

Characteristics Of Heavy Traffic On Various French Roads

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ABSTRACT

This study deals with the main characteristics of all in-service commercial vehicles weighing at least 2 tonnes, in order to evaluate pollutant emissions of heavy duty traffic. We have carried out the same study on 3 different road types to provide a precise description of the urban, interurban and international heavy traffic types. At each site, recordings lasted a full week, night and day, so that for all 3 sites more than 20,000 vehicles are fully described.

Two different methods have been used which lead to the same results : a large number of vehicle characteristics were collected to analyse both traffic and heavy-duty vehicles. One method couples weigh-in-motion with video recording (a camera is pointed at traffic) in a fully automatic station. A micro-computer processes values of truck weight in real time and selects vehicles over a 2 tonne threshold. Video tapes are subsequently analysed to complete files with make, model, horsepower, shape code and possibly nationality and whether they are equipped with a frigorific unit. The other variables are date & hour, weight by axle, axle number, instantaneous speed, length and wheelbases for each selected vehicle. This method has been applied to the urban and interurban cases. The international traffic was studied with a quite different method : taking advantage of the vehicles' stop at the Mont Blanc tunnel toll (France-Italy border), a survey among truck drivers has provided mainly the same variables (except length, axle number, weight by axle and instantaneous speed but with mileage in addition). Proposed statistics are of two kinds :

- an analysis of the heavy traffic for each road type : percentage of heavy vehicles in the global traffic, daily levels, week evolution, day/night differences and composition in 4 vehicle types (van, light truck, heavy truck and bus) ;
- a comparative study of the variables characterizing these 4 groups of vehicles : weight and horsepower means and distributions, analysis in relation to nationality, to the day of week, to the fact that the vehicle is equipped or not with a frigorific unit with statistical tests on mean comparison.

All these variables form an unique database on commercial vehicles running on French roads. This database can provide input data for models of pollutant emissions.

INTRODUCTION

The detailed description of heavy traffic is one step in the calculation of the quantities of pollutants from this vehicle group. Daily levels, total weight, horsepower and speed of the various categories of commercial vehicles are the main variables we need. Moreover, several routes in a country must be studied as the composition of the duty traffic can vary largely from an urban road to an interurban and an international one. Information on in-service commercial traffic is also useful to those managing the road network and to local authorities ; equally to the general public as concern is growing over the increase in heavy traffic in Europe.

The objectives of the investigations regularly lead by the Transportation Observatory (OEST, Paris) are to study heavy-duty traffic on the whole network, with categorization by road type. But the investigation of 1985 addressed only vehicles over 10 tonnes and the one of 1990, vehicles above 3.5 t. On the other hand, Road Services monitor the weight characteristics of traffic on several highways fitted with weigh-in-motion stations. These checks give indications of the damage risk due to heavy-duty traffic on surfaces and bridges. Traffic levels and weight by axle are then the main variables. But they give incomplete statistics on traffic characteristics : we need information on the horsepower, the total weight related vehicle type and other descriptive variables.

The first goal of this study is to describe 3 examples of duty traffic. The location of the 3 investigations were chosen in agreement with the Tunnel Study Center (CETU, Lyon) who supported the project and are involved in the calculation of future tunnel ventilator size ; and ventilation depends on emission of smoke and other pollutants . Therefore, the study spots were located at a tunnel entrance or exit in the 3 cases, to be sure to obtain a typical traffic image. The 3 tunnels each have a very specific duty traffic, so different from one another that we are practically sure to have encountered the widest range of duty traffic in terms of composition and weight characteristics. These case studies thus present a larger interest than just pinpoint descriptions of in-service vehicles :

(i) we think that these descriptions are typical not only of the tunnels but also of the roads passing through these tunnels and of the routes themselves. That is why we extend the results on the tunnels to the roads and the routes, i.e. an urban, an interurban and a international one.

(ii) The 3 descriptions of duty traffic we have can not apply of course to any traffic but give precise ideas and limits of composition, weight and horsepower values that can be found on the French network.

Statistics are based on samples of 6 to 10 thousand of vehicles on each site.

METHODOLOGY

SAMPLED VEHICLES

Our investigations have been extended to commercial vehicles from 2 tonnes of total weight. The use of light duty vehicles is somewhat closer to the trucks' compared to that of private cars. The choice of this threshold is the results of several constraints :

(i) weight reference is usually based on the Gross Vehicle Weight and a 3 t GVW threshold would have been suitable to cover an extensive range of commercial

vehicles, from the van to the road train weighing 40 t.

(ii) in fact the only reference we could use, was the real total weight given by the weigh-in-motion station. We have estimated with this reference, that a 2 t limit would enable to sample vans as well and even a larger part of them than with a 3 t GVW limit.

