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URBAN ROAD TRAFFIC NOISE : CHARACTERISTICS AND COMPUTATION METHODS

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Introduction

Urban road traffic noise prediction methods have been currently considered as satisfactory with an accuracy of about ± 3 dB(A) concerning L_{10} or Leq for most situations. Nevertheless some problems remained unsolved particularly regarding stop-and-go traffic conditions in built-up areas due to the following characteristics :

- non linear relationship between vehicle driving parameters (vehicle speed, engine speed...) and noise emitted (sound power level)
- non stationary traffic conditions in time and space
- non homogeneous propagation conditions between sources and receivers
- addition of several noise sources (different streets) in the neighbourhood of crossroads.

In this paper, we shall discuss some recent research work developped at IRT aimed at improving the understanding and computation results concerning urban road traffic noise. This work was firstly implemented with mathematical modelling of urban traffic conditions /1/ and propagation in built-up areas /2, 3/. Since then, further work concerned particularly the noise emission characteristics of road vehicles /4, 5/, and the in-traffic measurements of vehicle kinematics /6, 7/. Most of the material presented - which was developped for Leq values - could be adapted to L_{10} prediction.

Noise emission of road vehicles in urban traffic

We have a good knowledge of today's road traffic vehicle noise emission characteristics. A road vehicle can be satisfactorily regarded as an omnidirectional point source as discussed in /4, 5/ so that measurements of maximum sound pressure level (S.P.L.) value L_m at - for example - 7.5 m from the axis of the passing-by vehicle can give a good approximation of sound power level L_w according to equation (1)

$$L_w = (L_m)_{7.5} + 25.5 \qquad (dB(A)) \quad (1)$$

Such measurements have been widely performed. Operational results are shown on figure 1 : this figure shows the energy mean $(L_m)_{7.5}$ or L_w level for two classes of vehicles (passenger cars (< 3.5 tons) ; lorries (≥ 3.5 tons)) as a function of instantaneous speed, and driving conditions (freely-flowing, stop-and-go, accelerating, or decelerating). It was obtained from about 10,000 measurements and can be considered as fully satisfying for present time in-traffic vehicles in France. Very similar values have been obtained by other authors (for example /8, 9, etc.../). The chart of figure 1 is of current use as input for traffic noise prediction methods ; a correction is allowed for upper speeds (> 70 km/h) as a function of road surface. It is not generally included in urban traffic noise prediction methods, where speed is usually lower than 70 km/h.

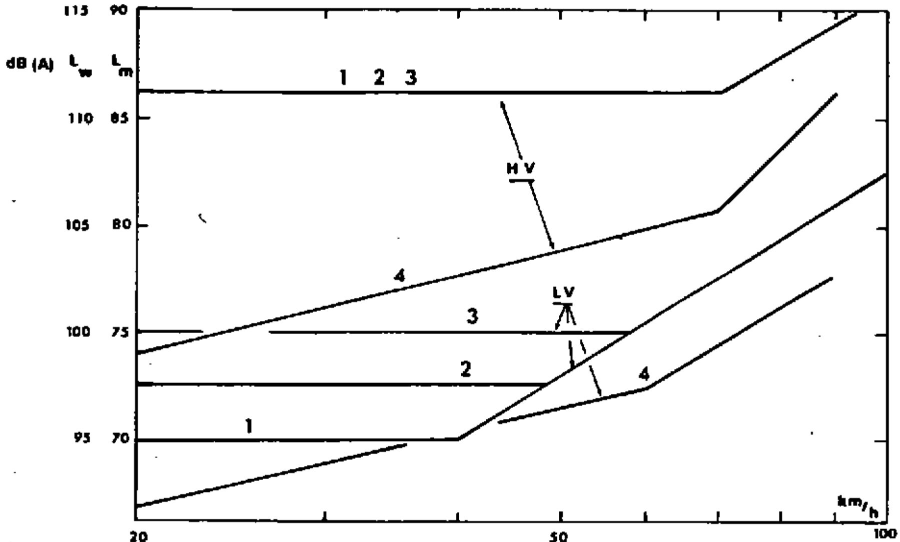

Figure 1 : Road vehicle sound power level (L_w) and sound pressure level at 7.5 m ($(L_m)_{7.5}$) as a function of type of flow, speed and category : freely-flowing on horizontal road (1), stop-and-go (2), accelerating (3), decelerating (4) /10/.

