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UPDATE OF THE SWISS SOURCE MODEL FOR ROAD TRAFFIC NOISE

Francois-Edern ABALLEA, Hervé LISSEK, Stephan UTZ

Ecole Polytechnique Fédérale de Lausanne, ELB – Station 11, 1015 Lausanne, Switzerland
francois.aballea@epfl.ch, herve.lissek@epfl.ch, stephan.utz@unil.ch

Pierre-Jean RENE, Philippe MARTIN

Acoustical Engineering & Research sàrl, Rue de l'Ale 25, 1003 Lausanne
pjrene@a-e-r.ch, pmartin@a-e-r.ch

Laurent COSANDEY

Office Fédérale de l'Environnement, Worblentalstrasse 68, Ittigen CH-3063, Switzerland
laurent.cosandey@bafu.admin.ch

In Switzerland, the calculation method of road traffic noise is specified in the Ordonnance sur la protection contre le bruit (OPB) (Noise Protection Ordonnance (NPO)). This method is mainly based on observations that were realized in the 80s, and that are not satisfactory many situations anymore. Since the 80s, the traffic volumes have increased, new developments in car and road technologies have occurred, behaviors of users have changed. All these parameters contribute to lower reliability of the initial method. Even if the model is still correct in some case such as for fluid traffic, the obtained levels in different types of traffic are hardly reliable. In collaboration with the Swiss Federal Office for the Environment (FOEN), a research program has been setup to update the method according to those observations. The objective was to give new guidelines to evaluate emission levels of roads. An important collect of data from cantons and others acoustics partners has been performed as well as measurements in real traffic conditions. That made it possible to gather about 7500 points of measurement through all Switzerland for several types of road and traffic conditions.

1. Introduction

The Swiss method of calculation of the emissions of road noise defined in appendix 3 of the Noise Protection Ordinance (NPO)[1], based on observations carried out in the Eighties, does not give any more satisfaction for the majority of the situations.

The NPO considers two types of vehicles: light vehicles (N_1, including private cars, delivery vans, minibuses, auto-cycles and trolley buses), and the heavy ones (N_2, including trucks, semi-trailers, buses, motor bicycles and tractors). When no data about the hourly flow rate are available, the night (10 pm-6 am) and day (6 am-10 pm) hourly flow rates N_n et N_t are computed from the annual average daily traffic:

$$N_i = \frac{\alpha_i}{100} \cdot TJM \qquad (1)$$

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where $i = n,t$ for night and day period. The NPO recommends values $\alpha_t = 5.8$ and $\alpha_n = 0.9$ with a proportion of tucks $\varepsilon_t = 10\%$ and $\varepsilon_n = 5\%$.

Since the 80s, the traffic volumes have increased, new developments in car and road technologies have occurred, behaviours of users have changed. All these parameters contribute to lower efficiency of the initial method.

The objective of this study is to adapt the current emissions calculation method according to news conditions of traffic in order to allow the reliable calculation of the emission levels of the road traffic when only the daily traffic is available. To achieve this goal, various categories of roads have to be characterised based on observations from confederation, cantons, communes, research taking into account the mode of traffic, the distribution N1-N2 and the difference day-night.

The methodology is presented here.

2. StL86+ and EMPA 97 models

2.1 Stl86+ model

The Federal Office of Environment (FOEN) published the StL-86 model dedicated to the calculation of the noise due to the road infrastructures in 1997[2]. Bases on a set on data from the Eighties, the method was updated by the EMPA in 1995 and became StL-86+[3]. This model is always used currently.

The emissions levels L_w in dB(A) are computed by the following relation :

$$L_w = A + 10\log\left[\left(1+\left(\frac{v}{50}\right)^3\right)\cdot\left(1+B\cdot\varepsilon\cdot\left(1-\frac{v}{150}\right)\right)\right] + 10\log(N) + Coor \qquad (2)$$

With $A = 43$ et $B = 20$ two empirical constants, v the average speed of the road, ε the trucks proportion, N the hourly flow rate of the road, $Coor$ a correction according to the type of the road surface and the slope of the road.

2.2 EMPA97 model

The Swiss model EMPA97 was developed by the EMPA and was published in 2004[4]. It allows the calculation of the immissions of noise of road traffic by respecting the recommendations of the NPO. This new method provides a description of the source much more detailed than for the StL86+ model, but must be used only for specifics cases[5].