As 80 % of the vans are diesel powered (as is 100 % of the whole truck range), the vehicles sample is consistent on this point.

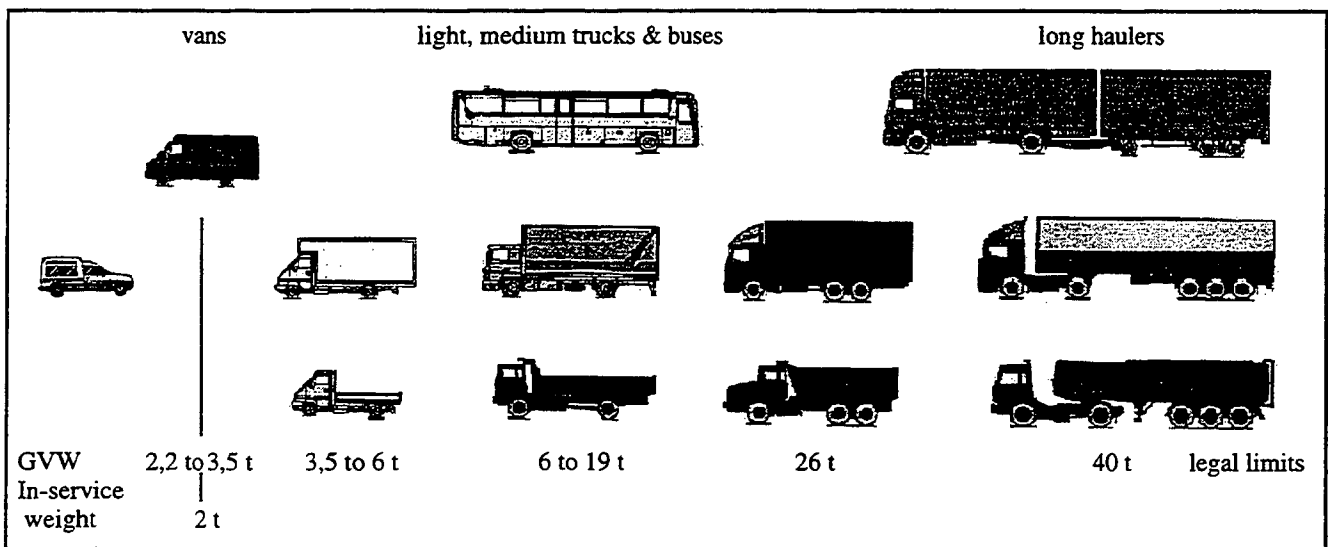


Figure 1 : The various existing commercial vehicles and the ones selected from the threshold of 2 tonnes (overall weight).

SITES

The urban route chosen is a main thoroughfare of Lyons which crosses the town through an hill by the Croix Rousse tunnel. This tunnel has an average daily traffic of 80,000 vehicles in both directions (all vehicle types). There are two lanes in each direction and just one right lane -where most trucks are found- has been investigated. A small survey has shown that this right lane concentrates 70 % of the vans and 95 % of the heavy vehicles (100 % of buses and HGV's).

The interurban route is a highway located in a mountainous area. It is a two-lane road with several curves but duty traffic is relatively heavy as it is a practical link between an alpine valley and the motorway towards the north of France and Europe. That is the reason why we found there a significant part of the heaviest trucks being in transit between Italy and the northern European countries. We noted then on

this road a mixing of interurban and international traffic and we have assessed the proportion of vehicles in transit, so that the corrected figures give the vehicle type composition relevant to a proper interurban traffic.

As international route, the quite obvious example is the road joining France and Italy through the Mont Blanc tunnel. More than an important gate between these two countries, this is the main way joining Italy with France and the United Kingdom. This importance increased when Switzerland decided to close their borders to trucks weighing more than 28 tonnes. Although this tunnel is located at an altitude of 1300 m (4300 ft) in a very attractive area, duty traffic is heavier than cars. The commercial traffic is not only as high as 2,000 vehicles a day averaging (up to 4,000) but is solely made up of the heaviest vehicles. The traffic in only one direction has been studied (France to Italy) as for the previous sites.

INVESTIGATION DURATION

We intended to be exhaustive for one whole week in this description of the duty traffic rather than sampling vehicles for a few hours along a month or along the year. A number of reasons have led to this choice :

- (i) once the investigators are on the spot or once the weigh-in-motion station is set, it is easy to describe all the vehicles passing all day long. It would be difficult to do the same investigation repeatedly for short periods. And, in that case, we would never be sure to obtain representative samples.
- (ii) the variability of the vehicles characteristics mainly depends on the hour of the day and on the day of the week. The follow-up of the daily and weekly traffic evolutions has the greatest interest because they are closely connected with the drivers' work rhythm. The monthly or seasonal evolutions are hard to describe and refer mostly to traffic rates.

