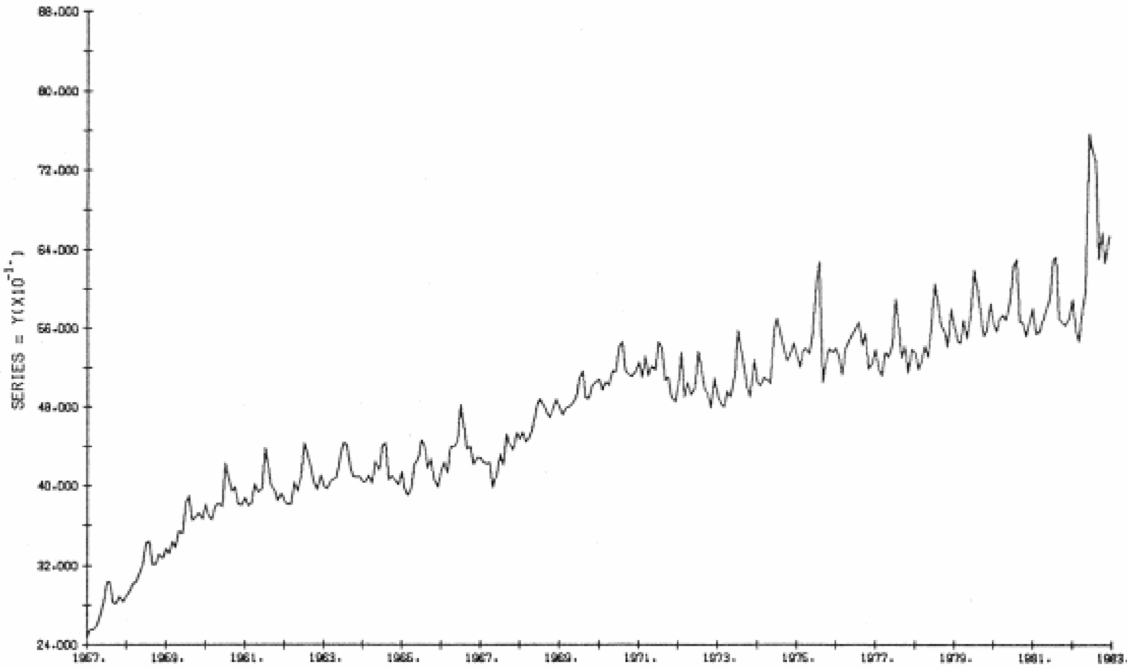
- surveillance from the *Sûreté du Québec* increases the diesel consumption, reduces the non fatal accidents and the accidents morbidity: it is indeed in the Urban Community that a more frequent police surveillance increases the number of injured people and the morbidity, effects that prevail in the aggregated index;
- the total responsiveness of the number of dead is higher compared to the surveillance of the *Sûreté du Québec* (- 0,61) than compared to the C.U.M. police's one (- 0,48); if we assume that the « populations » for which they are responsible are of the same size order, we understand that there would be more effects, per additional patrol, in increasing the service of the *Sûreté du Québec* than the one of the *Communauté Urbaine de Montréal* (Montreal Urban Community);

- the residual effects of the strikes differ: the number of people killed is more affected by the additional effects of strikes of the *Sûreté du Québec* than the ones of the *Communauté Urbaine de Montréal* (Montreal Urban Community); the raise of severity has something to do with this situation but not the number of fatal accidents: it diminishes in the first case and increases in the second.

- **<u>N-T = networks – transportation time, service</u>**

Let's limit ourselves to the following comments concerning table 9.5:

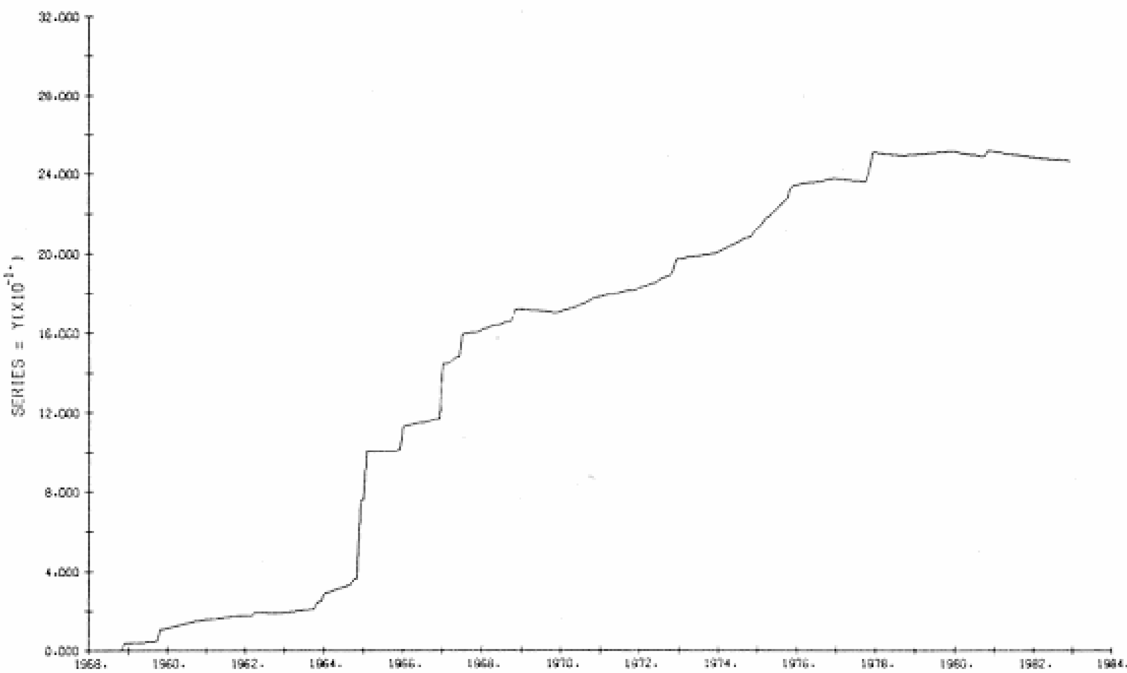
- the elasticity of the gasoline consumption, for the waiting time of the C.T.C.U.M. vehicles illustrated in graphic TW822 is of 0,21, which is too high. We have found elsewhere (Gaudry, 1980) elasticities calculated more precisely with data from Montreal. The indirect effects on accidents, their severity and the victims have the same defaults as the ones of the price-elasticity mentioned earlier;
- we can detect the impact of strikes on gasoline and diesel consumption;
- except for the complete strikes of the C.T.C.U.M., the direct effect of the other strikes (partial strikes of the C.T.C.U.M.; the C.T.C.U.Q. and Voyageur) is to reduce the casualty accident and their severity (with one exception in Quebec, for morbidity) and the number of persons injured and killed; the indirect effects are not perceptible, except for the ones of the C.T.C.U.M. partial strikes that are more important than its direct effects. In total, the C.T.C.U.M. strikes increase the victims; the C.T.C.U.Q. and the Voyageur's strikes decrease the number of victims, especially the number of people killed.



TW822

TRANSIT WAIT TIME IN MONTREAL (MINUTES)

(JAN 1957 - DEC 1982)



AUTPPKR

SHARE OF PROVINCIAL AUTOROUTES IN PROVINCIAL NETWORK

(JAN 1958 - DEC 1982)

TABLE 9.5: Direct and indirect elasticities,
N-T = networks – transportation time, service

N-T = NETWORK - TIME,SERVICE LEVELS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
TRANSIT WAIT TIME,MONTREAL	TW822	.213 ***		.185	.103	.125	.104	.167	.014	.160	.086	.178	.089
COMPLETE TRANSIT STRIKES,MONTREAL	STR813	.012 **	.048 *	.009 .013 *	.028 .007 **	.051 .009 **	.029 .007	.014 .012	-.007 .000 *	.007 .008 *	.019 .005 **	.053 .011 **	.021 .005
PARTIAL TRANSIT STRIKES,MONTREAL	STRP	.044 ***	.082 **	.040 .042 *	-.006 .024 *	-.044 .029 *	-.008 .024	.029 .038	-.002 .002 *	-.127 .032 **	-.022 .017 *	-.124 .038 **	-.025 .018
COMPLETE TRANSIT STRIKES,QUE.CITY	STRCUQ	.003 *	-.027 *	-.033 .001 **	-.033 .001 **	-.073 .001 **	-.034 .001	-.033 .001	.011 .001 *	-.054 .003 **	-.013 .001 *	-.086 .002 ***	-.016 .001
COMPL.INTRCITY BUS(VOYAGEUR)STRIKES	GRVOY	.004 *	-.068 **	-.031 -.001 *	.000 -.000 *	-.013 -.001 *	-.000 -.000	-.024 -.000	-.015 .001 *	-.033 .004 *	-.001 .002 *	-.018 .002 *	-.002 .002

- **<u>N-I = networks – infrastructure, climate</u>**

Concerning table 9.6.A, we can make the following comments:

- variable AUTPKRP represents the proportion of highways in the Montreal area on the total of provincial highways; we notice that the effects on fuels are opposite (increase of gasoline, reduction of diesel), that highways increase fatal accidents but decrease all other categories of accidents, accidents severity and the number of victims of all categories; there are more fatal accidents but they are sufficiently less severe so that the number of persons killed diminishes;
- use of the provincial proportion of highways, which we can see in graphic AUTPPKR, and for which the results are in table 9.6.B, insinuates that, globally, highways increase the consumption of all kinds of fuels; the effects on accidents, their severity and the victims, which have already been identified, are now being confirmed: the reduction of accident probability associated to highways would lead to a severity increase if we would go from point 4 to point 3 of figure 4 in table 1;

TABLE 9.6: Direct and indirect elasticities,
N-I = networks – infrastructure, climate

A. Reference Model

N-I = NETWORK - INFRASTRUCTURE,WEATHER		GARI	DICRI	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.077 **	-.139 *	-.409 .059 ///	-.035 .033 *	.049 .039 *	-.032 .033	-.327 .054	-.072 .007 **	-.095 .060 *	-.103 .040	-.127 .093	-.104 .042
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH ------	.020 *	.025 *	-.005 .019 *	.052 .010 **	-.037 .013 *	.048 .010	.007 .017	.004 .001 *	-.021 .014 *	.052 .011	.027 .025	.051 .012
HOT OR COLD REL.TO 56 FAHRENHEIT	TLK822	.023 ***	.016 *	.184 .021 ///	.027 .011 *	-.148 .014 ///	.020 .012	.148 .019	.022 .001 ***	-.070 .017 ***	.042 .013	-.050 .028	.038 .013
RAINFALL PER DAY,DORVAL AIRPORT	RFK822	-.008 **	.012 *	.034 -.007 ///	.000 -.004 *	-.000 -.004 *	.000 -.004	.026 -.006	.009 -.001 **	-.000 -.006 *	.009 -.004	.000 -.010	.009 -.006
SNOWFALL PER DAY,DORVAL AIRPORT	SFK822	.004 **	-.012 **	.038 .003 ///	.004 .002 *	.020 .002 **	.005 .002	.030 .002	-.000 .000 *	-.012 .003 *	.004 .002	-.007 .005	.004 .002
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMR822	-.016 ***	.058 ///	.025 -.010 ***	-.023 -.006 **	-.109 -.006 ///	-.027 -.006	.014 -.009	.003 -.002 *	-.006 -.013 *	-.024 -.008	-.033 -.018	-.024 -.008

B. Variant: Provincial Highways

N-I = NETWORK - INFRASTRUCTURE,WEATHER		GARI	DICRI	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.077 **	-.139 *	-.409 .059 ///	-.035 .033 *	.049 .039 *	-.032 .033	-.327 .054	-.072 .007 **	-.095 .060 *	-.103 .040	-.127 .093	-.104 .042
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH ------	.020 *	.025 *	-.005 .019 *	.052 .010 **	-.037 .013 *	.048 .010	.007 .017	.004 .001 *	-.021 .014 *	.052 .011	.027 .025	.051 .012
HOT OR COLD REL.TO 56 FAHRENHEIT	TLK822	.023 ***	.016 *	.184 .021 ///	.027 .011 *	-.148 .014 ///	.020 .012	.148 .019	.022 .001 ***	-.070 .017 ***	.042 .013	-.050 .028	.038 .013
RAINFALL PER DAY,DORVAL AIRPORT	RFK822	-.008 **	.012 *	.034 -.007 ///	.000 -.004 *	-.000 -.004 *	.000 -.004	.026 -.006	.009 -.001 **	-.000 -.006 *	.009 -.004	.000 -.010	.009 -.006
SNOWFALL PER DAY,DORVAL AIRPORT	SFK822	.004 **	-.012 **	.038 .003 ///	.004 .002 *	.020 .002 **	.005 .002	.030 .002	-.000 .000 *	-.012 .003 *	.004 .002	-.007 .005	.004 .002
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMR822	-.016 ***	.058 ///	.025 -.010 ***	-.023 -.006 **	-.109 -.006 ///	-.027 -.006	.014 -.009	.003 -.002 *	-.006 -.013 *	-.024 -.008	-.033 -.018	-.024 -.008

C. Variant: "Too hot or cold" desegregation

N-I = NETWORK - INFRASTRUCTURE,WEATHER		GARI	DICRI	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
SHARE OF MTL.AUTOR.IN PROV.NETWORK	AUTPKRP	.069 **	-.119 *	-.285 .020 ***	-.037 .031 *	-.025 .043 *	-.037 .032	-.231 .022	-.070 .006 **	-.158 .069 *	-.106 .038	-.195 .100	-.109 .040
STRIKE,STREET MAINTENANCE IN MTL.	GRMUMH ------	.018 *	.026 *	.056 .007 **	.054 .010 **	-.007 .014 *	.051 .010	.055 .008	.003 .001 *	-.026 .016 *	.054 .011	.026 .026	.053 .011
HOT RELATIVE TO 56 FAHRENHEIT	TLP	.010 ***	-.001 *	-.018 .004 **	.006 .005 *	.022 .007 **	.007 .005	-.012 .004	.002 .001 *	-.030 .010 **	.009 .006	-.024 .015	.008 .006
COLD RELATIVE TO 56 FAHRENHEIT	TLM	.019 ***	.010 *	.181 .007 ///	.010 .010 *	-.130 .014 ///	.004 .010	.143 .008	.019 .001 ///	-.048 .017 **	.023 .011	-.044 .027	.021 .012
RAINFALL PER DAY,DORVAL AIRPORT	RFK822	-.008 **	.011 *	.032 -.002 ***	.000 -.004 *	.004 -.005 *	.000 -.004	.025 -.003	.009 -.001 **	.000 -.008 *	.010 -.004	.001 -.011	.009 -.004
SNOWFALL PER DAY,DORVAL AIRPORT	SFK822	.004 **	-.012 **	.026 .001 ***	.004 .002 *	.012 .002 *	.005 .002	.021 .001	-.000 .000 *	-.012 .004 *	.004 .002	-.007 .006	.004 .002
ACCUMULATED SNOWFALL,DORVAL AIRPORT	CSFMR822	-.014 ***	.058 ///	.046 -.003 ///	-.023 -.005 **	-.080 -.008 ///	-.025 -.005	.030 -.003	.003 -.002 *	-.010 -.015 *	-.023 -.007	-.035 -.021	-.023 -.008

since the average severity lessens, the perceived augmentation of the severity variance pushes the consumer to go from point 4 to point 5 where speed is higher than at point 4 (speed v* can be achieved at point 4 or at point 4*) but severity variance is lower. At point 4* the consumer would travel at the same speed as before in point 4: he therefore sacrifices a part of the security gain in order to save time.

- strikes related to streets maintenance in Montreal during winter, GRMUMH, increase victims; non fatal accidents have the most important and significant growths per day of strike;
- analysis of the total elasticities of climatic variables shows that consumers, facing a rise of the accident probability, do not react by maintaining the average severity but by reducing it: the number of persons killed reduces, except for warmth and cold. We can notice that effects on injured people are mixed;
- we can see in table 9.6.C that making a distinction between components “too hot” or “too cold” of variable “too hot or too cold”, TLK, has no effect. Might the impacts of air conditioning or the cold engine warm-up explain the considerable growth in gasoline sales? We can see that cold increases a lot the material accidents and reduces a lot the fatal accidents.

- **Y-G = consumers – general characteristics**

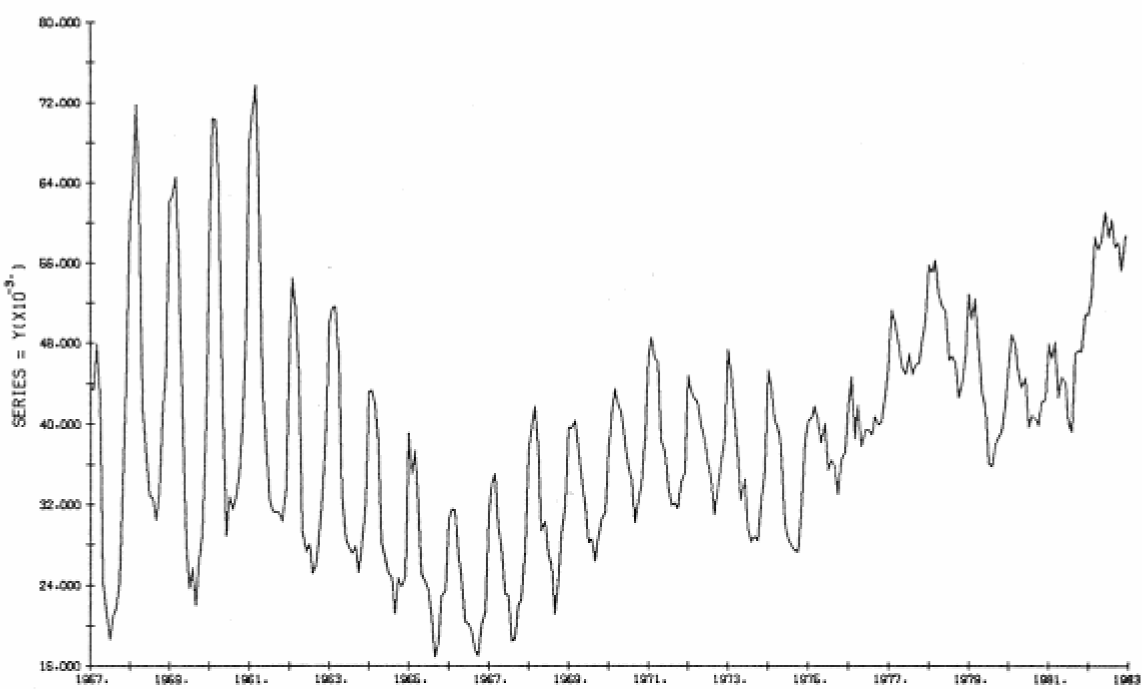
PERPA

We can notice in table 9.7 that the number of drivers’ licenses per vehicle, which we can see in graphic PERPA, does not have a very significant effect on gasoline demand. (The numerator and the denominator of this variable have a correlation between them that is higher than 0,99). We have studied, without any success, this sequence in

PERPA

NUMBER OF DRIVER'S LICENSES PER CAR IN QUEBEC

(JAN 1957 - DEC 1982)



PRCHOM

PROBABILITY THAT A DRIVER BE UNEMPLOYED IN QUEBEC

(JAN 1957 - DEC 1982)

TABLE 9.7: Direct and indirect elasticities,
Y-G = consumer, general characteristics

Y-G = CONSUMERS - GENERAL CHARACTERISTICS		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
N.OF DRIVER'S LICENSES PER CAR	PERPA	.073		-.371	-.089	.604	-.060	-.303	-.253	.317	-.351	.527	-.321
				.064	.035	.043	.036	.058	.005	.055	.030	.061	.031
		*		**	*	**			**	**	**	**	
PROB.THAT A DRIVER BE UNEMPLOYED	PRCHOM	-.094		-.272	-.110	-.202	-.114	-.238	-.053	-.072	-.150	-.182	-.151
				-.082	-.045	-.055	-.046	-.074	-.006	-.071	-.038	-.079	-.039
		***		///	**	***			**	*	***	**	
ROAD VICT.INDEMN.ACT 01/07/61	LOIIND61	.034	.124	.249	.131	-.037	.124	.222	-.065	-.215	.096	-.034	.091
	========			.036	.020	.026	.020	.033	.000	.023	.013	.031	.014
		**	**	///	///	*			///	///	***	*	
AUTOMOBILE INSURANCE ACT 01/03/78	LOIAS	.026	.050	.085	.263	.033	.253	.121	-.005	-.217	.247	.031	.239
	=====			.025	.014	.017	.014	.023	.001	.018	.010	.022	.010
		*	*	**	///	*			*	***	///	*	

appendix 2 of the extra models. The increases of licenses per cars seem to cause fewer injuries but more deaths. We get, with a linear model, elasticities that are a bit higher and, with a log-linear model, a slight drop in the number of people killed, instead of the increase that we get with the optimal functional form. That means that the effect on injured people is robust but the effect on the dead persons is uncertain.