For each vehicles category N_1 and N_2, the emission level is calculated starting from propulsion noise and rolling noise, according to the speed, the flow, the road surface and slope of the road. The sound power level, in dB(A), of an elementary point source located at *0.45 m* above the ground and representing a portion of road, is given, for a band of third of octave ranging between *100 Hz* to *5000 Hz*, by the relation:

$$L_{wt,j} = 10\log\left(\frac{M_{N_1}}{3600}\frac{3.6\Delta s}{V_{N_1}}10^{0.1\left(L_{w,A,N_1}+T_j\right)} + \frac{M_{N_2}}{3600}\frac{3.6\Delta s}{V_{N_2}}10^{0.1\left(L_{w,A,N_2}+T_j\right)}\right) \qquad (3)$$

With M_{N_1} et M_{N_2} numbers of light vehicles and truck per hour, V_{N_1} et V_{N_2} the average speeds of light vehicles and truck, Δs the length of the section considered, T_j the value of the road noise spectrum per third octave band. The sound power level in dB(A) for light vehicles and trucks on the considered section are given by:

$$L_{w,A,N_1} = 28.5 + 10\log\left(10^{0.1\left(7.3+35\log\left(V_{N_1}\right)+\Delta_{roul}\right)} + 10^{0.1\left(60.5+10\log\left(1+\left(\frac{V_{N_1}}{44}\right)^{3.5}\right)+\Delta_p\right)}\right) + \Delta_{rev}$$

$$L_{w,A,N_2} = 28.5 + 10\log\left(10^{0.1\left(16..3+35\log\left(V_{N_2}\right)+\Delta_{roul}\right)} + 10^{0.1\left(74.7+10\log\left(1+\left(\frac{V_{N_2}}{56}\right)^{3.5}\right)+\Delta_p\right)}\right) + \Delta_{rev}$$

(4)

With Δ_{roul} et Δ_{rev} a correction for to the road surface and Δ_p a correction due to the slope of the road.

2.3 Comparison between StL86+ and EMPA97

The two models do not use the same reference. The emission level given by StL-86+ model (eq. (2)) correspond to an equivalent energy level Leq in dB(A) instead of the the EMPA97 emission level which gives the source power output by a separated moving vehicle (eq. (4)).

The comparison between the two models can be undertaken using the following relation:

$$L'_{w,A} = L_{w,A} - 10\log(v) - 35$$

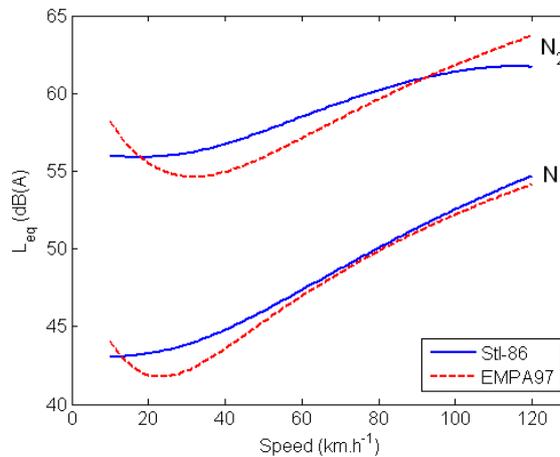(5)

with v the speed in $km.h^{-1}$.

Figure 1. Comparison between StL86+ and EMPA97 noise levels for N_1 and N_2 categories

3.   Database

A survey was carried out near cantonal offices and acoustical engineering offices to collect noise traffic measurements and traffic counting. That made it possible to gather about 7500 points of measurement through all Switzerland for several types of road and traffic conditions.

The type of data (format, contain,…) and the protocol used to obtain them is often specific to each canton. A huge work was made to insure compatibility between those data so that their exploitation becomes possible.

3.1 Road type

Each cantonal office uses its own way to name the road type. To harmonise the road type, we use the Swiss Federal Department of the Environment, Transport, Energy and Communications

(DETEC) road type database (VM-UVEK). It has 35 types of road from motorways to small paths. This classification is made according to the size and the function of the road.