As far as possible, we planned the investigations to operate on "normal" weeks, i.e. outside of holiday periods during which both industrial activity and commercial traffic are reduced.

EXPERIMENTAL METHODS

The survey among truck drivers initially appeared to be the best method to collect the numerous variables, taking advantage of the vehicles' stop at the Mont Blanc tunnel toll. A few pieces of information were obtained just by observing vehicles and reported on forms by investigators. In fact the stop duration at the tunnel toll is often limited to about 20 or 30 seconds and winning confidence of drivers concerning the very sensitive question of their vehicle weight, was a tough job. Despite a careful approach -assuring anonymity, showing the technical, not administra-

tive aspect of the survey, asking first about vehicle mileage and horsepower- a very few drivers refused firmly to reply (about 2 %). The interview also enabled us to obtain information on vehicle weight in the other direction when using the same road. We managed to get an answer on this point for 60 % of the vehicles.

Reliability of the answers about weight figures depends on the driver's honesty. And the vehicle weight is a major variable in our analysis. Only 30 % of the weight figures are actually suspected of being underrated, the ones at the very allowed limit of 40 tons. We may fear a slight underestimation of the average weight of trucks with such a survey. If we admit that the error is about 5 to 10 % on this 30 % vehicles (42 or 44 t instead of the 40 t declared), the global error on trucks is only a couple of percent.

Another method was to be developed for both other sites as no stop of the whole duty traffic could be imagined there. The weigh-in-motion technique is the proper answer to get descriptive variables on as many vehicles as wanted, keeping the traffic free. But the weigh-in-motion station can not yield all the variables we need ; we added a video camera pointed at traffic and analysed afterwards the images of commercial vehicles to get such variables as horsepower, make and model, nationality and possibly the presence of a frigorific van. (Frigorific compressors are suspected of additional pollution as they run with diesel fuel). The combination of both equipments (weigh-in-motion and video recording) is the original part of the method : the video recorder is under the control of the weigh-in-motion station ; the station puts the tape recorder on when detecting a vehicle of at least 2 tonnes and sets it back on stand-by after a few seconds, the time needed for the truck to pass by the camera. This setting on stand-by enables to save video tapes and avoids frequent tape

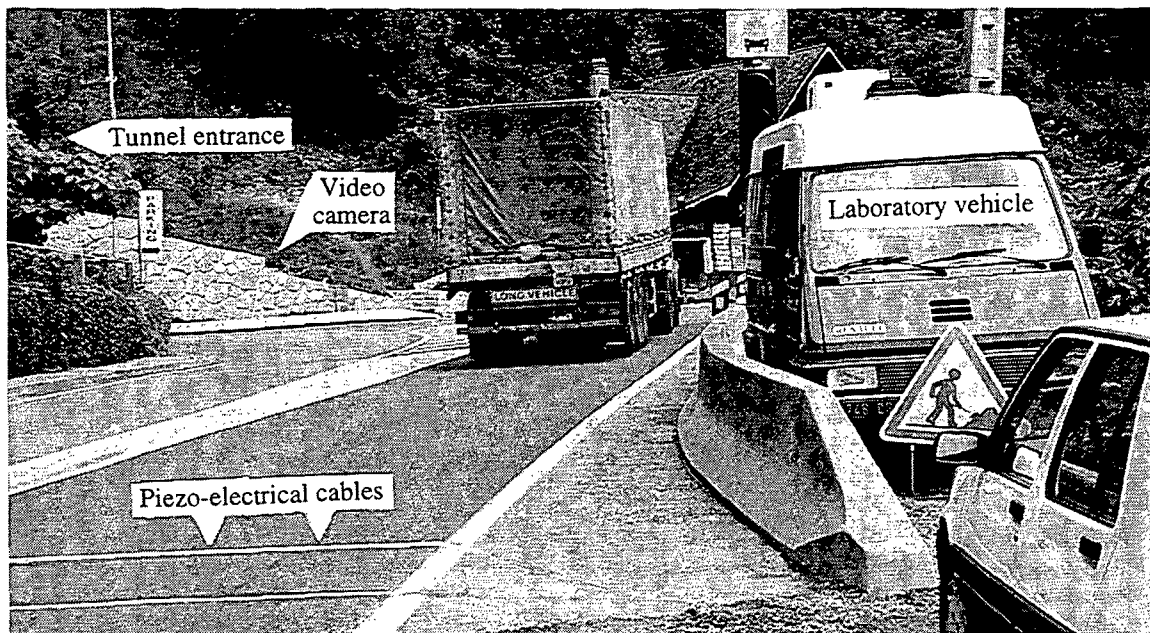


Figure 2 : Setting-up of the whole monitoring equipment (example of the interurban road)

replacements. The micro-computer of the weigh-in-motion station creates a primary file with date & time, weight by axle, axle number, length and axle wheelbase for each selected truck. The operator subsequently adds descriptive variables from the image analysis. As he finds also date & time on the images, he can easily match all characteristics for each vehicle.