PRCHOM

The increase of unemployment reduces the fuel consumption, the accidents, their severity and the number of victims. All the direct and indirect effects have the same consequences. In addition to reducing the activity, unemployment reduces the value of time, and very likely the speed, in a sizeable way. Adams (1981) has found similar results with a very simple model where delayed values of unemployment have no effect: only current values have an influence.

LOIIND61

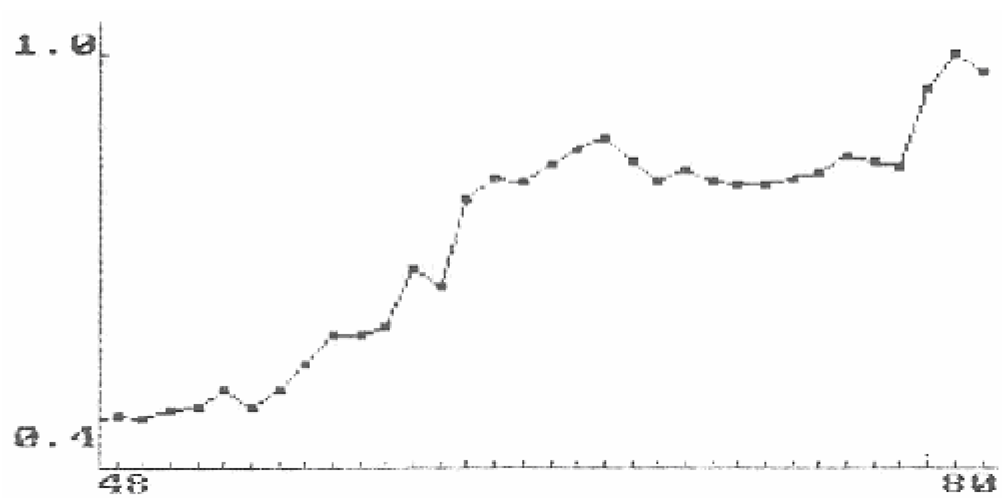
We will now deal with a certain number of modifications in the driving conditions that had, on the driving demand and the driving method, important impacts. The first is the Vehicle Accidents Claims Act of July 1961 that

a) defined the minimum value of the insurance amount (civil responsibility) awarded;
b) held liable of immediate drivers' license suspension someone who had an accident without being insured or violate a clause of the Highway Code (excessive speed, criminal negligence) even without conviction;
c) impose a reinforcement of the police procedures in case of an accident, especially where the police report is concerned;
d) created, in October 1961, a Vehicle Accident Claims Fund for cases where the person responsible for the accident was not insured or financially responsible, or cases of insurer's bankruptcy.

We can briefly discuss each of these points.

- Insurance minimum civil responsibility

When imposing a minimum amount of 10 000$, apparently higher than the average amount bought by drivers who used to insure themselves before the law came into effect, this law was putting a barrier to entry which could negatively affect the bad risks in the case where the cost of their premiums could proportionally increase more than the one of the good risks. However, the importance of the rise of the coverage that increased to 35 000$ in 1963, could have encouraged people (who would have preferred to buy less insurance or none at all) to be more careless where safety was concerned. Moreover, the important increase of the number of insured people could have, except for the cyclical effect on the concurrence in insurance markets, reduced the insurance price insofar as a sudden augmentation of 45 % in the number of insured people can provide economies of scale for the insurers for the fixed costs and the costs of handling the claims. We can see in graphic PROVPASS that the *proportion* of passengers vehicles that are insured (here measured per year of insurance policy)[18] has increased by at least 25 % more than its trend. We neglect here the effects of prices that are illustrated by the variable of maintenance cost ENTRNMDC, or the effects of the number of driving license per car, illustrated by variable PERPA, and the possible effects on registration, illustrated by variable AUPPOP. We are interested in measuring the residual effect on the *stock quality of the drivers* induced by the law. If the discrimination against the bad risks imposed by the barrier to entry is more important than the effect of reduction of motivation to drive safely, there should be less victims after the law is implemented.



Proportion of the passenger vehicles insured in Quebec per insurance year

Graphic PROVPASS

- Loss of the driver's license and reinforcement of the police procedures

The possibility, for someone who has an accident without being insured or by violating a clause of the Highway Code, of losing his driver's license tends to make him or her more prudent. Theoretically, the police had the authority to immediately suspend the licenses. In fact, the police report was used to start the process by which the director of the Motor Vehicle Registry asked for the license and demanded that the injured person abided by the law of the compensation funds before giving him or her a Certificate of Good Standing which would reinstate his or her license (or, having the *Sûreté du Québec* remove the license and the license plate). These new restrictions should invite the drivers to be more cautious and to reduce the number of dangerous drivers. However, it is possible that the most important role of the police report was to increase the number of light accidents *reported*: Montreal's policemen, for example, used a "personal notebook" to write down accident reports without necessarily doing a formal report right away. The presumption of drivers' responsibility, the new form with sketch and the increase of police investigations for accidents other than fatal (the coroner always did an investigation) could have increased the number of police reports for these categories.

- Compensation fund

In reality, the law imposed the *liability insurance* because the insurers were then held responsible without conditions towards the victims up to the maximum amount. The "non-insurable" bad risks were divided according to a formula linked to the sales figures of insurers. It became more difficult for them to "shop" among the insurers and impossible to avoid the immediate additional premium in case of an accident. The funds insured the victims against the insurer's bankruptcy.

Our measurement of the net effect of the law, implanted with abundant and aggressive publicity from its proclamation on May 10th up to its implementation on July 1st, was a drop of 9,1 % of the number of dead persons and an increase of 5,9 % of the number of persons injured. The dramatic increase of the number of material accidents (21,1 %) and the number of non fatal accidents (13,1 %) means that we might measure, to a given fuel consumption, more than the substitution of less severe accidents to fatal accidents but also an accounting effect. Moreover, gasoline and diesel sales have more than significantly increased (3,4 % and 12 %), which leads us to believe that many drivers or truckers are less cautious (or drive more kilometrage); the indirect effects included, the total elasticities are 28,5 % for the material accidents, 8 % for the injured persons and –4,7 % for the dead persons. A linear model would have 20,4 %, 3,9 % and - 10,6 %; a log-linear model: 32,9 %, 12,5 % and 1,2 %.

We cannot consider the indirect effects of the law on the maintenance cost of vehicles, which we do not want to explain. Its effects on the number of cars per adult or the number of licenses per car could not be identified during tests ran on subsidiary models of PERPA and AUPPOP presented in appendix 2.

LOIAS

The second variable describing an important modification of the driving conditions is the Automobile Insurance Act brought enforce on March 1st 1978. This law has the following principal components:

a) obligation to participate to the insurance plan for bodily injuries and obligation to have a private insurance of 50 000$[19] for material damages to others (civil responsibility);

b) suppression of the fault for the bodily injuries;

c) standardisation of the tariff per categories, uniform tariff of the insurance for bodily injuries;

d) subvention to the public plan with a budgetary allocation of a part of the revenues on fuel sales [20], without any specific increase of the taxes on fuels;

e) automatic compensation of the damages according to standard rules related to their severity and, up to a superior limit, the revenue.

- The average price of insurance

The obligation of having insurance reduces the cautious driver behaviour of people who were not insured before. Graphic PROVPASS shows that before 1978, 14 to 18 % of the vehicles were not insured. What about the other components? If, in a private sector working with categories of insured persons with default, we eliminate the default, the management costs and the price of the premiums will fall but the autoprotection and autoinsurance behaviours will be reduced. The growth of the number of drivers and the reduction of caution will increase the accidents, in total and per driver, and the average cost of fiscal balance premium will probably be lower than before.

If, in this private plan, we impose a uniform tariff of the individuals, we will be awarding a subsidy to bad risks on average; the number of accidents and the average premium of fiscal balance will increase. If the individuals have the choice, the good risks will leave: it is the problem of the "adverse selection" for which we can find a good summary in Dionne (1984) and the explanation of the participation obligation in (a). This obligation is independent of the public nature of the plan and can be imposed in a private plan. The only technical advantage of the partial nationalisation is the possibility to profit from future saving scales associated with *fixed* management costs if the latter are not compensated by the diseconomies of scale of the private enterprises touched by the nationalisation. The cumulative effect of the obligation to be insured, of standardising the tariff listing for bodily injuries and for the partial nationalisation on the average premium of fiscal balance of private and public plans considered together are uncertain since the three modifications are different. Two other elements complicate the computation. The first one is the imposition of a compensation system which includes important redistribution elements because the compensations do not really follow the rules of market economical compensation, especially because of the maximum revenue awarded. This reduces the apparent cost of the average premium of the fiscal balance, but not necessarily its social cost. In our case, the apparent cost is relevant. This element, as well as the subvention from the general incomes, would tend to reduce the premium if no moral hazard problem were to occur. The moral hazard comes from the fact that an automatic compensation structure which is composed of income redistribution elements can render some accidents beneficial. We expect that this effect be high *after* an accident, where the individual can profit from claiming having been injured. Therefore, in total, the average price of the apparent premium is probably the same as before. Higher or lower, its effect in our model would have to go through the maintenance cost variable of vehicles which include the price of the insurance: a lower price would mean a significant rise of accidents and victims, as we have seen when discussing the variable ENTRNMDC, and a higher price would have an opposite effect. A visual analysis of the PRASA sequence, reproduced in graphic seen later on is not inconsistent with a decrease of the price in Quebec, in 1978-79, but we have not studied closely this Canadian index.

- The number of cars and the number of licenses

The obligation of insuring a vehicle, as mentioned in (a), had the effect of reducing the number of registered passenger cars. We should not believe that the whole 1979 reduction of about 3 % on graphic AUPPOP is all caused by this obligation but it certainly has something to do with it. Our subsidiary model of this variable implies a statistically significant drop of - 0,3 % or 7500 cars, undoubtedly very old ones. Simultaneously, the model of the number of licenses per car, PERPA, indicates a small increase of 0,4 %, which would mean an increase of the number of licenses of 0,8 % or 25 000 licenses. This number is also a lot lower than what the graphic PERPA suggests: approximately 5 %. Since these two variables would have barely perceptible opposite effects on the number of deaths, even if the elasticities given by the subsidiary models were 5 times higher and more significant, we do not have to take them into account.

- Residual effect

Variables of prices, car availability and licenses which were affected by the law allow to consider the variations of the average cost (but not of its distribution) of the vehicle attribute (but not of the distribution and the change of the average characteristics of the selected cars) and of the number of licenses (but not of the change of the quality of the licenses). It is essential to try to detect a combined effect of the qualitative elements neglected by the *level* of variables and to consider the qualitative net effect on the vehicles stock and the drivers. We understand that compulsory insurance will improve the average quality of the vehicles stock, which will be cost-effective to keep. How can the above information be grouped in order to help us understand the change in the quality of the drivers' stock? The reduction of cautious driver behaviour, due to the compulsory insurance and the suppression of the fault do not improve the "quality" of the drivers' stock. The subsidy for bad risks and the standardising of costs do not improve the quality either. However, this last point has two distinct meanings: (i) in the meaning seen previously, it is obvious that the standardising of costs subsidises the bad risks since we reduce the number of classes; (ii) but we can show *in addition* that when we take off an element from the total cost of the premium which is a growing clause of this cost, the premium will decrease more in percentage for the bad risks than for the good risks. Lets see a fictitious example and a real example in table 10.

TABLE 10: Premium for complete coverage before and after March 1st 1978

Theorical Example

		Good risk			Poor risk		
		before	after	Δ%	before	after	Δ%
Fixed		100	100	0	100	100	0
Variables							
·	exploitation	100	100	0	200	200	0
·	material	100	100	0	200	200	0
·	bodily	200	0	-	400	0	-
		500	300	-40 %	900	500	-44,4 %

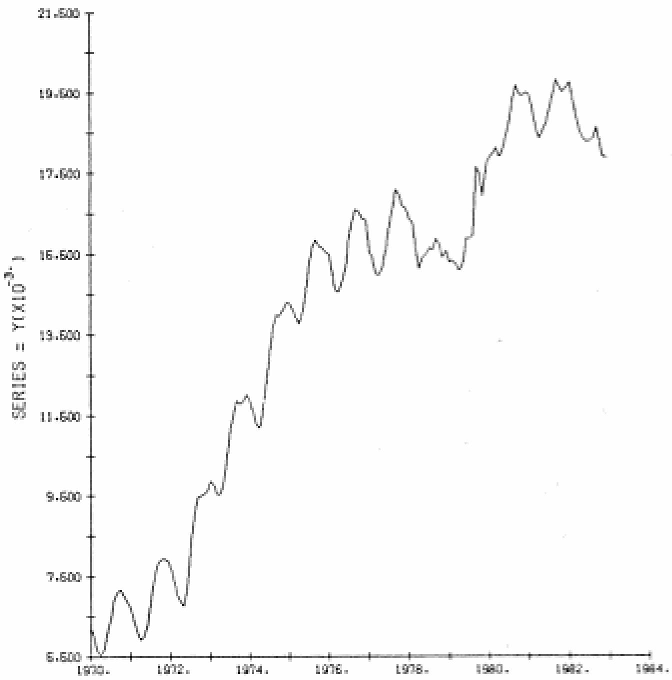
Real example (Groupe Commerce)

	category	before	after	Δ%
Adult man of more than 30 years old using his car to work or of 25 years old and married	(025)	363 $	273 $	-25 %
Adult woman using her car to go to work	(015)	323 $	243 $	-28 %
Young man, 19-20 years old	(111)	1 550 $	900 $	-50 %
Young woman, 16-20 years old	(181)	799 $	571 $	-29 %

We see that the transfer of the bodily injury part in the public plan, in addition to subsidising the bad risks, reduced the premiums for other damages proportionally more for category 111 than for the other categories; and there are categories not as good as category 111 – the category of young men of ages 16-18, for example.

Since the bad risks are especially young men, it is interesting to validate the effects of this law, working in their favour, using other statistics.

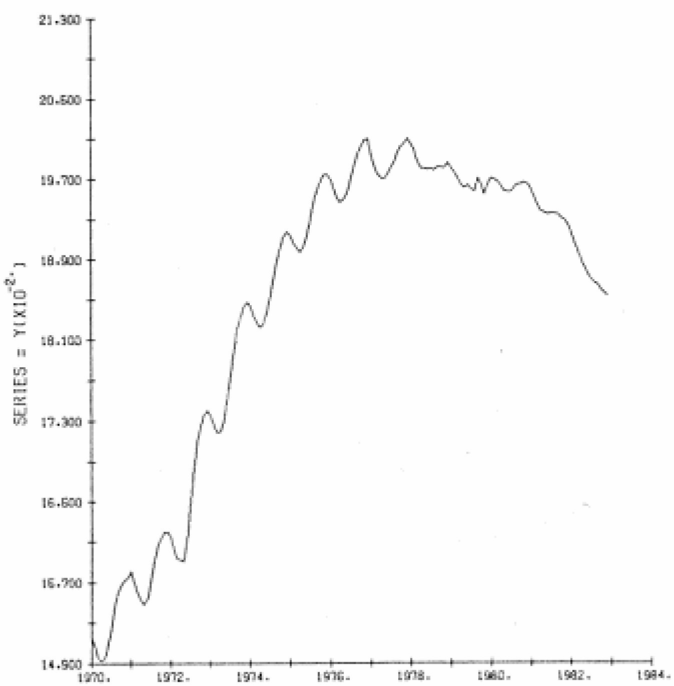
In graphics PR1617C and PR1824C, we see the evolution of the proportion of drivers belonging to age groups 16-17 and 18-24. Since the demographic pyramid narrows just about that area for these age groups, we distinctly see the impact of the law in the case of the 16-17 where the plateau 1976-78 suddenly moves towards the top; in the second case, the proportion decreases and we are tempted to believe that the law had no effect, instead of concluding it would have decreased more without this law. Indeed, a clearer image of the impact of the law is available in graphics[21] VTRP1617 and VTRP1819. The percentage of license holders increases every year; in June 1970, 49,19 % of the eligible adults had a license and in June 1982, 69,32 % had an active license. The younger age groups had growth rates higher than the average, for obvious reasons: the 16-17 years old went from a percentage of 4,9 % to 26,3 % and the 18-19 from 23,1 % to 58,6 %. As the percentage for a given age group increases, we expect that, *according to the average percentage of license holders*, its "progresses" become more and more difficult year after year. On graphics CTRP1617 and CTRP1819 variations of the *relative* percentages of license holders among the 2 groups mentioned previously decrease, year after year, until around 1977 and 1978 when they are then stabilised, the first one at a bit more than 2 % and the second one at 0. Since the numbers



PR1617C

PROP. OF DRIVERS 16-17 YEARS OLD (CORRECTED) IN QUEBEC

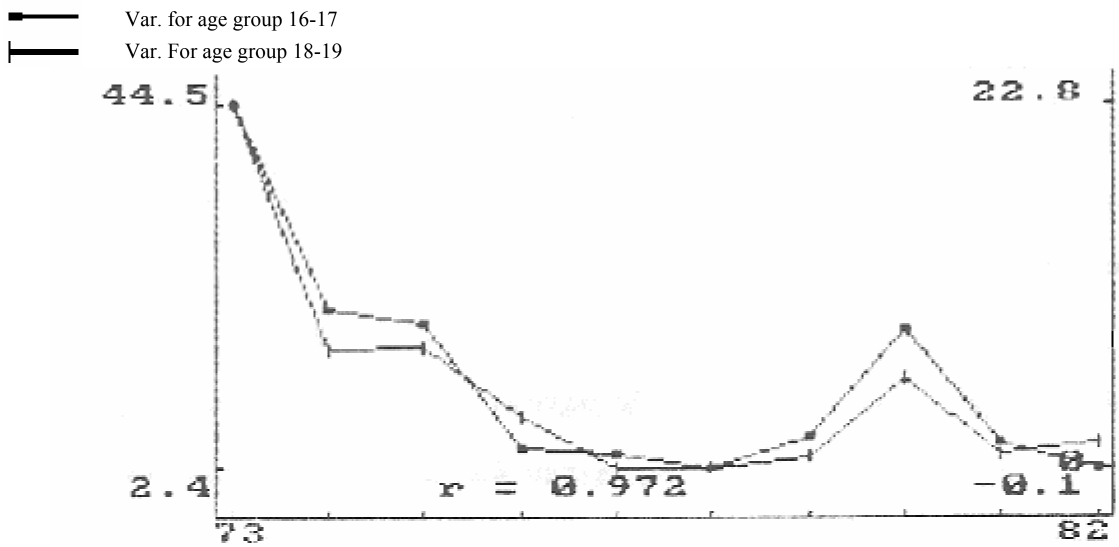
(JAN 1970 - DEC 1982)



PR1824C

PROP. OF DRIVERS 18-24 YEARS OLD (CORRECTED) IN QUEBEC

(JAN 1970 - DEC 1982)



Percentage variation, according to the previous year, of the driving license holders, in June, of age groups 16-17 and 18-19 compared to the population

Graphics VTRP1617 and VTRP1819

of June 1978 are already slightly affected by the new law, they are slightly too high: in 1979 and 1980, we encounter a huge gain in the growth rates of these groups (both located to higher relative *levels* of ownership) followed by, in 1981 and 1982, a restitution of the trend.

We can ask ourselves a similar question concerning the sexes. We will note, in graphic PRCOF70, that the linear trend of the increase of women license holders, compared to men, undergoes a clear modification in 1978 and resumes its linear movement with a new angle, which the reader will be able to calculate with a ruler.

The relative increase in the number of bad risks surely affects other groups that are more difficult to identify. Nevertheless, the increase of the moral hazard is barely detectable indirectly with the available data. We can only analyse its effects on the number of non-fatal accidents and of "reported" injuries without being able to find the level of the declaration effect or of free ride of the “real” level comparable to the level measured before the law was implemented. They are no manifestation of the moral hazard for fatal accidents but we think that the number of material accidents reported after the law is lower because an individual declares he is injured instead of not declaring anything.