All measurements data has been relocated on the swiss map using the VM-UVEK classification (Figure 2). Only 7 category of road were kept (Table 1), the others ones were not significant. The objective is now to exploit the data to give for each category of road:

- the average speed value for each NPO vehicle category
- the proportion of tucks
- the proportion of traffic daytime and night time

Table 1. VM-UVEK categories used for the database

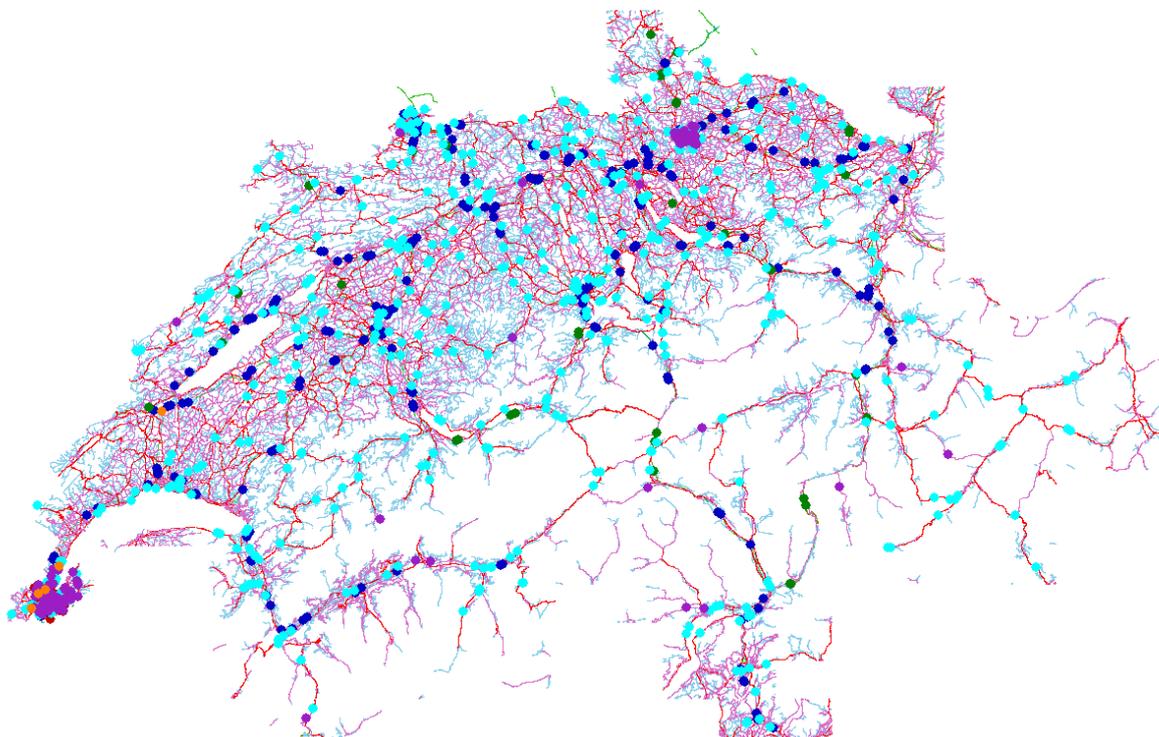| Category	Legend
Motorway	●
Freeways	●
Category 1	●
Category 2	●
Category 3	●
Category 4	●
Residential road	●

Figure 2. Measurement points on Swiss road

3.2 Vehicles counting

The choice was made to only consider data only resulting from automatic counting differentiating the categories of vehicles. Those data are not homogeneous since they depend on the type of classification given by the measurement device (SWISS 10, EUR13,…) and of its used (fixed meter installed at the year, meter installed for the time of a study,…). The table below summarizes the