The weigh-in-motion technique is not famous for the reliability of its measurements : despite good calibration, accuracy is about $\pm 10\%$ of the real static weights with influences of the surface uniformity, of the vehicle acceleration or deceleration. Improvements have been achieved on the signal processing but the system still gives a few abnormal data (vibration of vehicles on their axle are unavoidable despite a recent coating). Thanks to the truck images,

RESULTS

TRAFFIC DESCRIPTION

We present first a few figures about the distribution of the commercial traffic (vehicles from 2 tonnes in our case), in the overall traffic (Fig 2). The proportion of selected vehicles varies highly from one site to another : from 5 % on the urban road to 21 % on the interurban one and 51 % on the international one according to the weeks of investigation. For each site, this proportion changes with the hour of the day, with the day of the week and with the season. Thus on peak hours, the car traffic supersedes the commercial one in urban areas. As far as the week evolution is concerned, the percentage of commercial vehicles is higher during the working week than on Saturday and Sunday. The international traffic is specially subject to seasonal variations : the tourist traffic is much heavier on vacation periods when commercial activity is indeed reduced.

the operator can sometimes correct wrong data from the weigh-in-motion station : this is the case when the axle number revealed by views is different from the one given by the station. Consequently, the overall weight of the truck is not correct as it is the sum of the weights by axle. Actually this is the only variable common to both collector systems, but a very important one as it determines the axle class and the overall weight of the vehicles. As another way of correction, when the given weight seems overvalued with regard to the axle number, the vehicle type on images can help the operator to decide to remove this data or not (e.g. a 3 axle concrete mixer can reach 30 tonnes -for a 26 t allowed limit- whereas a van with trailer can not). In that sense, the coupling of the two equipments, weigh-in-motion and video, can improve the reliability of the weigh-in-motion station alone.

Deviations of heavy traffic levels clearly follow a weekly rhythm, typical of each road type (Fig 3). Levels are somewhat consistent during the working week on the urban and interurban routes whereas on the international one, the flow towards Italy is much more important on the week beginning. This flow is made up with all the trucks coming from northern Europe.

The share of night traffic, compared to total traffic, is also typical of the road type. Defining the nighttime by the period 8 p.m. to 6 a.m., i.e. 42 % of the 24 day hours, we obtain a light night traffic on urban road (11 %), a non negligible one on the interurban road (23 %) and a significant one on the international road (38 %). To simplify, we would say that the urban roads have a light commercial traffic at night whereas international goods exchanges induce, on the contrary, a significant night traffic.

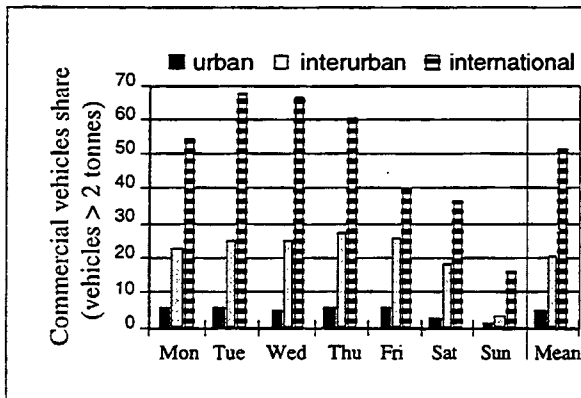


Figure 2 : Percentage of commercial vehicles each day and week average over the 3 sites.

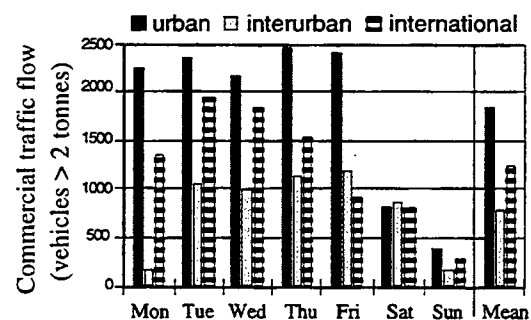


Figure 3 : Number of commercial vehicles each day and week average over the 3 sites.