We will notice in table 9.7 that the variable LOIAS, which measures the effect of the stock quality, as did variable LOIIND61 for the previous legal plan, has the following effects:

- slight increase of fuels consumption; we would expect it if the new drivers have a tendency to drive faster than the others;
- increase of all accident categories, the more statistically significant increases being the ones of the non fatal accidents, as the effect of moral risk lets us believe;
- reduction of the accident severity, especially the one of the fatal accidents;
- if we consider the indirect elasticities, an increase of 26,3 % in the number of people injured and 6,8 % in the number of people dead. In models that do not use the optimal functional form, we have 29,4 % and 10,6 % (linear) and 24,2 % and 3,2 % (log-linear).

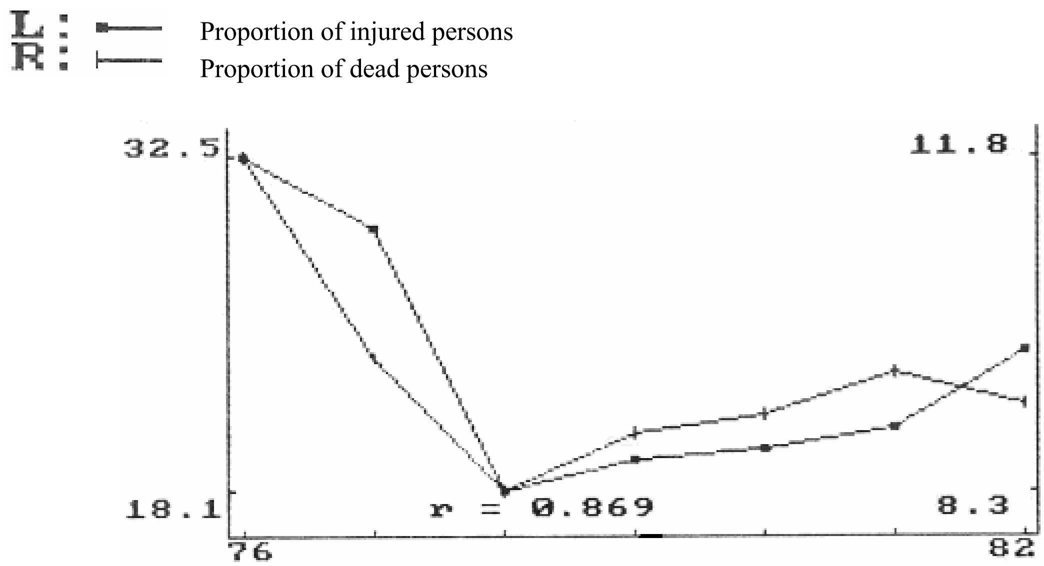
As we can see in graphic DE, the number of deaths decreased very fast between 1973 and 1977. The law has the effect of moving the trend in an approximately parallel way.

A visual computation of this shift suggests an increase, of about 10 %, in the number of deaths. However, such a computation does not consider the other variables for which the trend has changed, such as employment for example, visible in graphic EIQP. A total elasticity computation, done on other variants only partially shown here, gives for the number of deaths associated with the variable LOIAS :

- desegregation of the police surveillance index: 7,1 %;
- use of all highways instead of using only Montreal's highways: 8,9 %;
- desegregation of the climatic variable "too hot or cold": 6,5 %;
- desegregation of the pregnancy variable: 8,0 %;
- addition of the number of full moon days per month: 6,0 %.

All the results are compatible with the average cost of the disasters reported by the insurers from 1978 to 1979 (6 %, 22 %, 19 % in Report of the superintendent of insurance, 1980) where the index of the net cost of vehicle maintenance and the insurance cost ENTRNAS, was decreasing by 6 %. These increases are not a proof of a higher material severity, due to the addition of new policy holders (who, before the law, were not claiming anything), because of the advantages of the direct compensation implemented by the law (the consumer has less to gain by "settling" a claim without the help of an insurer) and because of the probable improvement of the quality of the stock of vehicles.

In order to get an idea of the geographic location of the additional victims, we can refer to graphics PROHTCUM and PRODECUM that describe the part of the *Communauté Urbaine de Montréal* (Montreal Urban Community) in the total of injured and dead persons in Quebec. We notice that these parts, that were dropping, have both been increasing since 1978. So, we have good reasons to believe that the quality of the sock of drivers was more modified by the law in Montreal than in the provinces.



Proportion of injured and dead persons when the accident occurs in the CUM area

Graphics PROHTCUM and PRODECUM

- **<u>Y-A = consumers – age</u>**

The third important modification of the driving conditions during our time frame was the modification, in July 1962, of the minimum age required for driving. The age was now 17 instead of 18 (16 with driving lessons) for cars and 21 for common carriers. Additional tests, to consider the restrictions brought in 1976, which changed to 18 years old the minimum required age for drivers who had not taken any lessons, did not have any different effect than the one obtained with the variable MOP62. We will therefore briefly comment the results of table 9.8.A.

TABLEAU 9.8: Direct and indirect elasticities, Y-A = consumer – age

A. Reference model

Y-A = CONSUMERS - AGE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
18 TO 16 LOW.MIN.DRIV.AGE 01/07/62	MOP62 =====	.010 *	.307 ///	.123 .025 ***	.067 .014 **	.450 .020 ///	.083 .016	.114 .023	.037 -.004 ***	.334 .002 ///	.120 .011	.417 .017	.131 .011

B. Variant: addition of the proportion of drivers of ages 18-24

Y-A = CONSUMERS - AGE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
PROP.OF DRIVERS 18-24 Y.OLD CORR.	PR1824C	.086 *		.949 .068 **	-.194 .042 *	1.650 .017 ***	-.117 .041	.718 .062	-.037 .006 *	3.030 .049 ///	-.153 .047	2.913 .091	-.049 .049
18 TO 16 LOW.MIN.DRIV.AGE 01/07/62	MOP62 =====	.011	.307	.105 .026	.072 .015	.394 .020	.086 .015	.101 .023	.039 -.004	.255 .005	.124 .011	.341 .020	.132 .012

MOP62

The easier access to driver's license for young people has increased significantly the diesel demand, all the categories of accidents and their severity and the victim of all categories. By considering the indirect elasticities, we can calculate an increase of the injured persons of 13,1 % (almost the same as the increase of material accidents of 14,8 %) and of persons killed of 43,4 %. A linear model would have allowed to calculate 9,3 % and 38,6 % and a log-linear model 14,2 % and 50,5 %.

We give in table 9.8.B the results of a variant that consists in studying the influence of the changes in the proportion of drivers of ages 18 to 24 illustrated in graphic PR1824C. Elasticities show a large responsiveness of the material and fatal accidents as well as the mortality to this proportion. There is nothing new there. We must, however, interpret this result carefully because our data are exact since 1970 only (before, we used a trend). This limitation, which comes from the monthly file, limits the possibilities of constructing an aggregated index of the "age quality" of the drivers, by using Carr (1969) as an example.

- **<u>Y-S = consumers – sex</u>**

We will find in table 9.9.A the direct and indirect elasticities associated to variable NFEVM that illustrates the proportion of women who gave birth to a child (alive or dead), balanced by the increasing part of licenses owned by women. We suppose that the number of pregnant women who drive is proportional to this index. We did a correlation study between the number of abortions and the number of pregnant women who gave birth to a child to ensure that the fluctuations of our index would correspond to the fluctuations of the actual number of pregnant women. This number is not observed due to the illegal abortions up to 1969, and because, since this date, the monthly number is not available for Quebec. The monthly Canadian number of abortions was very correlated with the number of 3 months pregnant women and a bit less with the number of 2 months pregnant women. These results suggested that the monthly repartition of the conception among women who will have a "therapeutic" abortion does not differ a lot from the repartition of the conception of women who will not have one. Consequently, we could expect that the variant of the sequence concerning these women would be almost identical to the one of the actual number of pregnant women. We found

- a significant drop of the sales of gasoline;
- a significant drop of mortality and a significant increase of light accidents;
- in total, more accidents but less bodily accidents, and less injured and dead persons.

These results are robust to the use of a linear or log-linear functional form.

TABLE 9.9: Direct and indirect elasticities,
Y-S = consumers – sex

A. Reference model

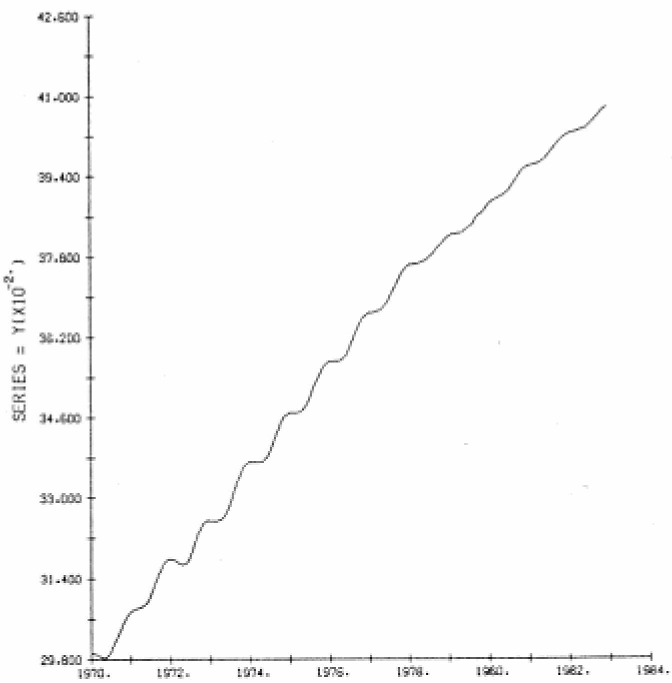
Y-S = CONSUMERS - SEX		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
PROB.THAT A DRIVER BE A PREG.WOMAN	PRFEVM	-.198 **		.211 -.172 **	-.175 -.095 *	-.211 -.116 *	-.177 -.096	.127 -.156	.057 -.013 *	-.289 -.149 **	-.256 -.080 **	-.550 -.166 **	-.266 -.083

B. Variant: desegregation of the number of pregnant women

Y-S = CONSUMERS - SEX		GAR1	DICR1		NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
PROB.THAT A DRIV.BE A 1M.PREG.WOMAN	PRFE1	-.024 *		.229 -.019 **	-.037 -.011 *	.036 -.017 *	-.034 -.012	.172 -.017	.099 -.001 *	-.120 -.017 *	.064 -.013	-.154 .028	.057 -.013
PROB.THAT A DRIV.BE A 2M.PREG.WOMAN	PRFE2	-.015 *		.139 -.012 *	.303 -.007 **	1.010 -.010 ///	.333 -.007	.181 -.011	-.024 -.001 *	.314 -.010 **	.309 -.008	.647 -.018	.320 -.008
PROB.THAT A DRIV.BE A 3M.PREG.WOMAN	PRFE3	-.070 *		-.142 -.056 **	-.150 -.034 **	-.503 -.050 ***	-.165 -.035	-.147 -.052	-.017 -.003 *	.097 -.050 *	-.182 -.037	-.068 -.065	-.178 -.039
PROB.THAT A DRIV.BE A 4M.PREG.WOMAN	PRFE4	.026 *		.062 .021 *	-.084 .013 *	-.628 .019 ///	-.106 .013	.028 .019	.027 .001 *	-.042 .019 *	-.079 .014	-.149 .032	-.082 .015
PROB.THAT A DRIV.BE A 5M.PREG.WOMAN	PRFE5	028 *		.258 .023 **	.052 .014 *	-.115 .020 *	.045 .014	.212 .021	.041 .001 *	-.078 .020 *	.086 .015	-.034 .034	.082 .016
PROB.THAT A DRIV.BE A 6M.PREG.WOMAN	PRFE6	-.077 **		.003 -.062 *	.032 -.037 *	-.134 -.055 *	.025 -.038	.008 -.057	.001 -.003 *	-.317 -.055 **	.026 -.041	-.292 -.093	.015 -.043
PROB.THAT A DRIV.BE A 7M.PREG.WOMAN	PRFE7	-.111 **		-.231 -.089 **	-.115 -.054 *	.027 -.079 *	-.109 -.055	-.205 -.082	-.032 -.004 *	-.226 -.079 *	-.141 -.059	-.335 -.134	-.148 -.062
PROB.THAT A DRIV.BE AN8M.PREG.WOMAN	PRFE8	.022 *		-.044 .017 *	-.005 .010 *	.090 .015 *	-.001 .011	-.035 .016	-.008 .001 *	.202 .015 *	-.010 .012	.201 .026	-.003 .012
PROB.THAT A DRIV.BE A 9M.PREG.WOMAN	PRFE9	.020 *		-.067 .016 *	-.133 .010 **	-.006 .014 *	-.128 .010	-.080 .015	-.031 .001 *	-.179 .014 *	-.158 .011	-.307 .024	-.164 .011

C. Variant: addition of the proportion of female drivers

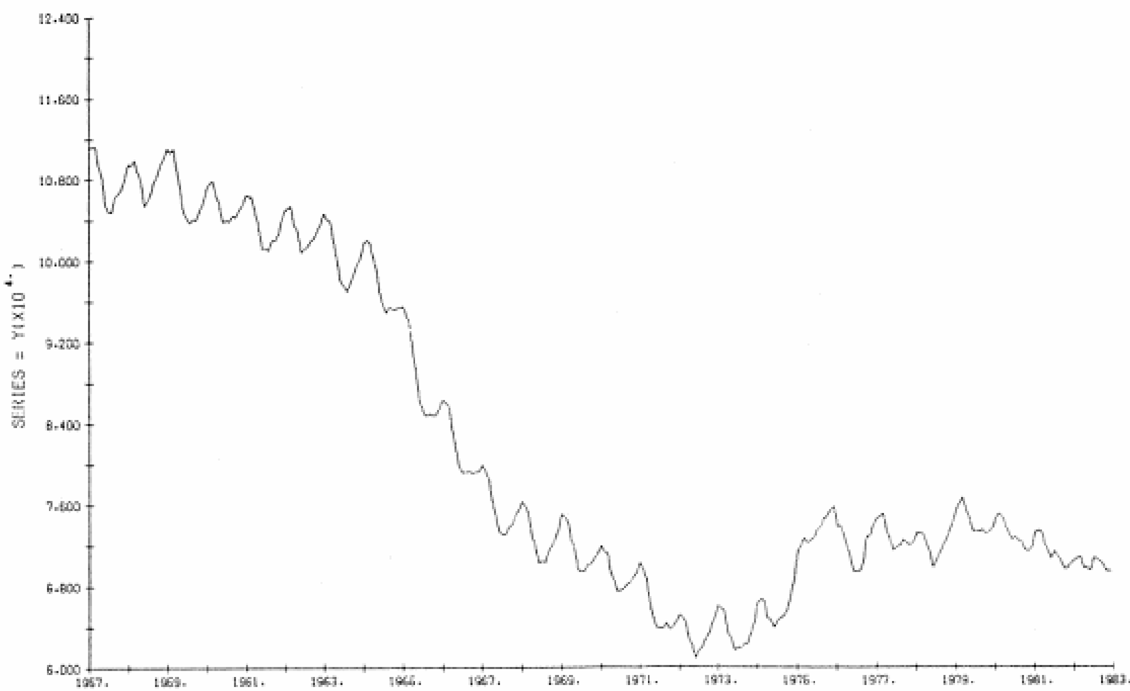
Y-S = CONSUMERS - SEX		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
PROP.OF FEM.DRIVERS(1970-82 PROC.)	PRCOF70	.145 *		1.220 .108 **	1.310 .048 **	.300 .080 *	1.268 .049	1.230 .095	-.069 .010 *	-.717 .131 *	1.199 .059	.551 .180	1.176 .064
PROB.THAT A DRIVER BE A PREG.WOMAN	PRFEVM	-.196 **		.201 -.146 **	-.176 -.064 *	-.229 -.108 *	-.178 -.066	.119 -.129	.061 -.014 *	-.242 -.178 *	-.118 -.080	-.420 -.244	-.128 -.086



PRCOF70

PROP. OF FEMALE DRIVERS (1970-82 MO.PROC.) IN QUEBEC

(JAN 1970 - DEC 1982)



NFEVM

NUMBER OF PREGNANT WOMEN IN QUEBEC

(JAN 1957 - DEC 1982)

Since fuel sales show the drop in activity associated with pregnancy, the results *to a given fuel demand* give a hint on the behaviour behind the wheel. How can we explain this increase in the number of light accidents and this drop of severe accidents and victims? We will present a conjecture in relation to this subject and we will try to explain it.

Conjecture 7

> An increase in the ratio between the oestrogen and the progesterone hormones, which is not compensated by a sufficient increase in the androgen hormones, reduces the capacity to execute mechanical tasks learned.

This conjecture repeats the ideas of Zuckerman's conclusion (1952), who did a controlled experiment on rats with which he has demonstrated that the injection of estradiol, one of the three "classic" oestrogen hormones, makes them unable to execute as well as usual mechanical tasks learned, unless we also simultaneously inject them a sufficient quantity of testosterone, the classic male hormone. How could this conjecture help us?

The evolution of the pregnancy is characterised by a considerable increase (from 100 to 1000 times, according to the considered oestrogen hormone) of the production of oestrogen hormones. This increase might not be exactly linear but the simultaneous increase of the progesterone production approximately is: it follows the increase of the prolactin that approximately is too (Yen and Jaffee, 1978, p.163). Therefore, the ratio of productions of estrogens and progesterone increases considerably. In table 11 we will find computation done from two principal sources, Page *and al.* (1972) and Wilson *and al.* (1971). The other sources used or consulted (Lipsett, 1978) give similar size orders: we have chosen the median values but the minimal and maximal values would not have changed the fact that the ratio considered increases considerably since the numerator always increases more rapidly than the denominator. The major raise of the oestrogen production is also accompanied by a certain increase of the production of androstenedione and of testosterone. However, the authors that we consulted (for example Page *and al.*, p.244) didn't considered it important.

We can imagine that the birth control pill, for which the active elements are oestrogens, accompanied of relatively few various progestogenes[22] (the average ratio of the 24 brands classified in Yen and Jaffee, 1978, p.445, is 33), will also increase the number of accidents. Indeed, in their study of the influence of various drugs on the accident risk, Skegg *and al.* (1979) have found that the drug that increased *more* the accident risk, when we compared the people who had an accident to reference groups, was the group "oral contraceptives": in their sample, the group increases 5,6 times the relative risk (sedatives and tranquillisers: 5,2 %; drugs on average: 2,0 %).

TABLE 11: Ratios of feminine sexual hormones

			Menstrual cycle		pregnancy	
Page *and al.*, p. 242[*]			middle			end
Estrogens :	estriol		0,029			39
	estradiol		0,008			0,62
	estrone		0,021			1,50
	E	=	0,058			41,12
Pregnanetiol[1]:	P	=	3,			42
Ratio E/P(1) :			0,02			0,98
Wilson et al., p. 120[**]			middle	three quarters	3 months	end
Estrogens :	estriol		0,064	0,042	0,5	40
	estradiol		0,012	0,006	0,07	1
	estrone		0,021	0,015	0,2	2
	E	=	0,097	0,063	0,77	43
Progesterone[2] :	P	=	0,61[3]	1,13[4]	4[5]	14[5]
Ratio E/P(2) :			0,16	0,06	0,19	3,07

[1] progesterone derivative.

[2] μ g/ml of blood plasma.

[3] Average of the follicular and liteinic phases in Lipsett (1978, p.84)

[4] Lipsett (1978, p.84); corresponds to 25 mg/24h, approximately.

[5] Approximate values, Yen and Jaffee, p.523 (1978). A level of 14 μ g corresponds to 250 mg/24h. approximately.

[*] Median values in mg/24h. in the urine.

[**] Median values in μ g of the average of production levels in urine during 24 hours.

We will be able to consult in table 9.9.B a variant of the reference model, which consists in distinguishing the various months of pregnancy. Let's analyse the direct elasticities:

- only the 3rd and 9th months have a decrease of *all* the accident and victims categories; it is possible that the 3rd month be similar to the 9th because of the legal limit of abortion: there is a sudden decrease which differentiates the third month from the first six ones;
- except for the 3rd month, there are generally more accidents and victims during the first 6 months, and less during the last 3 months;
- during the 2nd month there is an increase of all categories of accidents and victims;
- 5 months on 9, there are more fatal accidents but there are more deaths only 2 months on 9 since the mortality decreases;
- there is an increase of fatal accidents and of their severity, therefore deaths, at the 8th month.