various categories given by several counting machine. They illustrate the difficulty to merge together the different data.
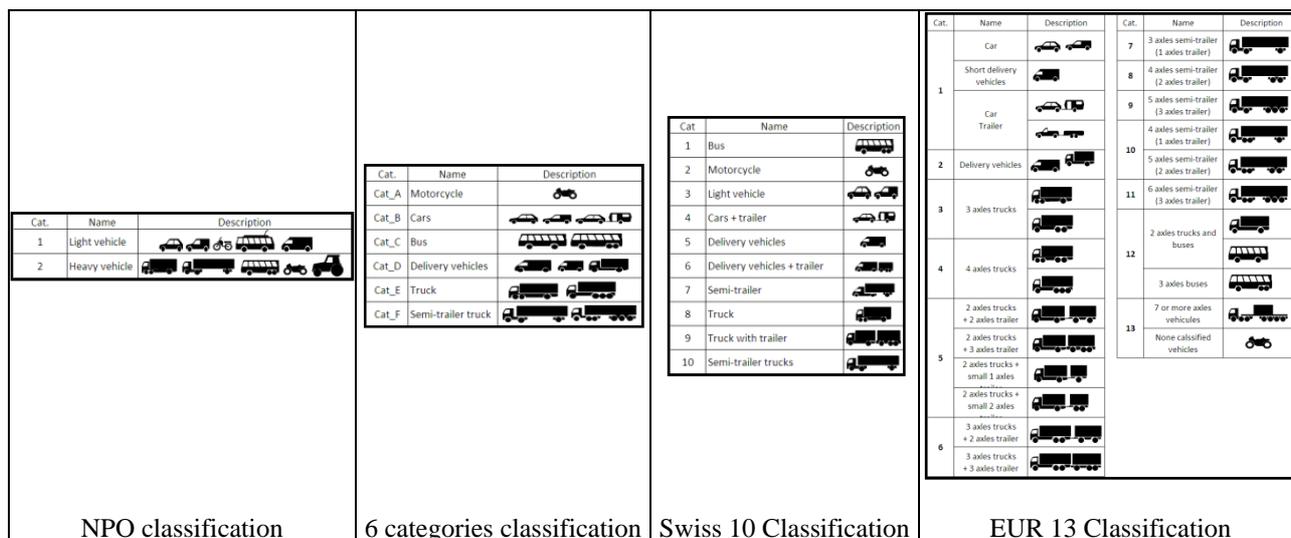

Figure 3. Different vehicles classification

3.3 Emission noise level

Too few useful data concerning measured emission traffic noise levels could be obtain. However they are essential to propose a method of aggregation of the categories of vehicles provided by automatic counting into two categories recommended by the NPO. A series of measurement are to be carried out to cure this lack of information.

4. Measurements

Several noise level measurements of one week have been performed in parallel with traffic counting. Some examples of results for Aclen site are presented here. Others Measurements are still in process.

$L_{eq125ms}$ are recorded according to ISO 362[6] with a microphone located at *1.2 m* high at *7.5 m* from the nearest line of the road. To characterize the road traffic, a EUR13 meter is used and located at *225 m* from the microphone in order not to affect L_{eq} measurements.

The counting data from EUR13 meter are used to estimate the proportion of each vehicle category and the average speed for each category (Figure 4). They allow to know exactly the characteristics of each recorded vehicle, its speed and its driving direction (Figure 5).
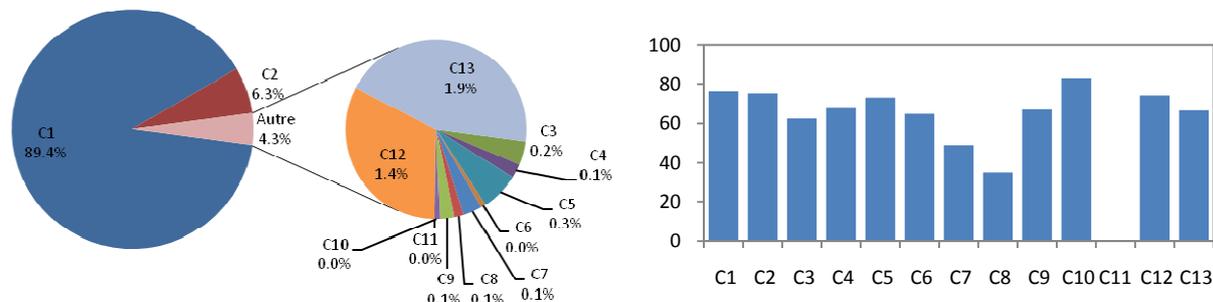