Urban road traffic conditions

They can be assessed from computer programme simulation, in-board measurements from a vehicle inserted into traffic, outside observations. Such surveys show that urban traffic flow can be characterized by (see figure 2) :

- stopping positions (points A)
- freely flowing sections (points B)
- pulsated flow sections with or without a noticeable decelerating then accelerating feature (points C and D).

Therefore we can define sections with a) freely flowing contitions, or b) undetermined pulsated conditions, or c) decelerating then accelerating conditions. These sections can be characterized either by a constant mean speed over the section (a and b), or a varying speed as a function of the distance to the stopping position (c). For this last situation, our surveys have led to a set of graphs giving the speed upstream then downstream the stopping point (figure 3).

From speed and traffic conditions as defined along the road, we can determine the mean vehicle noise emission as presented on figure 1.

Urban noise propagation

Nomogram methods or computer programmes such as BRUIT /2/ are of current use for general built-up areas. Nevertheless, we have developped a particular

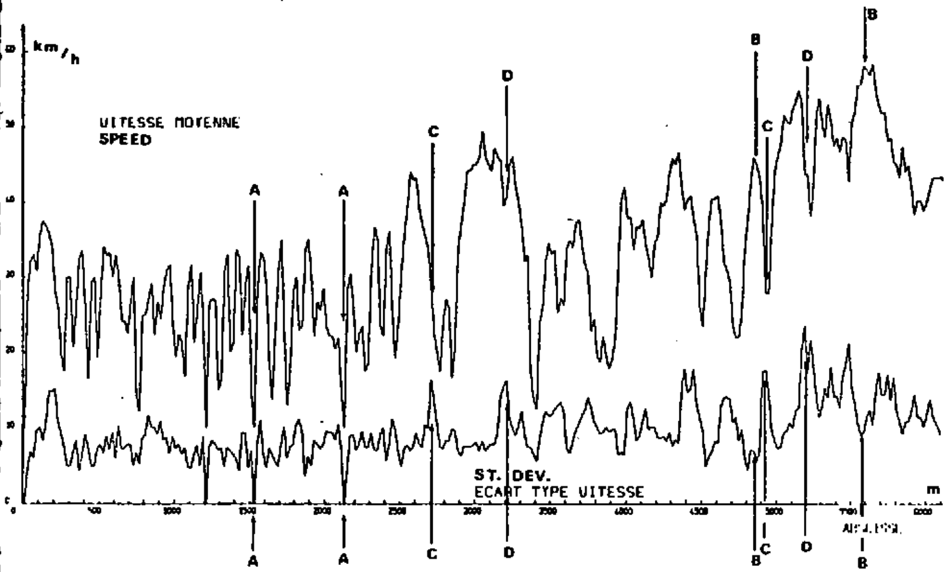

Figure 2 : Urban traffic kinematics along a given itinerary. Mean speed (km/h) and standard deviation (km/h) at every position over a 6 km length. Results obtained from 18 in-board measurements with one vehicle /11/.

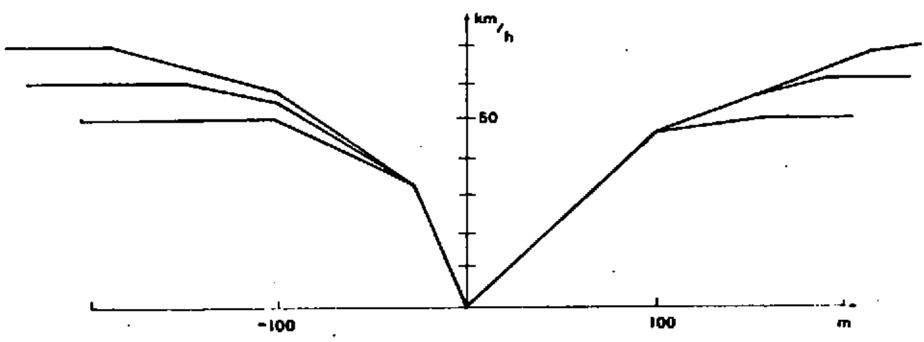

Figure 3 : Upstream then downstream urban traffic mean speed as a function of distance to stopping point, for different asymptotic speeds /10/.

computation method for urban districts made of streets with continuous parallel facades on both sides as shown on figure 4. The algorithm has been optimised for a fast computation and an improved accuracy for this type of network.