Classification of vehicles as a whole on the week according to the main variables (axle number, length, horsepower and weight) yields primary information about the structure and the significant vehicle types of the commer-

cial traffic. Both variables axle number and length are not available for the international route as there was no automatic monitoring station on this site (survey instead). But these variables are less valuable for this route where most

trucks have the maximum allowed dimensions. On this road, 94 % of vehicles identified are tractors-trailers or road trains having a length between 14 and 18.35 m (46 to 60 ft). Moreover, most of them are fitted with 5 axles, the 4 or 6 axle vehicles representing less than 20 %.

Such a prevalence exists on the urban route, from the 2 axle vehicles in this case, which are 81 % of the total amount of commercial vehicles (Fig 4 up). The upper chart on figure 5 clearly shows that prevailing length classes are those of the smallest vehicles (vans and then little trucks). Long vehicles are very few in spite of the fact that this main street leads directly on to a very busy shopping district. In the decreasing evolution of vehicle numbers versus length, we note a high point with the 11 m class which is the length of buses and heavy tipper trucks. Another bend in the length distribution is visible around the 15 and 16 m classes, the length of long haulers.

From a primary analysis, the interurban traffic reveals a majority of 5 axle vehicles (53 %) (Fig 4 down). The other axle classes are ordered as follows : 2 axles (27 %), 4 axles (14 %), 3 axles (4 %) and 6 axles (2 %). The long vehicles as a whole (4, 5 and 6 axles) are largely in the majority : their share is up to 70 % of the commercial traffic. The chart of the length classes confirms prevalence of long vehicles (Fig 5 down). But a thorough analysis of the vehicle nationality has shown that a significant part of the trucks, especially the long haulers, were just in transit between Italy and northern Europe on this route. We calculated the number of 5 and 6 axle vehicles in transit (development of the method in the next paragraph) and the new figures on the axle distribution for a proper interurban traffic are the following : 2 axles (41 %), 5 axles (37 %), 4 axles (16 %) and 3 axles (6 %).

The horsepower (Fig 6) and weight (Fig 7) value distributions underline even more the great inconsistency lying in the composition of the urban and international traffic types :

- 40 % of the vehicles identified on the urban route (daytime traffic between 8 a.m. and 8 p.m.) form the first horsepower class, centered on 70 hp (57 and 82 hp as bound values). And indeed 42 % of the 24 hour traffic is gathered in the starting class, between 2 and 4 tonnes ;
- on the opposite, 58 % of the vehicles on the international route have an horsepower exceeding 350 hp and 55 % have a weight of at least 38 tonnes. This road is possibly the most loaded French route as far as the mean vehicle weight is concerned ;

The interurban road presents in a more balanced way, the whole range of commercial vehicles, from the lightest ones with the vans to the heaviest ones with the long haulers. However, two categories are larger than the others and again these are the boundaries : lots of vans or light trucks are found (16 % have 60 to 105 hp) and even more heavy duty trucks in the primary analysis (34 % have more

than 350 hp). There is no such duality in weight figures : except for the peak with the 2-4 t class, values are then well shared out up to the greatest ones. This indicates that several vehicles are only slightly loaded since a large part of the vehicles having more than 300 hp weigh under 30 tonnes in service.

Figure 4 : Classification of vehicles according to axle number in urban and interurban traffics. (Gross percentage values in the case of the interurban traffic : mixing of interurban and international traffics).

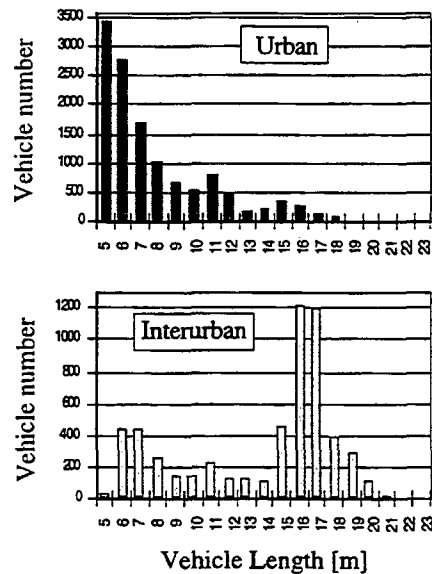
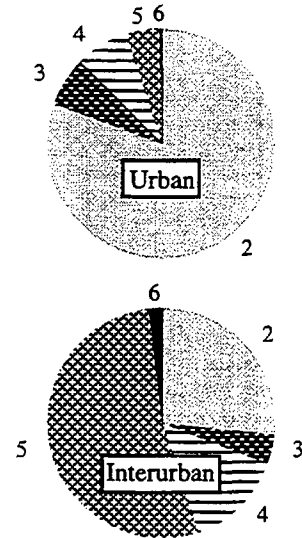


Figure 5 : Distribution of vehicles according to length classes in urban and interurban traffics (gross values).