We can ask ourselves this question: do women have more accidents than men? We tried to answer this question in table 9.9.C by adding to the reference model the proportion of female drivers PRCOF7Ø. Unfortunately this sequence is precise since 1970 only (we used a trend for the previous values): our results might therefore be fragile. Results imply that the augmentation of women proportion increases gasoline sales as well as all the accident categories, especially the material and non-fatal ones. For this result to be reasonable, it would require

- that adding one woman increases more the gasoline consumption than adding a man. Since less women than men own a driver's license, it is possible that these additions have this effect;

- that to an equal kilometrage, women have more accidents *of all categories* than men. Currently, an adult female who owns a car, which she uses to go to work, pays, for insurance on material damages, a premium almost equal to the one of a man under the same conditions. If, despite the fact that she works, she drives less often that the man, our result is possible. In the three-year inquiry done in Grand Rapids, Michigan, where we compared the drivers who had accidents to the others who never had any, women were over-represented. There was not, to our knowledge, any other inquiry of such a large scale (Goldberg and Havard, 1968) that would have allowed, with an appropriate reference group, to consider as well the kilometrage driven.

If we can believe Davies and Parasumaran (1982), nearly 20 % of the studies find significant differences between men's vigilance and women's. We therefore cannot eliminate the possibility that this result could be reasonable despite the poor quality of our sequence before 1970.

- **Y-E = consumers, ebriety or vigilance**

HEUHM

We will find in table 9.10.A the results concerning the variable measuring the hours worked in the manufacturing sector. These hours, illustrated in graphic HEUHM, have decreased by 10 % since 25 years. We cannot be sure that their variations measure more the fatigue than the fact that working longer forces people to drive during off-peak hours or during the night. We find that longer working hours increase bodily injuries, their severity and the victims. In his study on 10 000 drivers in Montreal in 1973-76, Liddell (1982) came up with the fact that working at *irregular* hours was the major factor

TABLE 9.10: Direct and indirect elasticities,
Y-E = consumers – ebriety or vigilance

A. Reference model

Y-E = CONSUMERS - EBRIETY OR VIGILANCE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
AVER.WEEKLY HOURS WORKED IN MANUF.	HEUHM			-.889 ***	.101 *	.613 *	.122	-.670	.136 *	.444 *	-.080 *	.463 *	-.062
PROB.DRIV.HAS TAKEN DRUGS($/ADULT)	PRMED	-.018 *		.061 -.016 *	.278 -.009 ***	.116 -.011 *	.271 -.009	.107 -.014	.008 -.001 *	-.093 -.014 *	.251 -.007 ***	.153 -.015 *	.248 -.008
PROB.DRIV.HAS TAKEN ALCOH.(LI/AD.)	PRALT	-.020 *	-.190 **	.033 -.028 *	-.012 -.016 *	-.257 -.020 **	-.022 -.016	.021 -.025	.035 .002 *	-.394 -.012 ***	-.017 -.007 *	-.288 -.020 **	-.026 -.007

B. Variant: change in the formulation of variables

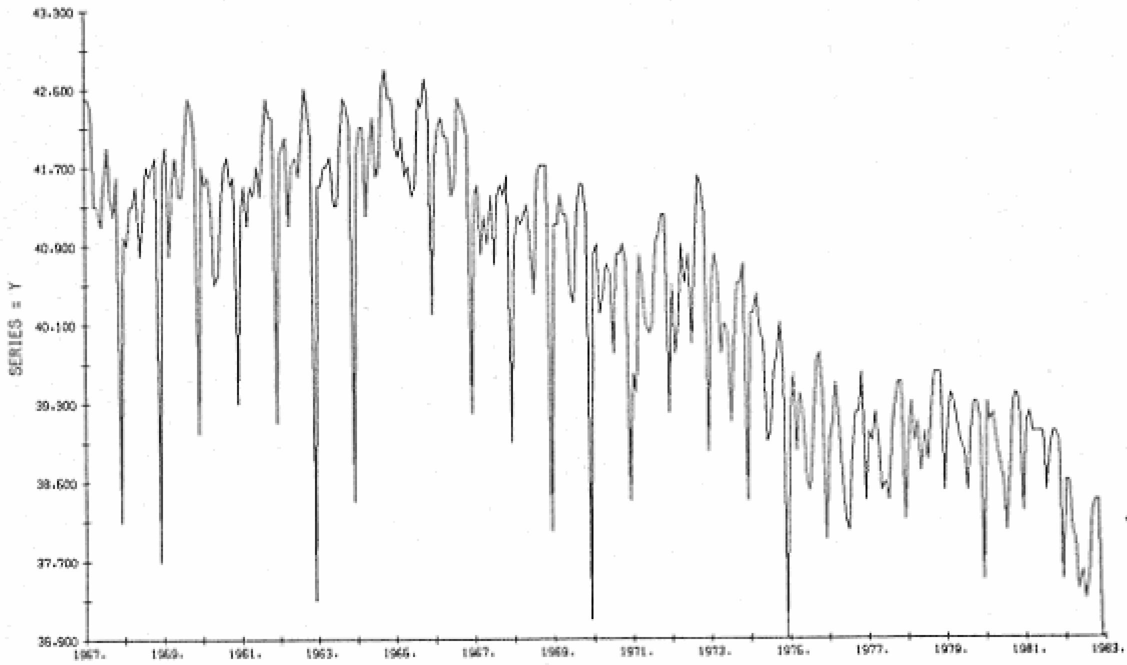
Y-E = CONSUMERS - EBRIETY OR VIGILANCE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
AVER.WEEKLY HOURS WORKED IN MANUF.	HEUHM			-1.080 ***	-.088 *	.423 *	-.067	-.860	.142 *	.513 *	.075	.446	.088
DRUGS PER DRIVER'S LICENSE	MEDPP	-.006 *		.015 -.005 *	.258 -.002 ***	.181 -.003 **	.255 -.002	.067 -.004	.012 -.000 *	.027 -.005 *	.266 -.003	.282 -.007	.267 -.003
TOTAL ALCOHOL PER DRIVER'S LICENSE	ALTOTPP	.018 *	-.155 **	-.021 .008 *	-.029 .004 *	-.246 -.000 **	-.038 .003	-.025 .007	.039 .003 *	-.315 .006 **	.001 .007	-.353 .010	-.011 .007

C. Variant: desegregation of the alcohol consumption

Y-E = CONSUMERS - EBRIETY OR VIGILANCE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
AVER.WEEKLY HOURS WORKED IN MANUF.	HEUHM			-1.190 ***	.051 *	.370 *	.065	-.918	.133 *	.705 *	.198	.770	.217
PROB.DRIV.HAS TAKEN DRUGS($/ADULT)	PRMED	-.032 *		.027 -.037 *	.274 -.019 ***	.161 -.017 **	.269 -.019	.079 -.033	.001 -.003 *	-.074 -.010 *	.271 -.021	.195 -.029	.268 -.022
PROB.DRIV.HAS TAKEN LIQUOR(LI/AD.)	PRSPI	-.019 *	-.127 *	.144 -.029 **	.026 -.015 *	-.057 -.013 *	.023 -.015	.118 -.026	.025 .000 *	-.138 -.005 *	.048 -.015	-.115 -.021	.042 -.015
PROB.DRIV.HAS TAKEN WINE(LI/AD.)	PRVIN	.009 *	.019 *	-.153 .012 **	-.020 .006 *	-.163 .005 **	-.026 .006	-.125 .011	-.009 .000 *	-.076 .003 *	-.035 .007	-.102 .009	-.037 .007
PROB.DRIV.HAS TAKEN BEER(LI/AD.)	PRBIE	.002 *	.001 *	-.190 .003 **	-.092 .001 *	.126 .001 *	-.083 .001	-.167 .002	.017 .000 *	.087 .001 *	-.066 .001	.004 .002	-.064 .001
PROB.DRIV.HAS TAKEN CIDER(LI/AD.)	PRCID -----	-.013 **	.005 *	.002 -.015 *	.007 -.007 *	.003 -.007 *	.006 -.007	.003 -.013	-.002 -.001 *	-.023 -.004 *	.004 -.009	-.017 -.012	.004 -.009

D. Variant: effect of the days of full moon on the visibility

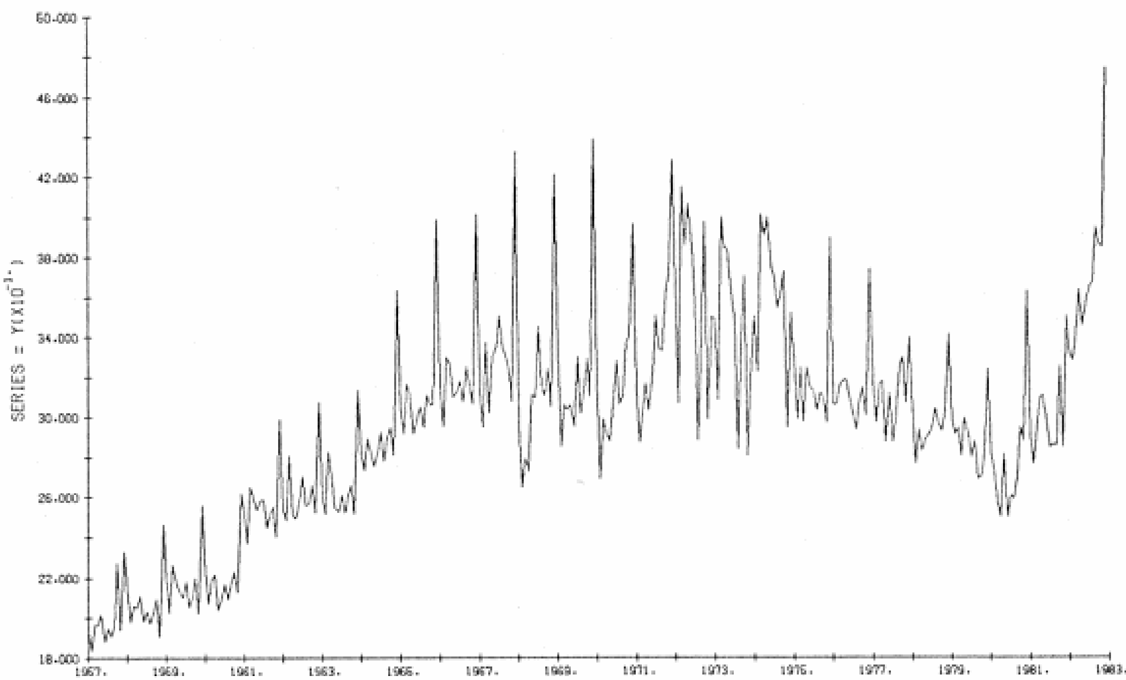
Y-E = CONSUMERS - EBRIETY OR VIGILANCE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
AVER.WEEKLY HOURS WORKED IN MANUF.	HEUHM			-.879 **	.100 *	.464 *	.115	-.663	.135 *	.330 *	.250	.445	.257
PROB.DRIV.HAS TAKEN DRUGS($/ADULT)	PRMED	-.018 *		.057 -.016 *	.279 -.009 ***	.128 -.011 *	.273 -.009	.104 -.014	.008 -.001 *	-.083 -.014 *	.281 -.010	.190 -.023	.278 -.010
PROB.DRIV.HAS TAKEN ALCOH.(LI/AD.)	PRALT	-.020 *	-.190 **	.027 -.027 *	-.010 -.016 *	-.238 -.021 **	-.020 -.016	.017 -.025	.035 .002 *	-.390 -.013 ***	.015 -.014	-.410 -.029	.001 -.015
DAYS OF FULL MOON PER MONTH	LUNPM -----	.003 *		.013 .002 *	-.002 .001 *	-.040 .002 *	-.004 .001	.010 .002	.001 .000 *	-.060 .002 **	-.003 .001	-.063 .003	-.005 .002



HEUHM

AVERAGE WEEKLY HOURS WORKED IN MANUF. SECTOR, QUEBEC

(JAN 1957 - DEC 1982)



PRMED

PROBABILITY THAT A DRIVER HAS TAKEN DRUGS ($/ADULT)

(JAN 1957 - DEC 1982)

that increased the relative risk of having an accident (smoking[23] while driving was the second).

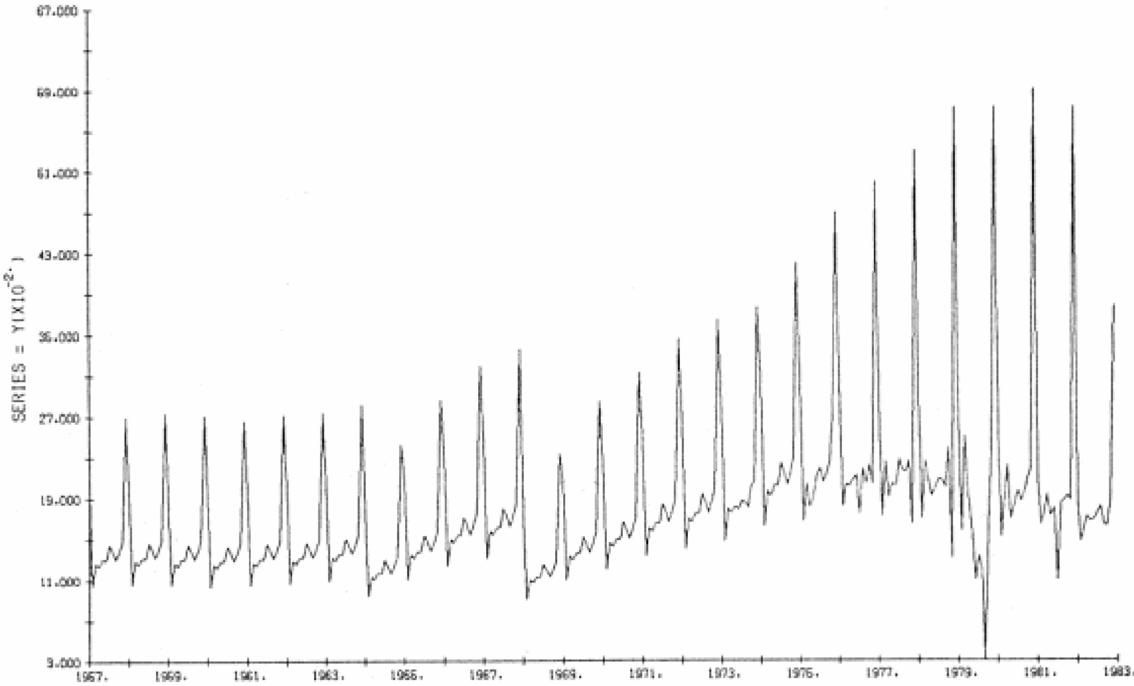
PRMED

We have built a sequence on real sales in drugstores, which is shown in graphic PRMED where we can possibly witness the impact of hospital insurance in 1961 and the one of health insurance in July 1970. We find studies that analyse the relative risk associated to drugs consumption (Skegg *and al*., 1979; Sabey, 1978). Neyroud (1976) concludes to an augmentation of risk of 50 % for French drivers, the effect being higher for women and younger drivers. Here our results show a significant increase of all categories of accidents but a drop and a slightly significant increase of the morbidity and the mortality; all categories of victims increase. We know that our sequence includes sales of products other than drugs. Amongst the prescribed drugs, the three most important categories, regarding the sales, are antiasthmatics, drugs for gastric ulcers and the birth control pill in Quebec.

PRALT and ALTOTPP

The total of alcohol consumption per adult, illustrated in graphic PRALT that we will find further on after those of its 4 components, has increased from 1961 to 1967, from 1969 to 1976 and has been decreasing since 1977. Its variance, however, increases[*]. In order to examine its effects on road safety, we have to ask ourselves the two following questions: What proportion of drivers drink? How does the accident risk vary with drinking?

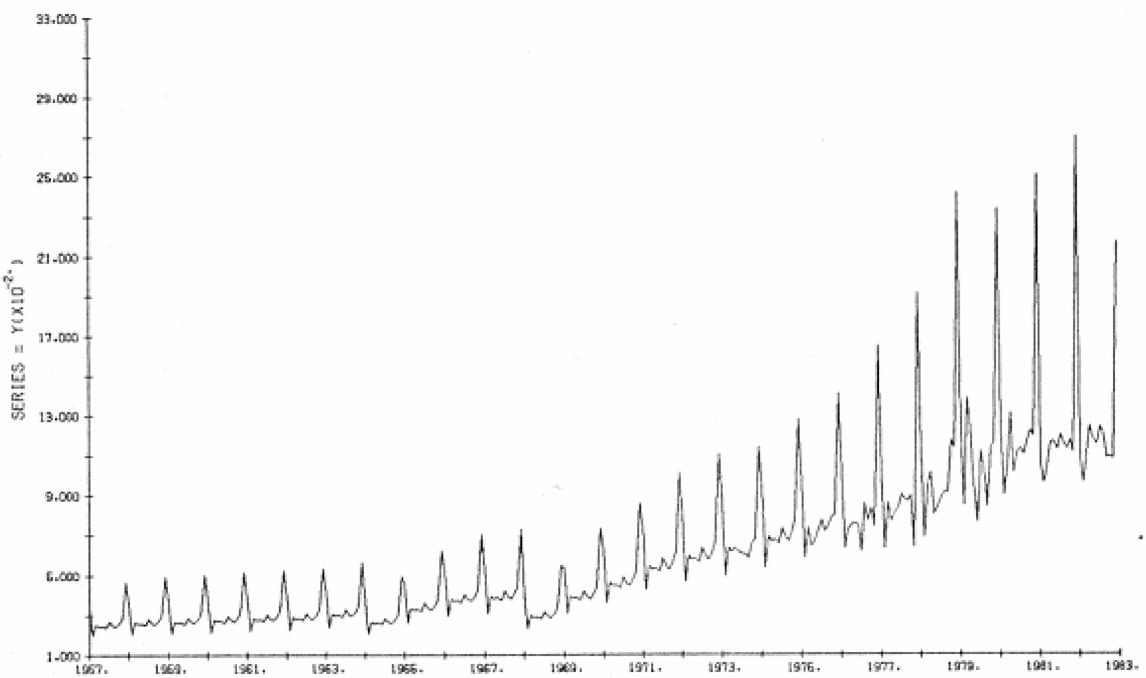
[*] Here are the "pure" concentrations of alcohol contained in the various alcoholic beverages: 12% of the volume of wine, etc.