Figure 4. Reparation (left) and average vehicle speed (right) for each vehicle category
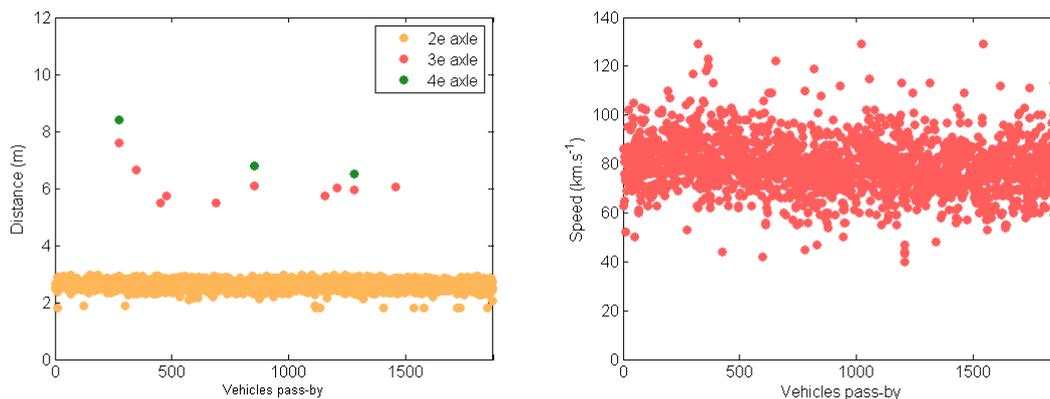
Figure 5. Distance between axles (left), and speed (right) for vehicle pass-by of category 1

The attenuation is estimate according the ISO 9613[7] and the road surface effect is approximate using ISO 11819-1[8]. Knowing the distance from the EUR13 meter, the vehicles speed and the driving direction of the car, it is then possible to evaluate L_w for each passing-by vehicle.

Figure 6 presents the speed versus average emission levels, i.e. one average level is compute for each speed (center), the vehicles distribution versus emission level (left) and the vehicles distribution versus speed (bottom) for EUR13 C1 category for 6 hours of measurement (about 2000 cars). Same results can be obtained for each of the EUR13 category.
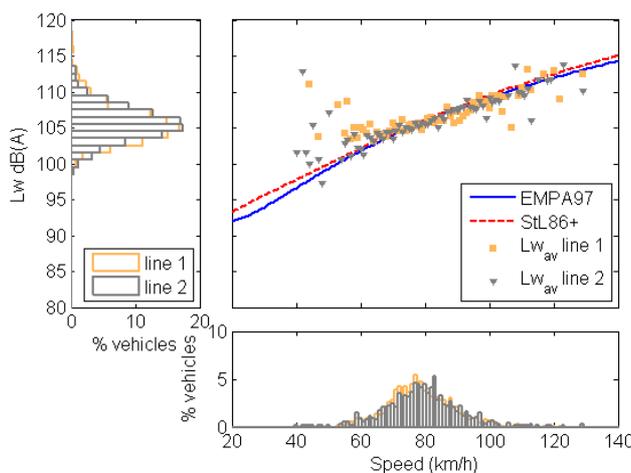

Figure 6. Speed versus average emission level (center), vehicles distribution versus emission level (left) and vehicles distribution versus speed (bottom) for EUR13 C1 category

The Figure 6 indicates that the general trend of emission level versus speed defined by the models is compliant with the measurements for the speeds greater than *60 km.h^-1*. For the lower speeds, the levels obtained with the models underestimate the measure levels.
Measurements under *60 km.h^-1* are not representatives: not enough vehicles have been measured at those speeds. The winter tires can explain partially the variation. Generally used in November in Switzerland, they generate more rolling noise especially at low speed[9].

Each category of each vehicle counting meters while be studied with the same approach. Results will be used to establish the smartest way to match categories from counting meters into the two one specified by the NPO.

5. Conclusion

The survey made possible to gather a consequent number of data. It is important to notice that even if noise abatement rules are quite strict and the same for each Swiss canton, each of them use its own method to perform its traffic noise evaluation. For that reason it is hard matching the collected data all together. The database is now harmonised and is still fed by new data which continue to be collected. The results from measurements have also been added to the database.

All data will be now exploited to suggest improvement for the appendix 3 of the NPO, that is to say:

- the determination of default means day traffic for various categories of roads according VM-UMVEC database,
- the default distribution of the traffic for the periods day/night for each category of road,
- the default distribution of the traffic of category N1/N2 for each category of road,
- the default average speed for each N1/N2 category for each category of road,
- the guidelines to reduce into 2 NPO categories the results from counting meters.

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