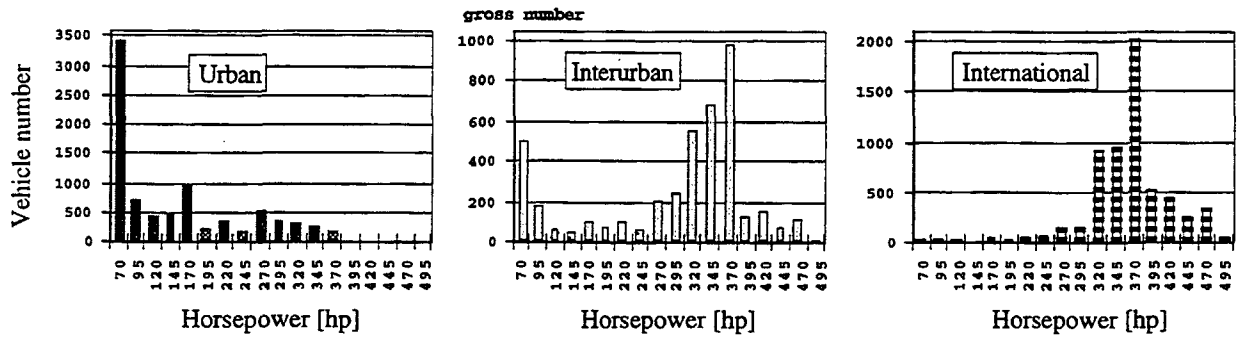


Figure 6 : Distribution of vehicles according to horsepower classes (25 hp range) over the 3 sites.

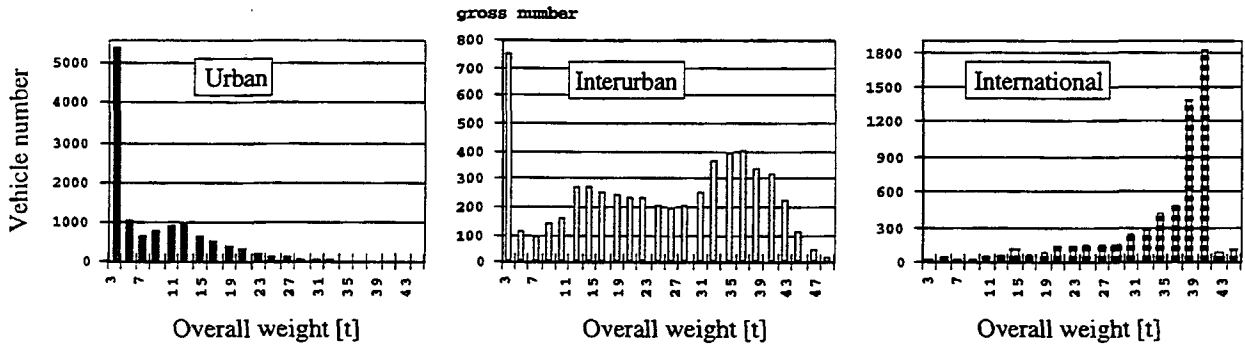


Figure 7 : Distribution of vehicles according to weight classes (2 t range) over the 3 sites.

The four main vehicle types -buses, vans, single trucks and long haulers- are used to compare traffic composition of the different routes. Each of these compositions is typical of one route (Fig 8). The three configurations are so different that they reinforce our choice of the sites ; our primary goal was indeed to investigate the largest possible variety of commercial traffics. Buses represent respectively 8.5, 2.4 and 1.7 % on these urban, interurban and international routes. These vehicles are mainly city buses in the urban case as the chosen site was located on two bus lines. This situation seems to be an intermediate one : some streets have several bus lines, others none. On the interurban road we found school buses as well as tour buses. The international road is largely used by touring buses but a shuttle also exists across the tunnel. Annual toll statistics report an higher share for buses (up to 4 %) ; it is true that the sample of bus represented is lower than that of trucks. There are many vans in urban area (28 % here) whereas they are hardly detectable on the international route (0.8 %). The share of vans in the interurban composition is initially of 7.8 % ; after correction due to in-transit haulers, the proper share is set at 11.4 %. "Single trucks" is a term that stands for a wide range of commercial vehicle, all trucks that are neither vans nor long haulers in fact. They are generally dedicated to goods delivery or works and do have a trailer sometimes ; the main point is that they cover short or medium distances. These vehicles are the most common in urban areas (52 %) and are very few, by definition, on the international route (3.5 %). Small to mid-sized trucks are a

significant group on the interurban route with a prior share of 19.5 % corrected to 32.4 % with the elimination of in-transit long haulers. Long haulers represent only 11.6 % on the urban route and 94 % on the international route with, once again an intermediate result on the interurban route (53.8 %).