PRSPI

PROBABILITY THAT A DRIVER HAS TAKEN LIQUOR (LI/ADULT)

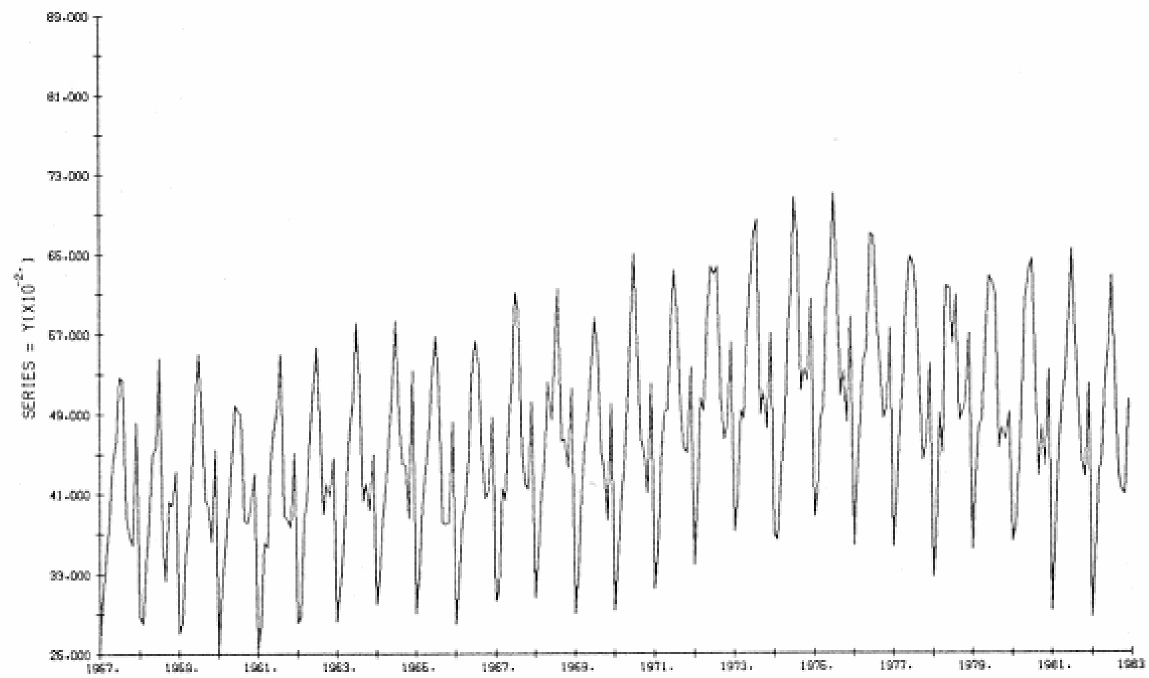
(JAN 1957 - DEC 1982)



PRVIN

PROBABILITY THAT A DRIVER HAS TAKEN WINE (LI/ADULT)

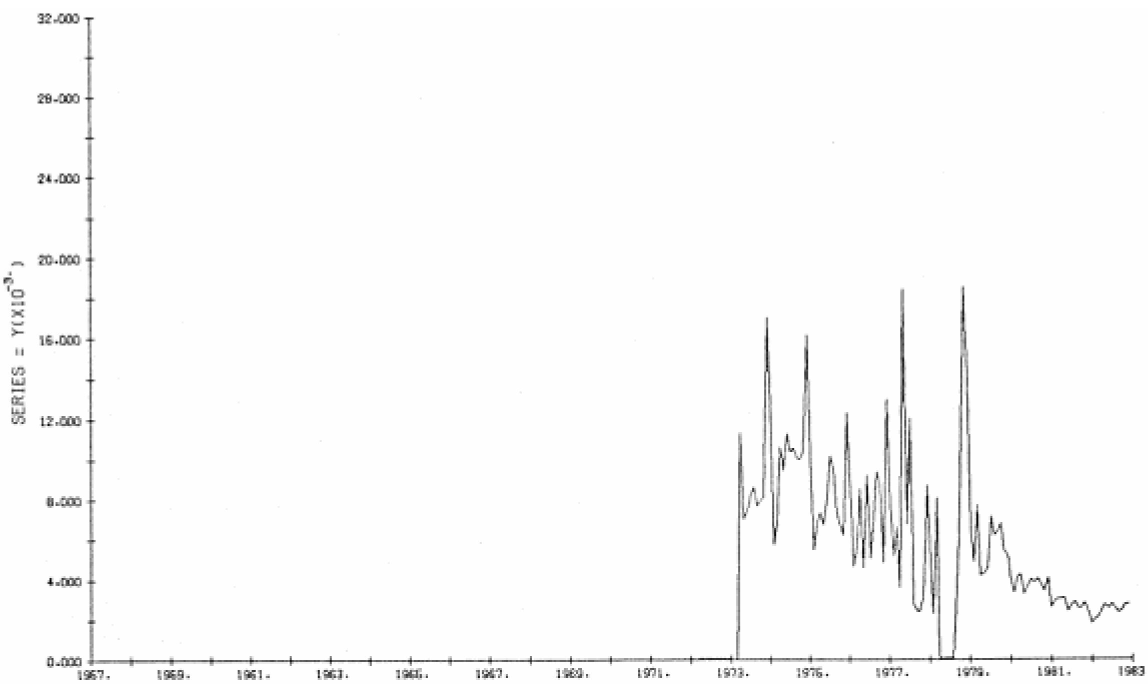
(JAN 1957 - DEC 1982)



PRBIE

PROBABILITY THAT A DRIVER HAS TAKEN BEER (LI/ADULT)

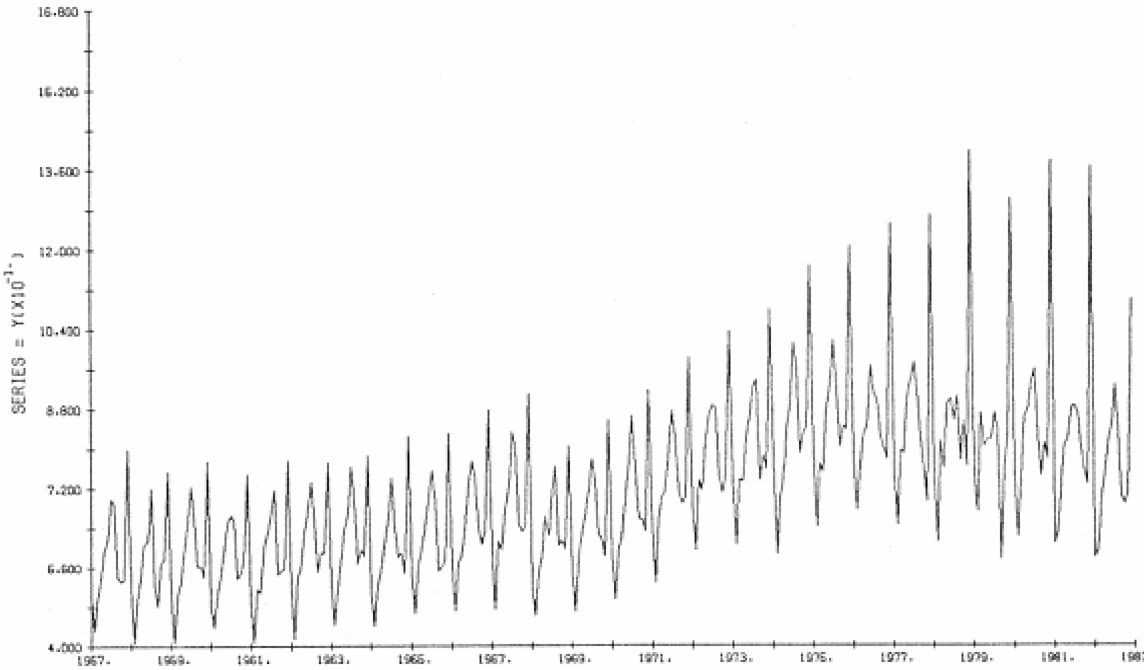
(JAN 1957 - DEC 1982)



PRCID

PROBABILITY THAT A DRIVER HAS TAKEN CIDER (LI/ADULT)

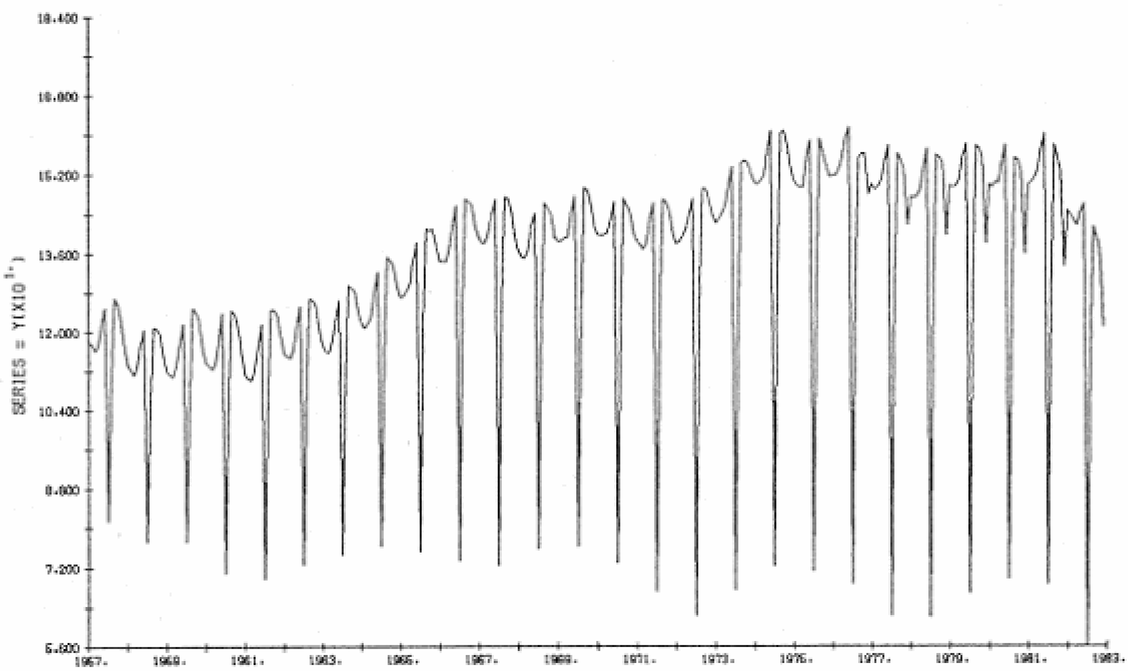
(JAN 1957 - DEC 1982)



PRALT

PROBABILITY THAT A DRIVER HAS TAKEN ALCOHOL (LI/ADULT)

(JAN 1957 - DEC 1982)



EIQP

EMPLOYMENT PRESENCE INDEX IN QUEBEC (1949=100)

(JAN 1957 - DEC 1982)

The blood alcohol concentration (BAC) is measured in mg/100ml. To answer the first question, we have to measure the sample consumption of drivers. The rare measurements done show that a very low percentage of drivers have a BAC above 50mg/100ml, as we can see in table 12, abstract of *Recherche Routière* (1978) (*Road research*),

TABLE 12: Percentage of drivers showing various BAC's

Countries	Year	Hours	BAC in mg %		
			0-49	50-99	100+
England	1964	18-24 h.	97,8	1,9	0,3
France	1977	18-24 h.	92,4	5,3	2,3
United States	1973	22-03 h.	86,5	8,5	5,0
Netherlands	1973	22-03 h.	85,0	9,0	6,0
Canada	1974	22-03 h.	88,8	7,1	4,1

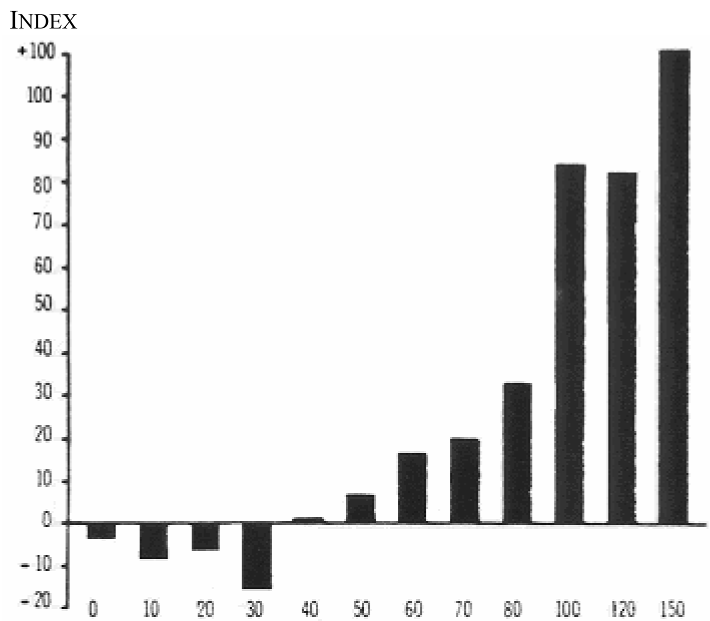
and a even lower percentage have BAC of more than 100mg/100ml, level at which the driver is considered as "inept", even at hours where we find the most drivers having taken alcohol; measured on a 24 hour basis, percentages would be even lower.

We cannot answer the second question only by calculating the percentage of injured persons who have taken various quantities of alcohol. When we do so, we find out that an inept driver is involved in 5 to 10 % of accidents with severe bodily injuries and approximately 35 % (England and Netherlands in 1975, Canada in 1973) or more (United States in 1972) of the fatal accidents. However, these results do not reveal the percentage of those who had the same BAC before and *had no accidents*. Of course, we need to measure how the relative risk varies with the alcohol consumption, but few studies do so.

In the study of *Recherche Routière* (1978) (*Road research*) from which these data are taken, and which summarises this question, we find only 5 researches that use this methodology. The most important is the one of Grand Rapids, Michigan (which considered 4 times more accidents than all the other taken together), from which we will draw important information. In the group of injured persons:

(i) drivers who have a BAC lower than 40 mg/100ml were represented in a *less* than proportional way; the representation of the curve is given in graphic RISK from Goldberg and Havard (1968); we clearly notice a *drop* of the risk as long as the consumption stays under 35 or 40 mg/100ml; curves of Manhattan and Toronto illustrated in *Recherche Routière* (1978) (*Road research*) also indicate in the same field a reduction in the relative probability of implication in an accident according to the level of alcohol in the blood.;

(GRAND RAPIDS, MICHIGAN, ALL ACCIDENTS)
PROBABILITY OF ACCIDENTS INDEX ACCORDING TO THE BLOOD ALCOHOL CONCENTRATION



Blood Alcohol Concentration (in mg per 100 ml)
Graphic Risk

(ii) by isolating, from all the accidents, those in which only one vehicle is involved, in order to isolate the “responsible” drivers, the effect is even more pronounced: at 30 mg/100ml, a driver has 33 % *less* chances of causing an accident than if he has not drunk at all;

(iii) by isolating drivers who admit drinking alcohol daily, we find that they are *under*-represented by 40 % in the accident-involved people group. Perrine *and al.* (reported in *Recherche Routière*, (*Road research*) 1978, p.48) have also found, from Vermont’s inquiry, that the percentage of drivers killed decrease linearly from 40 to 10 % when we linked it with the Index Quantity-Frequency (IQF) of the favourite beverage. The percentage of people killed also diminished from 30 to 20 % following the index for drivers in the state of “alcoholic wet brain”; however, it increases from 3 to 60 % for drivers without any past record (without a conviction for drinking and driving).

Our results are the following for table 9.10.A:

- a higher alcohol consumption slightly increases the gasoline consumption; it might be that people who drank, in average, reduce considerably their speed[24], and at the same time alcohol symbolises the social activity that is not represented in section A of the economical activities;
- to a given fuel consumption, alcohol reduces the fatal accidents, the mortality and the deaths, but increases the material damages and the injured persons;
- the total elasticities, which are of - 0,001 et - 0,442, would be 0,089 and - 0,311 with a linear model and 0,008 and - 0,50 with a log-linear model;

- we can then say that alcohol reduces the number of persons dead without affecting the number of injured ones. There is no effect (0,004) on the total number of accidents.

For these results to be possible, the additional alcohol consumption have to be in the zone of less than 40mg/100ml or that the habit of drinking often and in small quantities every day, during a meal in particular, be spread over the population.

In order to test this result, we have modified the economical formulation of the model several times: we have used the absolute level of all the following variables: unemployment, number of pregnant women, drugs and alcohol consumption; we have also formulated a model by dividing all these variables by the number of drivers' licences instead of using the number of adults as in the reference model. In vain! We will see in table 9.10.B. that the results have barely changed, neither for ALTOTPP, or for the other (MEDPP) that we see (the same is true for CHOMPP and FEVMPP that we cannot see).

In table 9.10.C we will notice that there are important differences between the various categories of alcohol. They are essential because we can observe on graphics that wine is the only kind of alcohol for which the consumption is increasing: spirits and beer are decreasing; cider is not very fizzy … In the sample of Grand Rapids mentioned earlier, the wine and beer drinkers are over-represented; however, Perrine has found, in the entire American data, that the significant variables correlated to the impact after having drunk were beer (positively) and wine (negatively).

We find that

- fuel consumption increase with beer and wine, diminish with spirits and have both effects with hard cider;
- wine reduces all accident, severity and victim categories, especially the people killed;
- beer is the only kind of alcohol that increases mortality and death while reducing the injured people; hard cider and spirits have the opposite effect.

We will find in table 9.10.D a variant of the reference model that consists in adding to the variables the number of full moon days per month LUNPM. This variable, that can represent the probability that we see better at night, reduces the deaths by 6 % per full moon day and the injured persons by 0,3 %, but these effects are not very significant.

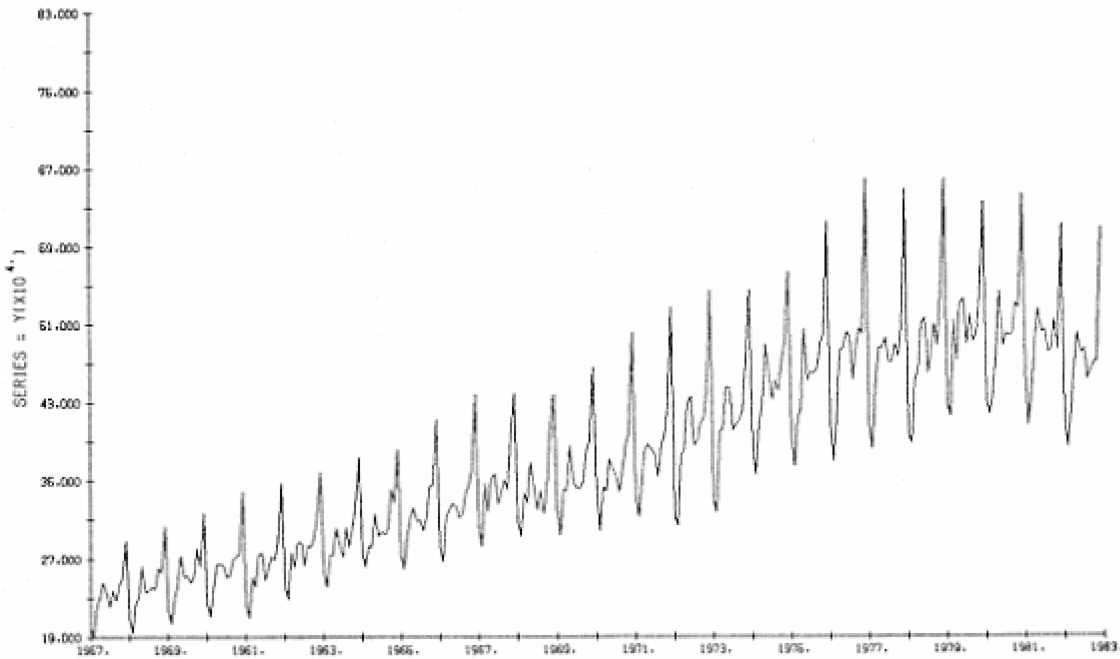
- **A = final and intermediate activities**

The gasoline sales are, as we can see in table 9.11, a lot affected by certain recurring activities such as employment (see graphic EIQP), retail sales (see graphic RSIDPQ), holidays, manufacture deliveries (remember that the majority of utility vehicles and trucks run on gasoline) and a bit by the special activities which encourage people to go out, such as the Expo 67, or to watch television, such as the Olympic Games. Diesel sales also depend on retail sales, manufacture deliveries, and the level of services of surface vehicles of the C.T.C.U.M. All these variables have, on accidents, their severity, and the victims, effects per indirect elasticities.

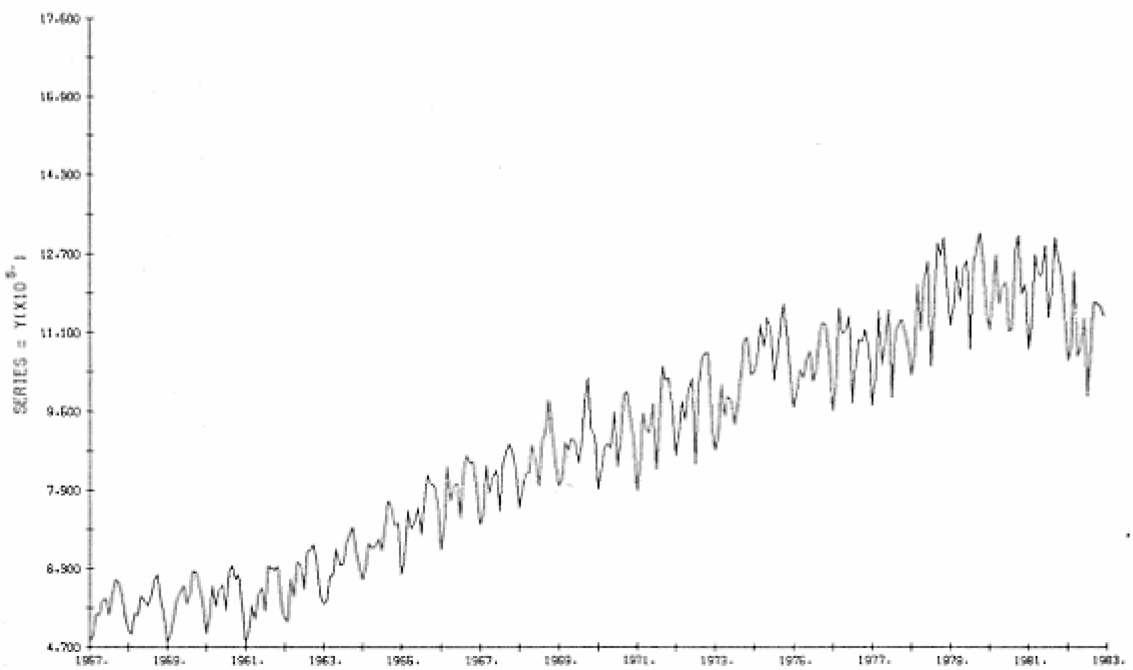
TABLE 9.11: Direct and indirect elasticities,
A = final and intermediate activities

A = ACTIVITY FINAL AND INTERMEDIATE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
EMPLOYMENT PRESENCE INDEX	EIQP	.163 **		.142	.079	.096	.079	.128	.011	.123	.066	.137	.068
PROB.OF WORK TRIP(MEASURE R.1)	PRMTRAR1			.448 ***	.265 **	.246 *	.264	.408	.046 *	.074 *	.154 *	.383 **	.162
REAL RETAIL SALES INDEX	RSIDPQ		.492 ***	.026	.015	.022	.016	.024	-.007	-.008	-.003	.009	-.003
REAL RETAIL SALES PER EMPL.PERSON	RSIDPQPE	.240 ///		.209	.116	.141	.117	.189	.016	.181	.097	.201	.101
PROB.OF SHOPPING TRIP(MEASURE R.1)	PRMMAGR1			.211 **	.160 **	.447 ***	.172	.203	-.076 *	.694 ***	.128 *	.412 **	.138
VACATION INDEX	VWMD	.018 **		.016	.009	.011	.009	.014	.001	.014	.007	.015	.008
PROB.OF VACATION TRIP(MEASURE R.1)	PRMVACR1			.029 ***	.012 *	.058 ///	.014	.026	.005 *	.028 **	.007 *	.064 ///	.008
EXPO 1967	EX7 ---	.020 *		.017	.010	.012	.010	.016	.001	.015	.008	.017	.008
OLYMPIC GAMES 1976	JO --	-.002 *		-.002	-.001	-.001	-.001	-.002	-.000	-.002	-.001	-.002	-.001
REAL MANUFACT.SECTOR DELIVERIES	LIVMAD		.228 *	.012	.007	.010	.007	.011	-.003	-.004	-.001	.004	-.001
REAL MANU.SECT.DELIV.PER EMPL.PERS.	LIVMADPE	.094 *		.081	.045	.055	.045	.073	.006	.070	.052	.116	.054
BUSHOURS,MTL.TRANSIT COMMISSION	VEHSF		.192 *	.010	.006	.009	.006	.009	-.003	-.003	.003	.003	.003

Three of these elasticities appear in the equations of accident and severity (and have therefore direct consequences on victims) in the form of activities indexes per unit of fuel sold: they represent the effect of each of these 3 *purposes* to travel compared to the "residual" purpose which is not represented. We can assume the latter to be personal activities and family life. *Compared to that purpose*, the 3 ones represented increase the number of victims, especially deaths; the most important relative effect on deaths is the one related to travel for shopping purpose; the employment purpose has an effect distributed equally among dead and injured persons.



RSIDPQ
REAL RETAIL SALES IN QUEBEC (THOUSANDS OF $)
(JAN 1957 - DEC 1982)



LIVMAD
REAL MANUFACTURING SECTOR DELIVERIES (THOUSANDS OF $)
(JAN 1957 - DEC 1982)

- **<u>ET = et cetera – administrative, aggregation and constants</u>**

We will only comment briefly the administrative constants that influence the measurement of accidents: the aggregation variables and the constant presented in table 9.12 are not useful. Indeed, the aggregation variables play a complex normalisation and correction role to take into account variable length of months. The constant, which we never interpret, assures the invariance of the coefficients to measurement units in addition of playing its usual role.

TABLE 9.12: Direct and indirect elasticities,
ET = et cetera – administrative, aggregation and constant

ET-AD = ET CETERA - ADMINISTRATIVE		GAR1	DICR1	MA	NM	MO	COR	ACC	MBC	MTC	HT	DE	VI
EXISTENCE STAND.ACC.REPORT IN 1978	DUM78RAU			.029				.023					
				*									
UNDEREST.DUE TO STD.ACC.REP.IN 1978	SED78RAU			-.024				-.019					
				*									
REAL MIN.MAT.DMAGE REPORT.CRITERION	DMSR			-.818				-.641					
				///									
ACC.WITHOUT POL.REP.REQUIR.01/06/79	CONSTA			-.073				-.057					
				*									
ET-AG = ET CETERA - AGGREGATION		**GAR1**	**DICR1**	**MA**	**NM**	**MO**	**COR**	**ACC**	**MBC**	**MTC**	**HT**	**DE**	**VI**
WORKDAYS PER MONTH	WD	.154	-.515	.425	.183	-.076	.172	.370	.120	-.052	.292	.120	.286
				.106	.058	.067	.058	.096	.018	.124	.077	.183	.080
		**	**	***	**	*			**	*			
SATURDAYS PER MONTH	SAT	-.032	-.147	.148	.160	-.049	.151	.149	.060	-.187	.212	-.036	.203
				-.036	-.020	-.025	-.020	-.032	.000	-.022	-.020	-.042	-.021
		**	**	***	***	*			*	**			
SUNDAYS AND HOLIDAYS PER MONTH	SHD	-.049	-.130	.156	.095	-.008	.091	.142	.058	-.038	.149	.053	.145
				-.049	-.028	-.035	-.028	-.045	-.001	-.035	-.029	-.062	-.030
		**	**	***	**	*			*	*			
ET-SC = ET CETERA - SEASONALITY,CONSTANT		**GAR1**	**DICR1**	**MA**	**NM**	**MO**	**COR**	**ACC**	**MBC**	**MTC**	**HT**	**DE**	**VI**
REGRESSION CONSTANT	CONSTANT	-2.150	-.186	6.490	.119	4.100	.286	5.144	.779	4.370	1.065	4.656	1.188
				-1.878	-1.042	-1.273	-1.052	-1.699	-.142	-1.616	-1.194	-2.668	-1.244
		**	*	///	*	**			*	**			

DUM78RAU and SED78RAU

Accidents are reported by the police. During our period, 3 events could have had a important influence on the measurement. The first one is the reinforcement of the police procedures included in the compensation law of road victims in 1961. As we indicated in our discussion on variable LOIIND, we cannot separate the “countable” effect from the real effect except on fatal accidents since there was no modification on the coroner’s inquest: it usually always happens. The second event is the imposition of an accident report by the Police Commission starting in 1970. This report, done by regulation, could not be modified and let anyone who would not report it to the Department of Transports getting a penalty. Because of the tightening imposed 9 years before and after discussion with the concerned policemen as well as the advent of the computer systems, it did not seem appropriate to perform a test with an auxiliary variable, which might have something to do with the measurement of the light accidents and might have been collinear with the law on breathalyser. However, it was important to verify if the implementation of a standardised, long and complex accident report in January 1978 had caused a decreasing under-estimate during the year of 1978 (SED78RAU) and its average level (DUM78RAU) : we have not found any significant effect.

DMSR

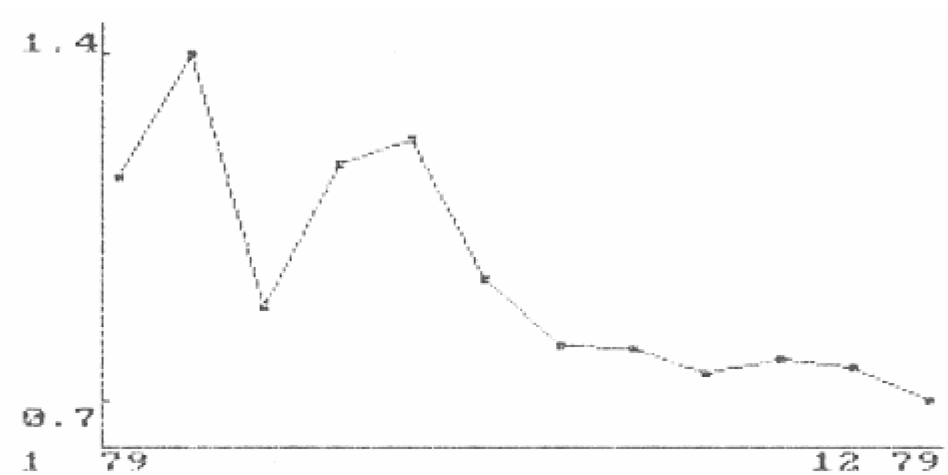
Policemen have to decide, on the location of the accidents, the proportion of the material damages. The official statistics used here exclude accidents from the lower category, for which the *criteria* has changed in time. We estimate that doubling this limit has reduced the number of accidents with material damages by only 80 %. The difference between the number reported and the number without criteria is shown in table 13. The criteria has increased from 200 $ to 250 $ during the year of 1978.

TABLE 13: Accidents with material damages only
measured with or without criteria

		1978	1979	1980	1981	1982
1. Without criteria	:	226 384	216 704	204 492	191 024	165 235
2. With criteria	:	172 489	159 747	152 348	143 868	124 761
3. Difference	:	53 895	56 957	52 144	47 156	40 474
3/1 × 100	:	23,81 %	26,28 %	25,50 %	24,68 %	24,50 %

CONSTA

Since June 1st 1979, drivers can fill a joint report of accidents with material damages only. We think that this rule has reduced the number[25] of material accidents MA (with criteria value) explained by the model, by 7,3 % and the total number of accidents ACC by 5,7 %.



1979/1978 ratio of the total monthly number of material accidents
(with value criteria) reported to the police
Graphic RASC7978

To calculate the reduction of the number of accidents reported to the police, we need to consider the numerous accidents for which the value is lower than the criteria of 250 $. We see in graphic RASC7978 the ratio between the total number of accidents with material damages only reported to the police in 1979 and its value in 1978: the ratio drops dramatically in June. If we accept the fact that the sudden decrease from 1,17 on average before June to 0,958 on average after June is an estimation of the real effect, the total number of material accidents reported to the police has decreased by 18,4 % : 11,1 % are accidents that would have been estimated by policemen to less than 250 $ and 7,3 % are accidents that would have been estimated to more than 250 $. To compare the accidents of 1978 and of 1980 in table 13, we would have to increase them by 23,0 % (or multiply them by 1,174/0,958) : the number for 1980 would then be 250 598 or 10,54 % more than in 1978.

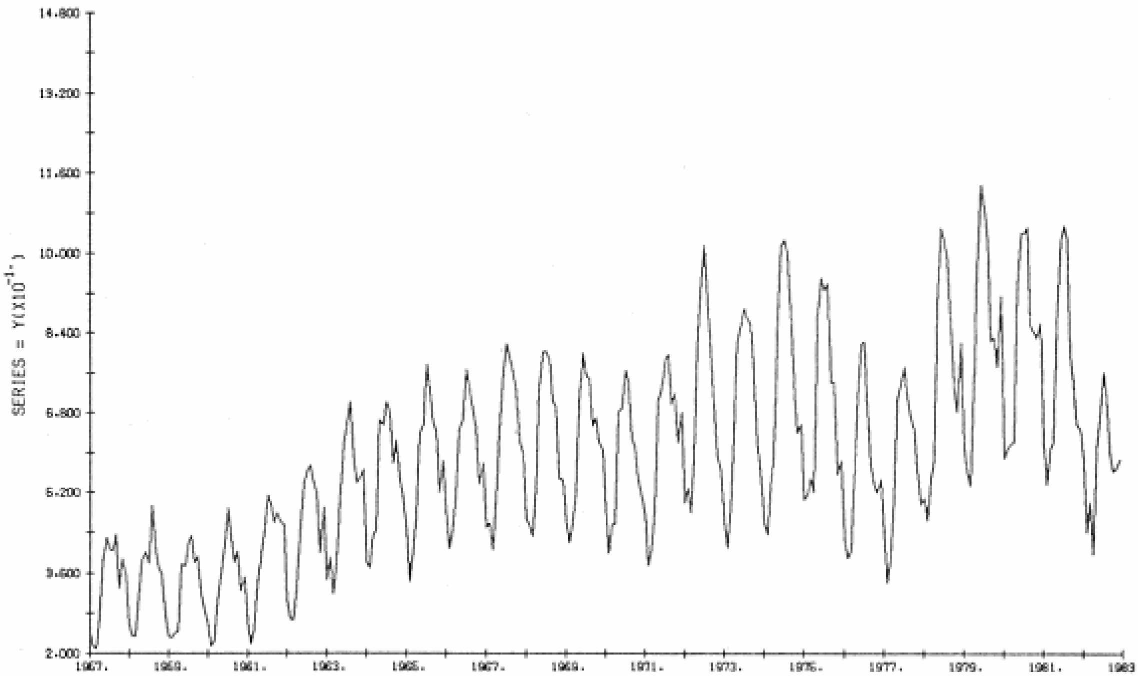
5. CONCLUSION

5. CONCLUSION

When we compare the graphics of the number of injured and dead people per capita, HTPCAP and DEPCAP, to the graphics representing the number of injured and dead people HT and DE, we observe that the first two curves are more flat than the two last ones. That is all we notice. If we had chosen to explain the *rates* of dead and injured people, instead of the *levels*, we would certainly have had similar results.

We notice that, despite the fact that the conjectures we used were fragile, and that the complexity of the reduced forms caused by the absence of usable sequences on speed and the use of the seatbelt and the shoulder belt, the results are interpretable. Furthermore, we have often compared our results obtained with the optimal mathematical forms to the ones that would have been obtained with a linear or log-linear model and the reader would have noticed that our results were generally located between. He would also have felt the numeric robustness of the results. This robustness was put to test by a series of tests specifying the economic model and by various modifications of the list of explanatory factors. Our 313 monthly observations and the use of multiple autocorrelation specific to each equation have helped us achieve a certain efficiency in the use of the information contained in our folder.

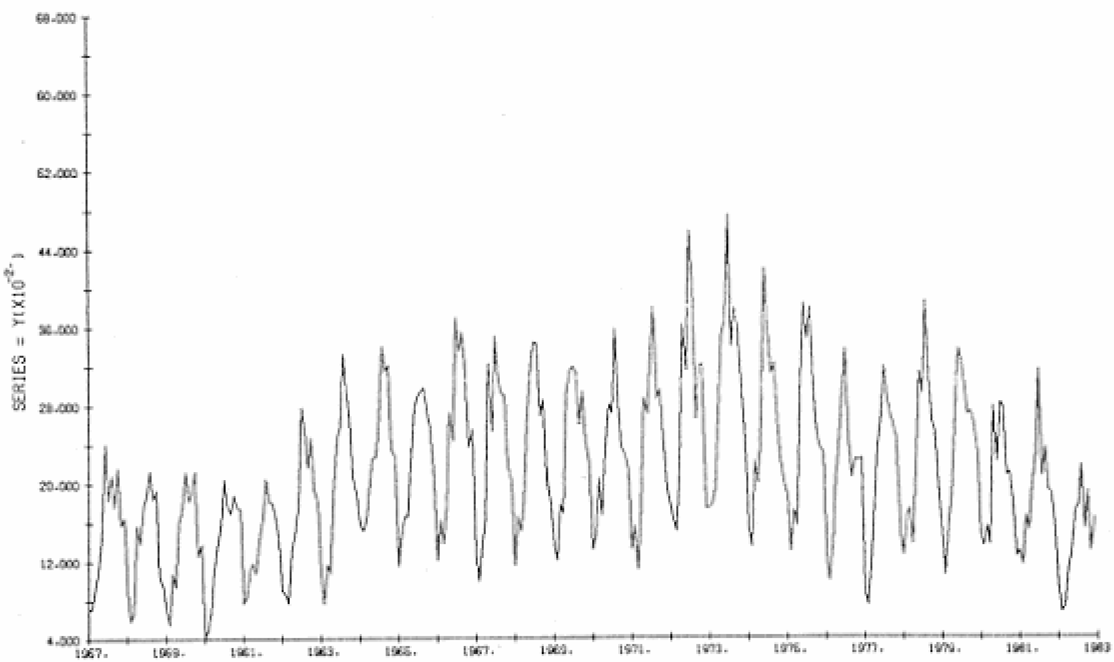
We will briefly summarise the results by following the structure of this research: first the variables specific to the fuel demand model, then the variables from DRAG model and its variants. We finally add some results taken from the extra model. We will omit giving any warnings or nuances in the description of results.



HTPCAP

NUMBER OF PERSONS HURT ON QUEBEC ROADS PER 1.000 INH.

(JAN 1957 - DEC 1982)



DEPCAP

NUMBER OF PERSONS KILLED ON QUEBEC ROADS PER 10.000 INH.

(JAN 1957 - DEC 1982)

5.1. Fuels demand: abstract of results for off-highway factors

1. the tax evasion, which consists of people purchasing their fuel in Ontario rather than in Quebec, or the contrary if it is beneficial, can reduce the diesel sales by 15 % if the price in Quebec is 10 % higher than in Ontario;

2. in November 1981, the use of red colouring in heating oil has reduced the important tax evasion existing since April 1961, when heating oil was introduced at a restricted rate. The addition of a blue colouring in June 1973 had only partially eliminated this tax evasion. Fraud probably reduced the diesel sales from 5 to 15 %;

3. diesel sales are affected by several off-highway activities, such as agricultural activities, engineering construction and forestry. Agricultural has also a big impact on gasoline sales. An increase of 50 % in these activities results in a growth of 18 % in diesel sales and 2 % in gasoline sales;

5.2. DRAG model and its variants: abstract of results

D = demand

4. the rises in gasoline consumption increase the total number of deaths more than proportionally and the number of injured persons less than proportionally;

5. the rises in diesel consumption slightly increase the total number of injured and dead persons; at a kilometrage similar to other vehicles, heavy trucks increase the number of injured and dead persons (45 %) less than proportionally; indeed, at a same kilometrage, they cause as many injuries as the other vehicles but 2 times less deaths;

this result is possible since the low severity of their accidents compensate for accidents rates per kilometre that are higher than those of cars;

P = price

6. a 10 % rise in the real price of gasoline reduces the number of injured persons by 4,2 % and the number of persons killed by 2,2 %;
7. an 10 % rise in the real price of diesel reduces the total number of victims by 2 % (and seems to have a disproportionate effect on the number of deaths);
8. a rise in the real cost of vehicle maintenance reduces proportionally the number of deaths and (20 %) less than proportionally the number of injured persons;
9. a rise in the price of public transit in Montreal slightly increases the number of victims;
10. a rise in the cost of others goods than transportation encourages the gasoline consumption, which the relative price has dropped, and indirectly increases the number of victims;

M = motorization

11. the additions to the utility vehicle fleet, which run on gasoline, seem to show that these vehicles are two times more used than the vehicles added to the already exiting vehicle fleet; the structure of the model shows that every additional utility vehicle has two

times more influence on accidents and their consequences than the additional passenger cars;

12. despite the fact that small cars added to the fleet are on average two times less used than bigger ones, an increase of their part in the market increases considerably the number of deaths and a bit less the number of injuries;

13. the availability of the seatbelt and the shoulder belt has probably increased the number of all accidents categories, reduced their average severity and increased the number of dead and injured persons;

<u>N = networks – regulations, laws, police</u>

14. the law on the mandatory use of seatbelts and shoulder belts combined with the reduction of speed limits since 1976 has reduced the number of injured people by 4,9 % and of dead people by 2,9 %: the reduction of casualty accidents has more than compensated the increase of the severity of accidents;

15. the law on breathalyser of December 1st 1969 has reduced the number of injuries by 2,9 % and has practically not reduced the number of deaths;

16. the penalty point system of March 1st 1973 has reduced the number of injuries by 11 % and the number of deaths by 2,4 %;

17. the new highway code of April 1982 has reduced the number of injuries by 23,8 % and the number of deaths by 13,2 %;

18. a rise of 10 % in the surveillance of the *Sûreté du Québec* reduced the injured persons by 2,7 % and the persons killed by 6,1 %; for the Urban community police, the corresponding effects are an increase of the injuries of 7,5 % and a decrease of the deaths of 4,8 %;

N = networks– transportation time, service

19. the strikes of the common carriers have significant effects on gasoline and diesel consumption; strikes of the entire network of the C.T.C.U.M. increase the victims, but strikes of the C.T.C.U.Q. and of *Voyageur* reduce them considerably, especially the people killed;

N = networks – infrastructure, climate

20. highways raise the fuel consumption and the number of fatal accidents but reduce the number of injuries and deaths;

21. severe weather reduces the number of deaths and has mixed effects on the number of injuries;

22. cold weather increases a lot the material accidents and reduces considerably the fatal accidents;

Y = consumers – general characteristics

23. a rise in the number of driving licenses per car reduces the accidents with material damages and the number of injuries; it increases the number of persons killed;

24. a rise in unemployment reduces the gasoline demand and, to a given gasoline demand, the number of accidents of all categories and their severity;

25. compensation law of road victims of July 1961 has increased the level of material accidents by 28,5 %, percentage which surely includes a part of the effect of a tightening up in the police accounting procedures; it has increased the injuries of 8 % and reduced the deaths by 4,7 %;

26. the Automobile insurance act of March 1978 has increased the material accidents of 11 %, injuries of 26,3 % and deaths of 6,8 %; the first of these percentages is artificially low due to the growing incitement to declare oneself injured; the second one is increased for the same reasons;

<u>Y = consumers – age and sex</u>

27. the diminution of the required age to drive in June 1962 has increased the material accidents of 14,8 %, the injuries of 13,1 % and the deaths of 43,4 %;

28. material and fatal accidents as well as mortality are influenced by changes in the proportion of drivers between age 18 and 24;

29. there are good reasons to believe that pregnancy raises the material accidents but reduces the casualty accidents and the victims. However, there seems to be important differences between the 2nd month, where there is more of all categories of accidents and victims, and the other months; the 3rd month, limit for legal abortion, is similar to the 9th month when there is less of all the categories of accidents and victims;

30. fragile indexes suggest than women might have more accidents *per kilometre* than men;

Y = consumers – ebriety and vigilance

31. a rise of the number of hours worked per week in the manufacturing sector seems to reduce significantly the material accidents and increase the injuries and deaths;

32. a rise of drug consumption increases all categories of accidents and victims;

33. a rise of the total alcohol consumption has no effect on the total number of accidents or on the number of injured people; it reduces the number of people killed;

34. the distribution of alcohol per category shows that wine reduces all categories of accidents, severity and victims; beer increases deaths and reduces injuries, but spirits and cider do the opposite;

35. the full moon seems to improve visibility at night and reduce the number of victims;

A = final and intermediate activities

36. the employment, the retail sales, vacations and manufacturing deliveries determine the level of gasoline sales; retail sales and manufacturing deliveries are the most important indexes in the determination of the level of diesel sales for highway uses;

37. the trip purposes influence the driving behaviour; travelling for shopping purposes produce proportionally more deaths than travelling for employment purposes, which cause relatively more injuries, and therefore victims, than the first ones;

38. the use by police forces of a new accident report form since 1978 has not caused any significant sub-estimations of the number of material accidents;

39. the joint report plan has reduced by 18,4 % the total number of material accidents reported to the police and by 7,3 % the number of material accidents of more than 250 $ (explained by the model).