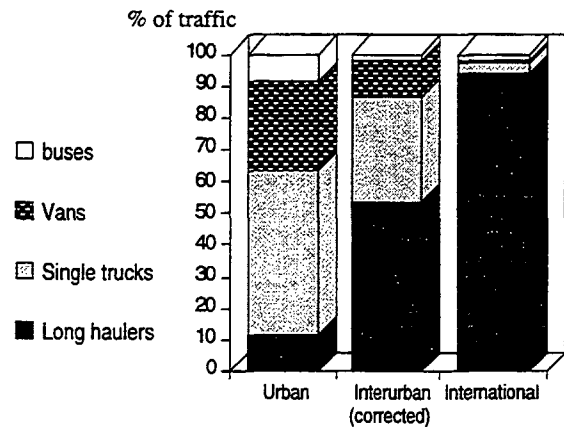


Figure 8 : Comparative composition of the 3 traffic types according to the 4 types of commercial vehicles : buses, vans, single trucks and long haulers.

The traffic means of horsepower and weight differ greatly from one site to another (Table 1). Interurban traffic characteristics have been corrected by eliminating vehicles in transit (international) from the files, retaining only vehicles limited to a national traffic.

Table 1 : Mean values of length, horsepower and weight of the 3 traffics over the full week.

Traffic over a week	Vehicle number	Length [m] [ft]	Power [hp]	Weight [t]
Urban	8 925	7.8 25	153	9.2
Inter gross city corrected	5 936	13.9 45	292	24.3
	* 3 800	12.5 41	263	19.5
International	6 240	* ≥ 16 52	358	34.1

* estimation

VEHICLE CHARACTERISTICS ON THE VARIOUS ROUTES

We develop in this paragraph the description of the traffics by vehicle type. The week mean values given in table 2 for the urban traffic have been calculated from the identified vehicles, those passing between 8.00 a.m. and

8.00 p.m. The comparison of daytime traffic with nighttime traffic did not yield significant differences in terms of axle class composition, length and weight of vehicles. We may then adopt these figures for the whole week traffic.

Table 2 : Characteristics of the 4 vehicle types (number, percentage, mean length, horsepower and weight) in the urban traffic.

Traffic over a week	Identified vehicles	Share [%]	Length [m]	Power [hp]	Weight [t]
Buses	757	8.5	11.4	185	12.9
Vans	2 503	28.0	5.5	72	2.7
Single trucks	4 628	51.7	7.0	156	8.8
Long haulers	1 037	11.6	14.0	323	23.7

The single trucks class is then made up of various commercial vehicles, from the light truck of 3.5 t GVW to the heavy dump truck fitted with 3 axles and weighing up to 26 t. The horsepower as well spreads over a wide range of values (70 to 350 hp) and the mean of 156 hp hides a large value scattering ($\sigma = 77$ hp). The light pick-ups dedicated to works are a majority. Then the delivery trucks, from 120 to 200 hp and the dump trucks are many. The overall weight lightness of this category also comes from

the high number of bottom range models and from the low level of loading on the heaviest trucks. The same configuration is detected with the vans, their weight is often near the threshold of 2 tonnes : 62 % of vans weigh less than 2.6 t. The long haulers have power and weight values at a lower level than on the other routes because a large part are semi-trailers with 2 axles and dedicated to works. 70 % of the buses are city buses.

Table 3 : Vehicle characteristics (number, percentage, mean length, horsepower and weight) according to axle number in the corrected interurban traffic (after elimination of in-transit long haulers).

Axle number	Vehicle number	Share [%]	Length [m]	Power [hp]	Weight [t]
2	1 570	41	7.9	150	7.9
3	230	6	9.7	283	20.4
4	600	16	15.4	328	22.5
5	1 400	37	16.7	355	31.0

Instead of a vehicle type classification, a description according to axle number is preferred in the case of interurban traffic analysis (Table 3). Indeed, this method enables us to identify French long haulers in transit between Italy and France on the basis of the daily traffic of 5 axle vehicles (Fig 9). We analysed the 5 axle traffic flow because this axle class gathers 83 % of the foreign vehicles, which means that most of in-transit vehicles, French or not, are in this axle class. We think that the French 5 axle vehicle flows passing on the first days of the week do form the typical local and interurban traffic, because it is rare that the French trucks come back from Italy at the beginning of the week. As traffic levels increase during the week, the flow differential on each day represents the international traffic share for the French vehicles. We assume that the

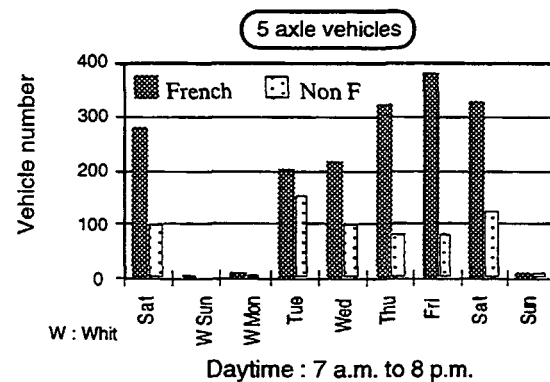


Figure 9 : Daily 5 axle traffic flow on the interurban route.

foreign vehicles are in transit.