5.3 Additional model: summary of the results

40. the Automobile insurance act has reduced the stock of passenger cars in a statistically significant way, but not as much if we evaluate it with a simple model (- 0,3 %) instead of with a visual analysis of the sequence that suggests a 10 times higher effect; it has also increased the number of driver's licenses in an almost undetectable manner;

41. the price of alcohol, substitute to other goods, has reached a level equal to its maximum of 1970; elasticity-price suggests than an increase of the prices would proportionally reduce the sales;

42. the law on breathalyser of December 1969 has increased alcohol sales of 4 %;

43. the 1970 reduction of the minimum age to buy alcohol has increased the sales of 7,6 %;

44. the sale of wine and cider in grocery stores has increased the total sales of alcohol of 0,9 %;

45. the alcohol has an elasticity-income of 0,50.

NOTES

1. We have examined in detail all the speed-inquiries done by the Quebec department of Transportation since 1960. It does not allow constructing monthly time series. However, there are more data on speed in Montreal streets but the sequence we get (see the complementary report of the Centre for research on transportation (C.R.T) # 360) gives an acceptable trend for Montreal but not for all of Quebec.

2. Required conditions for this data correction to not be biased, in the statistic meaning of the word, will be exposed in a following technical report we will write with our co-worker Jean-Marie Dufour.

3. We have estimated a "direct" model, which directly explains the number of victims (injured, dead) with the same variables as those used in the reference model (which defines the injured and dead persons as products of a number of accidents by a severity). We give in table 7 little information on this formulation; complete results of the estimations, as well as the direct and indirect elasticity tables, are available. We could also define the severity as a ratio of the number of victims of a certain category on the total number of victims; this would be beneficial if we were interested in severity measurements (Lai, 1980) or if we wanted to explain otherwise the structure (D) – (P) and neglect the distinct explanation of the number of accidents.

4. We did not succeed in taking into account the off-highway uses of gasoline for snowmobiles and private planes. We might have not taken into account the use of diesel for some stationary generators of Hydro-Québec (climate variables might do

so) before July 1970 and after August 1976; we have constructed an index of mining activity for which the coefficient was always zero.

5. Tests have suggested that none of these measurements have had an impact on the measurement of the number of other accidents. Their results have been confirmed by discussions with policemen and an exam done by the R.A.A.Q.; this exam has shown that the implementation of the standard accident report form had not changed the number of police forces who reported the fatal or non fatal accidents to the Motor vehicle registry.

6. We could transform the variables that include null observations and keep the invariance of the results to the units of measurement as long as we add, for each variable transformed that way, a specific auxiliary variable equal to 1 when the transformed variable is null and equal to 0 otherwise. This would increase the number of variables and would require another algorithm than ours.

7. The reference model use the aggregated index of police surveillance SURPOL (and the aggregated index of police strikes) instead of its 2 components; its uses the number of unemployed workers, of pregnant women, of drugs sold and of alcohol consumed per adult instead than per driver's license. The fuel demand model includes variable MOP76 to consider the modifications of the minimum age for driving alone without driving lessons, variable without effect that was not chosen in the reference model.

8. Experienced drivers, to whom we have spoken, estimated that more than 90 % of transportation by truck between Quebec and outside of the province crossed the Ontario border.

9. Parts go from 0,5 to $((1,1)/(2,1)) = 0,524)$, a difference of 4,76 %. We obtain both effects by multiplying this percentage by the elasticities for which the calculated values for 1982 were - 0,09 for PQPIGA and - 2,07 for PQPID.

10. We will not provide to the readers, who might be upset by the results of the elasticities, the details that were given to us recently by truckers.

11. In this equation, the constraint model ($\lambda_y = \lambda_x$) did not converge. Additional tests done on this equation MBC by using another inverse algorithm than ours will show, in a Jean-Victor Coté's report soon to be available, that $\hat{\lambda} = -0,95$ is optimal without autocorrelation. It is therefore a model were we regress 1/y on explanatory forms $1/X_k$. Values of the likelihood log obtained by Côté are for $\lambda = -0,95$: 508,968; for $\lambda = 0$: 496,135 and for $\lambda = 1$: 477,497.

12. Concerning this point, we followed T.C. Liem's suggestion :

$$E(HT_t) - E(NM_t) \bullet E(MBC_t)$$

$$E(DE_t)_1 = E(MO_t) \bullet E(MTC_t)$$

$$E(DE_t)_2 = E(MO_t) \bullet E(MTMO_t)$$

where HT demonstrates the injured persons, DE the persons killed, NM the non-fatal accidents, MO the fatal accidents, MBC the morbidity level, MTC the mortality level and MTC the mortality level defined otherwise (deaths/fatal accidents). The component to the left is used at (R-5) numerator; at the denominator, we use HT or DE, according to the case.

13. This information comes from conversations with a person responsible of Marlin, Detroit Diesel Inc., which makes the engines. We estimate that a gain of 0,1 mi./gallon represents a fuel saving of approximately 1000 $ per year in 1983. Since the official consumption level used for tax purposes is of 5 mi./gallon, an additional gain is possible with today's engines.

14. They are responsible for 2 times more accidents with material damages only: we obtain for the heavy trucks $(0{,}054 \times 32) =) 1{,}73$ and the corresponding value for cars is 0,86.

15. In order to better consider it, we would need to know the total kilometrage distribution between the vehicles of different ages. The construction of the rate of effectiveness of stock COAUT suggests a standard use. In some countries, such as Australia, new vehicles are responsible for an important part of the kilometrage. In Canada, during the last quarter of 1979, the new personal cars travelled 27 % more kilometrage than the cars of 1978 or older (Statistics Canada, 1981).

16. Tests done by using PGRMDSI and COAUT instead of PGRPKM have given an elasticity-price higher of 0,02 units than the one reported for PGRPKM.

17. Between Quebec and Montreal, in 1976, the distribution of the people's trip was the following: car, 82,59 %; plane, 8,83 %; rail, 3,70 % and bus, 4,88 %. In Quebec, there is very little competition between passenger cars and other transportation modes.

Therefore, the fact that we do not have the prices of other transportation modes in the function of gasoline demand is not relevant.

18. These data come from Crète (1982, p.73-74) who reconciles the definition period of the registrations with the one of the insurance policies. The 1979 and 1980 values are affected by the reconciliation method used. It is also likely that the change of the registration charges associated with the Automobile insurance Act of March 1st 1978 encourages farmers to register less agriculture vehicles (plate N) than they really do and/or to declare proportions of agriculture vehicles different from the one they declared before the change of tariff structure. This behaviour would affect the values of the table 1978, 1979 and 1980.

19. Most of the insured people bought 100 000 $ (the legal minimum was of 35 000 $). The price difference between 50 000 $ and 100 000 $ is of 3 $ per year.

20. All of the gasoline sales were subject to budgetary charges, including the diesel sales for off-highway uses (agricultural, engineering works, forestry, etc.).

21. Data on participation rates on June 1st of each year were drawn from F. Pichette (1984). We have calculated the ratio of licences holders aged 16-17 and 18-19 with the entire population aged 16 and over, and we have drawn their variations in percentage from these relative rates.

22. We do not know yet the possible mixture of new birth control products that will prevent pregnancy with the help of antiprogresterones.

23. We conducted a close examination of the taxation data from Quebec department of revenue on tobaccos and we have come to the conclusion that it would be very hard to construct a useful index for our model.

24. Several policemen stated that a driver who drives too slowly and without swerving from his trajectory is often drunk.

25. Insofar as the 1979 Automobile Insurance Act had not eliminated it, the important drop of the number of accidents with material damages reported can reduce the probability of wrongfully classifying the accidents between "material damages" and "non-fatal accidents" because the proportion of non-fatal accidents is on the rise. There are also less accidents to report on and a higher probability that a policeman arrive sooner on the accident site before the drivers involved in minor accidents leave the premises.

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APPENDIX 1

FUNCTIONAL FORM AND HETEROSCEDASTICITY TESTS

APPENDIX 1

Functional form and heteroscedasticity tests

We performed tests of functional form and of heteroscedasticity on an immediate predecessor (code # : I.N.6.R.) of the reference model (code # : I.F.10.R.). The predecessor uses distinct police surveillance variables for the *Sûreté du Québec* and the Montreal urban community police instead of the combined level of service, and variable MOP76 in all equations. Some additional variables (AUPPOP, MOCYPAD and CASQMOT) are added only in performance functions. Two auxiliary variables, DUM78RAU and SED78RAU, are added only in equations NM, MO, COR, MBC and MTC. Finally, in all equations, the 4 variables of unemployment, pregnancy, drug consumption and alcohol consumption are defined per drivers' licenses instead of per adult. Most of these differences between the two models were variants of the reference model. Since 6 of the additional variables are auxiliary variables, the results of the experiments reported here are not significantly different from those that would have been obtained if the experiments would have been conducted on the reference model. These results are presented in table A-1.

The structure of the experiments is the following. All equations have an autocorrelation structure determined by the model form that uses a Box-Cox transformation common to the dependent variable and to all the transformable independent variables (it is case 2.1 in table A.1). The presence of autocorrelation in all equations is marked by the symbol AU+ in the experiment description. Each column represents an experiment where we modify the functional form, except for columns $2.3.F_1$ and $2.3.F_2$ where we simultaneously determine the functional form and the heteroscedasticity (in addition to the autocorrelation). The lines show, for a given equation, the value of the likelihood logarithm. Two major directions are taken in the structure of the experiments, according to what we are interested in (to a given autocorrelation structure) between the functional form only and both the functional form and the heteroscedasticity.

1.1 Global functional form

We can compare

- particular log-linear cases (0.1) and linear (1.1) to the more general case with 1 Box-Cox transformation (2.1). There is one degree of freedom of difference between the particular cases and the general case. We can verify with table 3 that none of the functions is linear or log-linear;
- the advantage of using a Box-Cox transformation of the dependent variable and another of the transformable independent variables: case (3.1). The comparison of (2.1) and (3.1) shows that there are significant gains in 5 or 6 of the equations but certainly not in equations GAR1 and ACC;
- the additional advantage of distinguishing, amongst the explanatory variables, all the variables of “base level” and the rest of the variables. The comparison of (3.1) and of (4.1) shows that there are no significant gains;
- the advantage of isolating an activity variable from the others ($5.1.F_1$) or a variable of vehicle availability (5.1.Q), or a variable of vehicle size ($5.1.C_1$), or finally a variable of drivers ebriety ($5.1.C_2$). Each of these four cases includes (4.1) as a particular case. Even when we easily find the global maximum (a local maximum is identified by an X), there is generally nothing interesting to gain.

1.2 <u>General form heteroscedasticity</u>

With the "cost-effective" case (2.1), we can seek the presence of heteroscedasticity of general form (E-2) using one or the other variables of "level" of an equation. In equations of road use demand, we use the economic activity levels F_1, F_2 or* F_3 and in the other equations we use the variables of road use demand F_1 and F_2 corresponding as explanatory variable of heteroscedasticity in (E-2). Since two degrees of freedom are involved (one for the δ and one for the λ_z), only equations DICR1 and MTC show sure signs of heteroscedasticity.

All results presented here were verified for their solution uniqueness, they were done using up to 4 different initial solutions. The likelihood function in equation NM shows several cases of multiple solutions. The other cases are produced when at least 2 Box-Cox transforms are used on groups of explanatory variables.

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* These variables are defined in the upper part of table A.1. The description BC(1) + HG(F_1) of column 2.3.F_1 means that in this model with a Box-Cox transformation we add the general form heteroscedasticity explained in (E-2) by using as explanatory variable z the variable F_1. This variable varies from equation to equation as we can see in the small table.

TABLE A.1 : Functionnal form and heteroscedasticity tests

Code:		0.1	1.1	2.1	2.3.F_1	2.3.F_2	3.1	4.1	5.1.F_1	5.1.Q	5.1.C_1	5.1.C_2
Description:	AU+	LOG	LIN	BC(1)	BC(1) + HG(F_1)	BC(1) + HG(F_2)	BC(2)	BC(3)	BC(4)	BC(4)	BC(4)	BC(4)
Box-Cox:	λ_y	0	1	$\hat{\lambda} = \{$ -	$\hat{\lambda} = \{$ -	$\hat{\lambda} = \{$ -	$\hat{\lambda}_Y$	$\hat{\lambda}_Y$	$\hat{\lambda}_Y$	$\hat{\lambda}_Y$	$\hat{\lambda}_Y$	$\hat{\lambda}_Y$
	λ_{x_1}	0	1	-	-	-	$\hat{\lambda} = \{$ -	(F_1,F_2,F_3)	(F_1)	(F_1,F_2,F_3)	(F_1,F_2,F_3)	(F_1,F_2,F_3)
	λ_{x_2}	0	1	-	-	-	-	$\hat{\lambda} = \{$ -	(F_2,F_3)	(Q)	(C_1)	(C_2)
	λ_{x_3}	0	1	-	-	-	-	-	$\hat{\lambda}_{x_3}$	$\hat{\lambda}_{x_3}$	$\hat{\lambda}_{x_3}$	$\hat{\lambda}_{x_3}$
Equation: DR	GAR1	73,480	93,764	101,830	103,505	---	102,188	103,440	103,65	103,48	106,44	---
DR	DICR1	-359,546	-326,513	-303,428	-295,010	---	-300,729	-298,750	-297,258	-298,036	-298,032	---
AC	MA	-304,022	-343,248	-300,102	-296,800	-299,498	-290,93	-290,848	-288,491	-290,718	-291,070x	-290,008
AC	NM	96,249	90,157	118,876	98,105x	122,248*	124,182*	124,532*	124,771	132,363*	124,870	124,863*
AC	MO	189,054	174,736	197,056	199,962	197,960	199,310	202,034*	204,701*	203,335	202,110	202,116*
AC	COR	83,388	88,859	113,175	114,127	115,884	119,608	120,044*	120,130	120,049	120,026x	120,166
AC	ACC	343,442	314,858	345,951	346,124	---	346,020	346,073	355,822	346,834	351,900	---
GR	MBC	496,791	470,915	520,583	non couv.	---	528,156	528,559	528,570	529,857	528,896	529,782
GR	MTC	380,385	380,683	384,354	390,009	388,141	387,486	387,742	387,758	390,215	387,511x	387,936

Equation:		GAR1	DICR1	MA NM MO COR ACC MRB MRT
Variable:	F_1 :	EIQP	LIVMAD	KMPARR1
	F_2 :	RSIDPQPE	RSIDPQ	DICR1
	F_3 :	LIVMADPE	VEHSF	-
	Q :	AUPPOP	VUTDIPAD	AUPPOP
	C_1 :	PPAS	---	PPAS
	C_2 :	ALTOPP	ALTOTPP	ALTOTPP

(AUT+) = autocorrelation plus
(*) ≡ global
(x) ≡ local
BC ≡ Box-Cox
HG ≡ general heteroscedasticity

APPENDIX 2

ADDITIONAL MODEL

APPENDIX 2

Additional model

We have formulated 3 extremely simple models to detect the impact of "interventions" on the level of the number of cars per capita, the number of driving licenses per car and the alcohol consumption per adult. We will find in table A.2 the elasticities, the parameters of autocorrelation and functional form as well as various appropriated statistics. We will comment each equation.

2.1 Car demand per capita

The price of cars, which we can see in graphic PRAAC, is less important than the cost of living. Since the sign of this price is negative, the car is a substitute to the other goods. The participation to the employment has also a far too low effect. The most significant variable is the intervention LOIAS. Undoubtedly the seasonal constants and the autocorrelation structure "whitened" the sequence.

2.2 Driver's license demand per car

A higher cost of living increases the license demand, which suggests that the license is a complement to other goods. The Automobile Insurance Act has increased the license demand but the effect detected by the model is low.

2.3 Alcohol demand per adult

Alcohol, by definition, is the alcoholic percentage contained in different alcoholic beverages. The elasticity-price of the alcohol demand is - 0,99. This means that additional increases in prices or real taxes would reduce the revenues, as long as the retail price is linked to the percentage of pure alcohol content in beverages; the elasticity calculated for 1982 is identical. The actual price of alcoholic beverages reproduced in graphic PRBALC, has reached a level equal to its maximum of 1970. As the elasticity of the consumer price index indicates, alcohol is a substitute to other goods.

The law concerning the breathalyser has increased the alcohol demand of 4 %, the law on the wine and cider sale in grocery stores of 0,9 % and the reduction of the minimum age to buy alcohol in July 1971 has increased the demand of 7,6 %. Also, the alcohol has an elasticity-income of 0,50 and the sales have increased during Expo 67 and the Olympic Games.

TABLE A.2: Car, licence and alcohol demand: direct elasticities, autocorrelation or functional form parameters et t statistics

		AUPPOP	PERPA	PRALT
	CODE NO. =	8	8	8
	DEP.VAR. =	AUPPOP	PERPA	PRALT
P = PRICES		AUPPOP	PERPA	PRALT
REAL PRICE VEH.MNT.EXC.GAS.INS.PUR.	ENTRNAS		.024 (.44) EL1	
REAL PRICE AUTOMOBILE INSUR.,CANADA	PRASA		-.001 (-.07) EL1	
REAL PURCHASE PRICE OF VEHICLES	PRAAC	-.008 (-.82) EL1		
CPI EXC.AUTO+MTL TRANSIT COMPONENTS	PCBNETT	-.047 (-1.27) EL1	.123 (1.51) EL1	
REAL PRICE OF ALCOHOL BEV.,MONTREAL	PRBALC			-.990 (-3.28) EL1
CONSUMER PRICE INDEX, MONTREAL	PCB			-.105 (-2.19) EL1
N-L = NETWORK - LEGAL,REGULATION,POLICE		AUPPOP	PERPA	PRALT
BREATHALYSER LAW(0.08) 01/12/69	P08PC =====			.040 (1.58)
Y-G = CONSUMERS - GENERAL CHARACTERISTICS		AUPPOP	PERPA	PRALT
REAL AVERAGE WEEKLY WAGE	SALRHMQ		.055 (.66) EL1	.504 (4.26) EL1
EMPLOYMENT PARTICIPATION RATE	PARTEMPL	.020 (.83) EL1		
AUTOMOBILE INSURANCE ACT 01/03/78	LOIAS =====	-.003 (-2.54)	.004 (.67)	
Y-A = CONSUMERS - AGE		AUPPOP	PERPA	PRALT
20 TO 18 AGE TO BUY ALC. 29/07/71	AGAL2018 ========			.076 (2.96)
Y-E = CONSUMERS - EBRIETY OR VIGILANCE		AUPPOP	PERPA	PRALT
STRIKEDAYS QUEBEC LIQUOR BOARD	GRSAQ -----			-.141 (-7.08)
A = ACTIVITY FINAL AND INTERMEDIATE		AUPPOP	PERPA	PRALT
EXPO 1967	EX7 ---			.022 (.84)

		AUPPOP	PERPA	PRALT
OLYMPIC GAMES 1976	JO			.006 (.06)

ET-AD = ET CETERA - ADMINISTRATIVE

		AUPPOP	PERPA	PRALT
DBLE DRIV.LIC. REGISTRATION SYSTEM	DOURPER		-.003 (-.34)	
NEW DRIV.LIC. REGISTRATION SYSTEM	NREPER		.006 (.31)	
NEW DRIV.LIC. REGISTRATION FILE	NFIPER		.009 (1.22)	
SALE OF WINE IN GROC.STOR.18/09/78	VINEP			.009 (.50)

ET-AG = ET CETERA - AGGREGATION

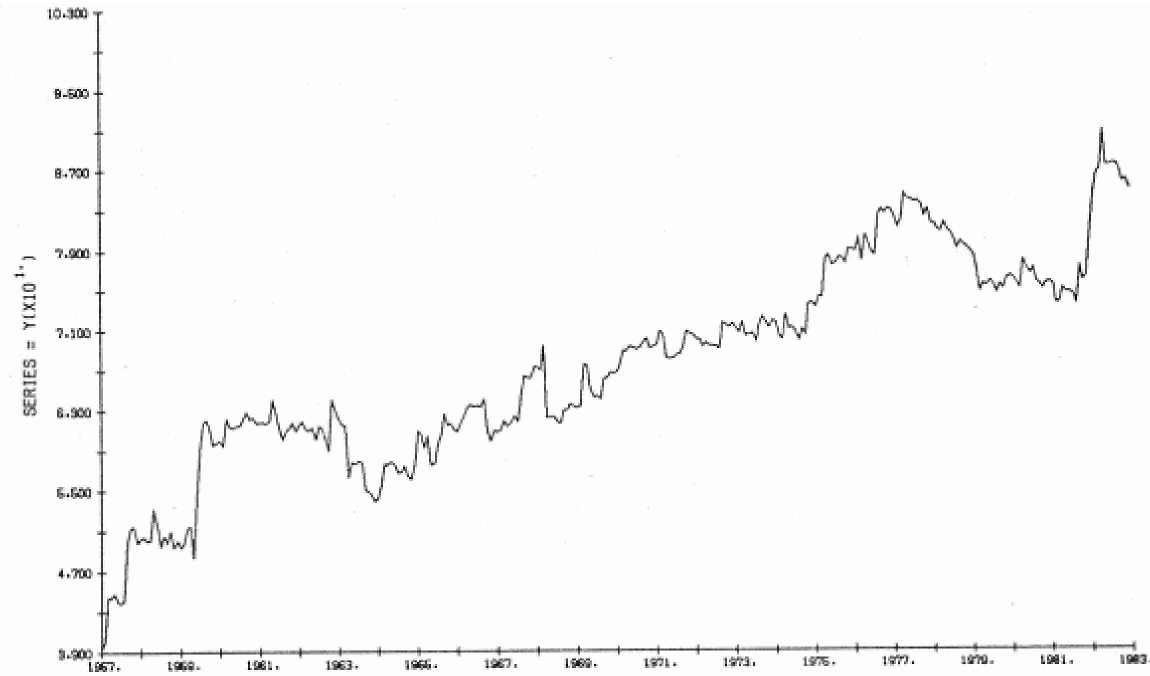
		AUPPOP	PERPA	PRALT
WORKDAYS PER MONTH	WD			.471 (1.84) EL1
SATURDAYS PER MONTH	SAT			.019 (.31) EL1
SUNDAYS AND HOLIDAYS PER MONTH	SHD			.062 (.97) EL1

ET-SC = ET CETERA - SEASONALITY,CONSTANT

		AUPPOP	PERPA	PRALT
SEASONAL DUMMY FOR JANUARY	JANVIER	-.000 (-1.05)	.000 (.05)	-.037 (-23.06)
SEASONAL DUMMY FOR FEBRUARY	FEVRIER	-.000 (-1.22)	-.000 (-.99)	-.049 (-13.38)
SEASONAL DUMMY FOR MARCH	MARS	-.000 (-.59)	-.000 (-1.57)	-.034 (-17.60)
SEASONAL DUMMY FOR APRIL	AVRIL	.000 (.34)	-.001 (-1.97)	-.029 (-14.44)
SEASONAL DUMMY FOR MAY	MAI	.000 (1.15)	-.001 (-2.15)	-.023 (-10.13)
SEASONAL DUMMY FOR JUNE	JUIN	.000 (1.57)	-.001 (-2.21)	-.016 (-7.60)
SEASONAL DUMMY FOR JULY	JUILLET	.000 (1.75)	-.001 (-2.01)	-.012 (-6.88)
SEASONAL DUMMY FOR AUGUST	AOUT	.000 (1.04)	-.000 (-1.31)	-.017 (-10.19)
SEASONAL DUMMY FOR SEPTEMBER	SEPTEMB	.000 (.18)	-.000 (-.28)	-.029 (-14.68)
SEASONAL DUMMY FOR OCTOBER	OCTOBRE	.000 (.34)	-.000 (-.25)	-.029 (-15.71)

SEASONAL DUMMY FOR NOVEMBER	NOVEMBRE	.000	-.000	-.029
		(.63)	(-.05)	(-14.63)
REGRESSION CONSTANT	CONSTANT	-.345	.111	.124
		(-.72)	(2.09)	(.21)

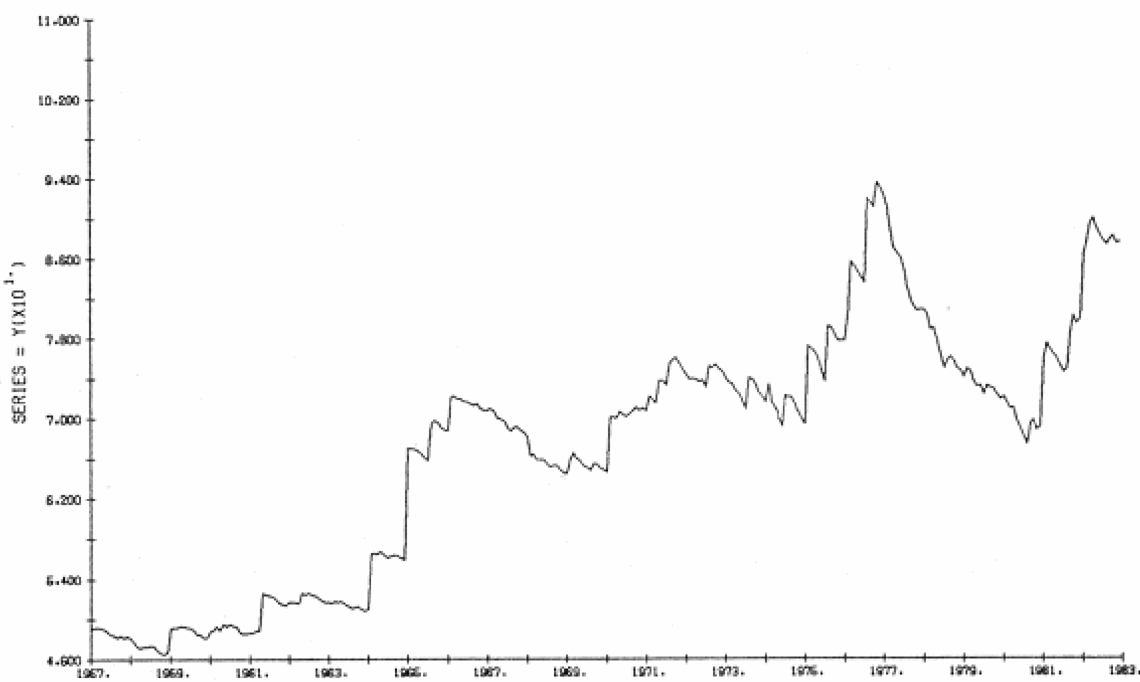
	CODE NO. =	8	8	8
	DEP.VAR. =	AUPPOP	PERPA	PRALT
AUTOCORRELATION				
	RHO 1	1.000	1.000	.170
		(22.51)	(12.77)	(3.25)
	RHO 2	.783	.546	
		(6.17)	(2.83)	
	RHO 3	-.797	-.606	
		(-3.75)	(-2.38)	
	RHO 4	-.206	.095	
		(-.80)	(.48)	
	RHO 5	.711	.024	
		(2.53)	(.10)	
	RHO 6	-.999	-.020	-.004
		(-6.29)	(-.07)	(-.07)
	RHO 7	.917	.017	-.056
		(4.48)	(.05)	(-.89)
	RHO 8	-.543	-.249	
		(-2.01)	(-.82)	
	RHO 9	.153	.103	-.064
		(.50)	(.32)	(-1.06)
	RHO 10	-.066	.201	
		(-.19)	(.64)	
	RHO 11	-.001	-.110	
		(0.00)	(-.37)	
	RHO 12	.048	-.018	.255
		(.33)	(-.12)	(5.27)
BOX-COX TRANSFORMATIONS				
ESTIMATED LAMBDA(X) - GROUP 1	EL1	-.215	2.565	-.432
		(-2.18)	(1.84)	(-3.92)
		(-12.32)	(1.12)	(-13.00)
ESTIMATED LAMBDA(Y)	ELY	-.215	2.565	-.432
		(-2.18)	(1.84)	(-3.92)
		(-12.32)	(1.12)	(-13.00)
LOG-LIKELIHOOD		1791.831	622.422	594.084
PSEUDO-(L)-R2		1.000	.997	.960
NUMBER OF OBSERVATIONS		300	144	300
ESTIMATION PERIOD		14-313	170-313	14-313
NUMBER OF INDEPENDENT VARIABLES		16	20	24



ENTRNAS

REAL PRICE OF VEH.MAINTENANCE EXC.GAS INS.PUR.(1956=39.6)

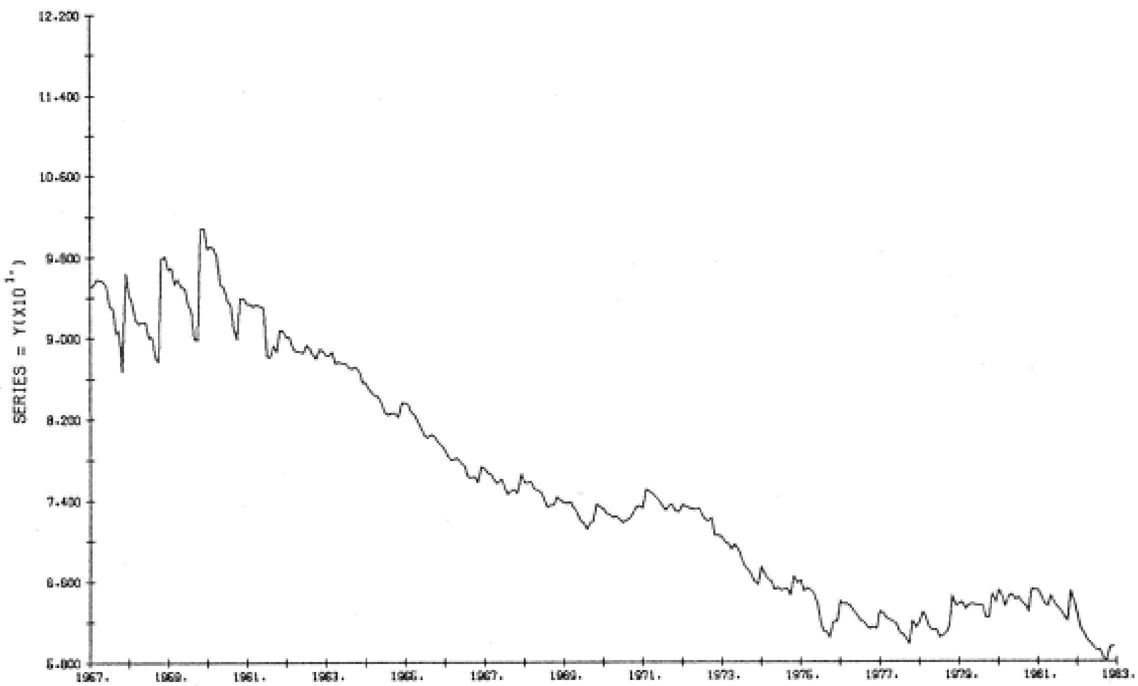
(JAN 1957 - DEC 1982)



PRASA

INDEX OF REAL PRICE OF AUTO.INSURANCE.CANADA (1956=49)

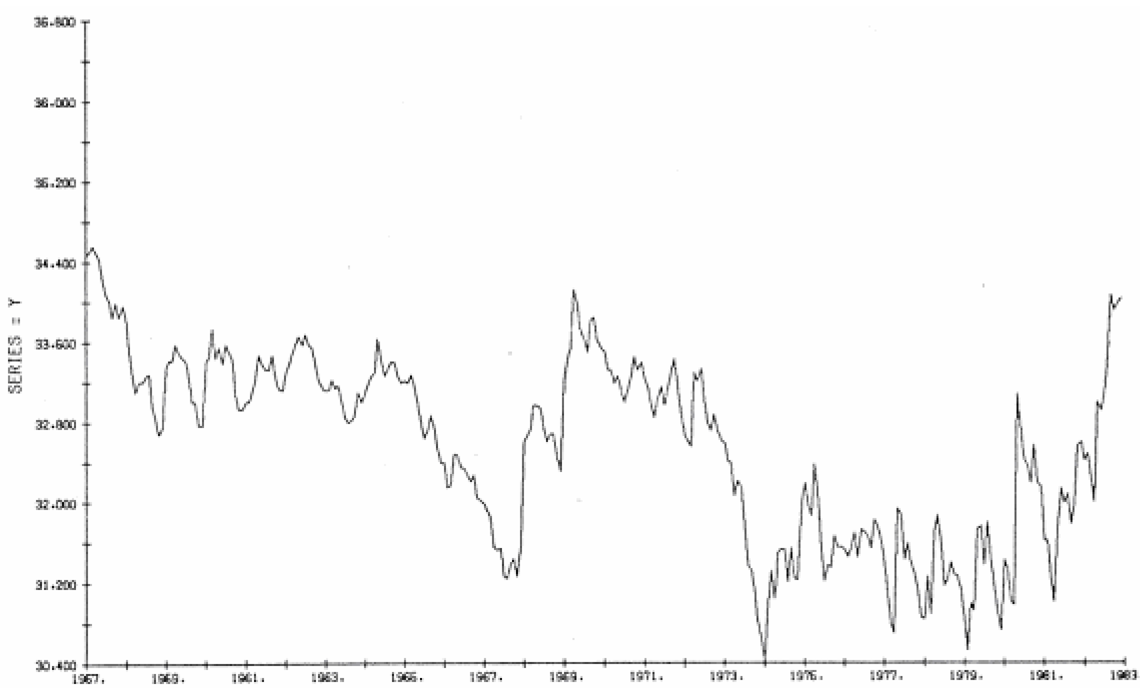
(JAN 1957 - DEC 1982)



PRAAC

INDEX OF REAL PURCHASE PRICE OF VEHIC.CANADA (1956=92)

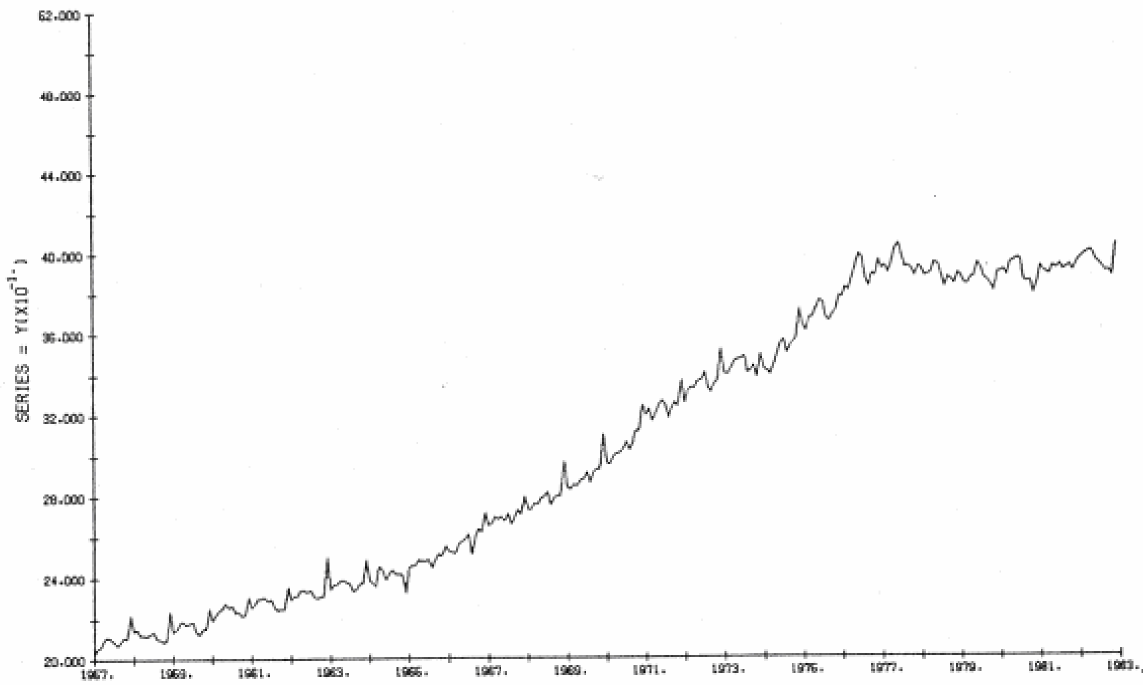
(JAN 1957 - DEC 1982)



PRBALC

INDEX OF REAL PRICE OF ALCOHOLIC BEVER.MTL (1956=34.4)

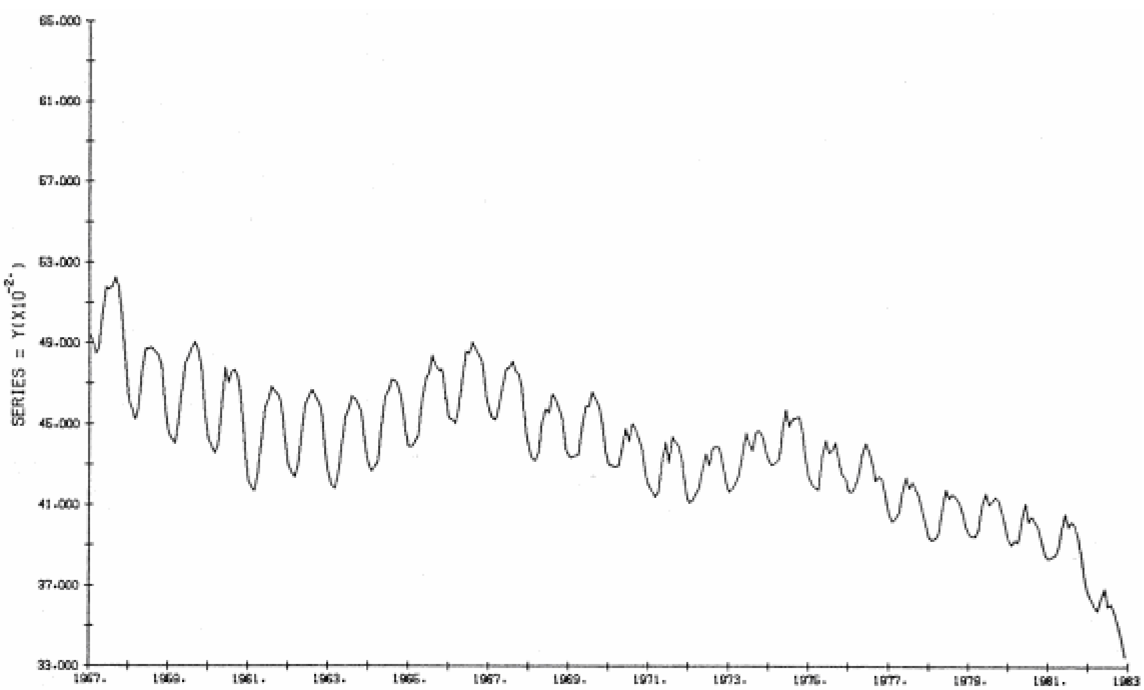
(JAN 1957 - DEC 1982)



SALRHMQ

REAL HOURLY WAGE IN MANUF.SECTOR IN QUEBEC ($.1971)

(JAN 1957 - DEC 1982)



PARTEMPL

EMPLOYMENT PARTICIPATION RATE IN QUEBEC

(JAN 1957 - DEC 1982)