We come back on table 4 to the 4 vehicle types for the international traffic description (France-Italy border) :

- 94 % are long haulers (75 % are tractor-trailers and 19 % road trains) ;
- these vehicles have a mean horsepower of 367 hp and a mean total weight of 35.6 tonnes ;
- 77 % of the tractor-trailers have at least 350 hp or have a weight of at least 35 t. ;
- 37 % of the tractor-trailers have a weight greater or equal to 40 t.

These high values of horsepower and weight are typical of long distance traffic; these averages are even expanded here due to the roughness of the route : vehicles used are the newest and the most powerful of the European market. Reported mileages indicate that long haulers are 3 years old on average, on the basis of 60,000 miles a year. Weights in the Italy-France direction estimated by drivers are slightly but significantly lower than in the direction studied, due probably to a not so good loading rate for vehicles which are, for most of them, on their way back. (A majority of commercial vehicles using this route is based in the northwest part of Europe as indicated further).

Table 4 : Characteristics of the 4 vehicle types (number, share, mileage, horsepower and weight in both directions) in the international traffic.

Traffic over a week	Vehicle number	Share [%]	Mileage [miles]	Power [hp]	Weight F→I	Weight I→F
Buses	107	1.7	163 000	288	14.7	15.0
Vans	52	0.8	81 000	84	3.9	4.0
Single trucks	216	3.5	140 000	196	11.9	12.5
Long haulers	5 865	94.0	205 000	367	35.6	34.1

Nationality analysis over the identified vehicles gives nearly the same composition as the one obtained with the annual toll statistics, which include, as far as they are concerned, both traffic directions. This similarity shows that vehicles are just the same in both directions and that characteristics resulting from the survey on the France-Italy traffic are valid as well for the opposite traffic, except for weight. French vehicles are the most numerous with 35.8 % of the total, then the Italian, 23.1 % and the northern European countries : Belgium+Luxembourg= 14.5 %, UK+IRL=9.6 %, Netherlands=10 %, Germany+Austria=3.4 %. Vehicles from north and west of the Alps represent 70 % of commercial traffic. The Belgian and French long haulers are the heaviest on average with respectively 37.5 and 36.9 tonnes. The French heavy duty trucks have the largest proportion (51 %) of vehicles weighing at least 40 t, the allowed limit (Fig 10) ; and 36 % of the French drivers declare a weight at the very limit. The possibility of overload is then the greatest among the French vehicles.

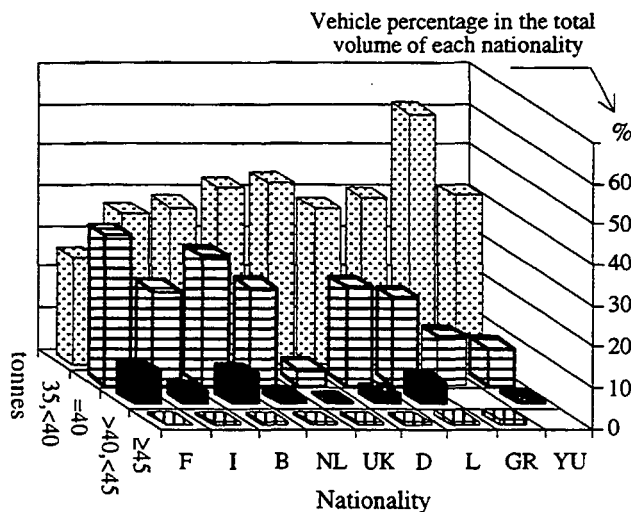


Figure 10 : Share of the heaviest vehicles for each nationality

CONCLUSION

The variety of the chosen routes, the great number of descriptive variables and the large size of vehicle samples yield extensive information on the heavy duty traffic. All the records form an interesting database and further comparisons or data processing can be carried out. It provides input data for models of pollutant emissions from this traffic. We have to remember that these analyses can not be considered as representative models of urban, interurban and international commercial traffics on the French network but rather as illustrating descriptions of different traffic types. Nevertheless, they should provide good indications of horsepower and weight values for any commercial traffic insofar as the composition of vehicles in axle class or type is known.