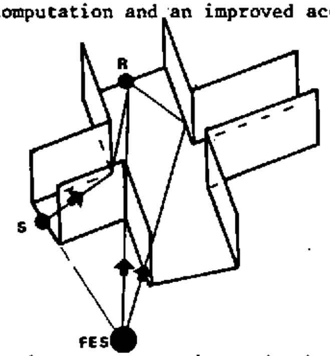

Figure 4 : Computer programme BURTIT
Point source to receiver paths in a cross-roads geometry

It is based on ray-acoustics and takes into account high order reflexions on facades (with Wiener formula, see /12/), diffractions around corners, acoustic intensity loss at cross-roads. One uses a new concept, the "fictitious equivalent source" of n^{th} order (FES) which has the following properties :

- it replaces the infinite set of image sources over order n
- its power is the same as the cumulated power of these image sources
- its position is the barycentre of the image sources, weighted by their respective power.

For instance, for n = 1, the FES replaces the set S_1, $S_2 .... S_\infty$ of image sources on one side of the street. Its power is $W/(1-r)$ and its position is $lr/(1-r)$ from the axis of the street, where W is the power of the real source, r is the reflexion coefficient of the facades (in terms of energy), l the width between the two facades /13/.

The total field of the source is the addition of the direct and image sources (up to n^{th} order) fields, and of the FES field. For example, figure 5 gives the total acoustic field due to S in the transversal street, for different distances of S to the cross-roads, as the combination of direct and FES field (n = 1).

Results

An experimental survey has been done in the LYON area : many measurement positions were defined, either along current sections or near cross-roads (every 50 m from the cross-road, along every road, up to 250 m) ; noise (Leq, L_1 and L_{90}) and traffic measurements (flows, types of vehicles) were done at several times along the year for each position, and form a complete basis for comparisons with computations. In the following results, 340 measurement values were retained in built-up areas with streets and parallel facades.

The computations include :

- a very simple method of current use in France taking into account traffic volume for light vehicles (Q_{LV}) and heavy vehicles (Q_{HV}) , and geometry.

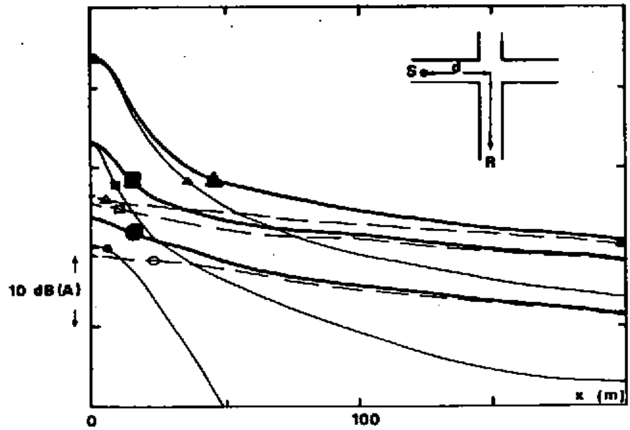

Figure 5 : Variation of S.P.L. with distance along transversal street (the source is in principal street), for several geometries. d = 20 m (▲,△), 60 m (■,□), 200 m (●,○). Dark symbol : real source, light symbol : SF source 1st order.

The formulas are /10/ :

$$(Leq_{facade})_P = 55 + 10 \log (Q_{L.V} + 10\ Q_{H.V}) - 10 \log l \qquad (2)$$

$$(Leq_{facade})_T = Leq_{facade} - 3 - 0{,}1\ x \qquad (3)$$

The value is for a height < 4 m above the ground. l is the width between facades, x is the distance from the cross-roads center (in m). Formula (2) is for the noise in the principal street, formula (3) for the noise in the transversal street, due to traffic in principal street. The computation is done for all the streets in the neighbourhood of the receiver point involved, and values are energy-added.

- a computer method using the noise emission, traffic, and propagation characteristics as discussed before.

The data include the geometry of the network, the absorption by the facades, and the traffic defined as different successive sections of homogeneous characteristics, and stopping positions. One-way streets, green waves, stop marks, bus lanes can then be taken into account. Figure 6 gives an example.

The graphs on figure 7 show the comparison between computed (x axis) and measured (y axis) Leq levels for about 60 receiver positions along the streets, concerning 6 typical cross-roads geometries. The left figure is for formula computation, the right for computer program computation, with traffic under accelerating or decelerating conditions in the main streets. The results are slightly modified with the computer method, which can give improved accuracy

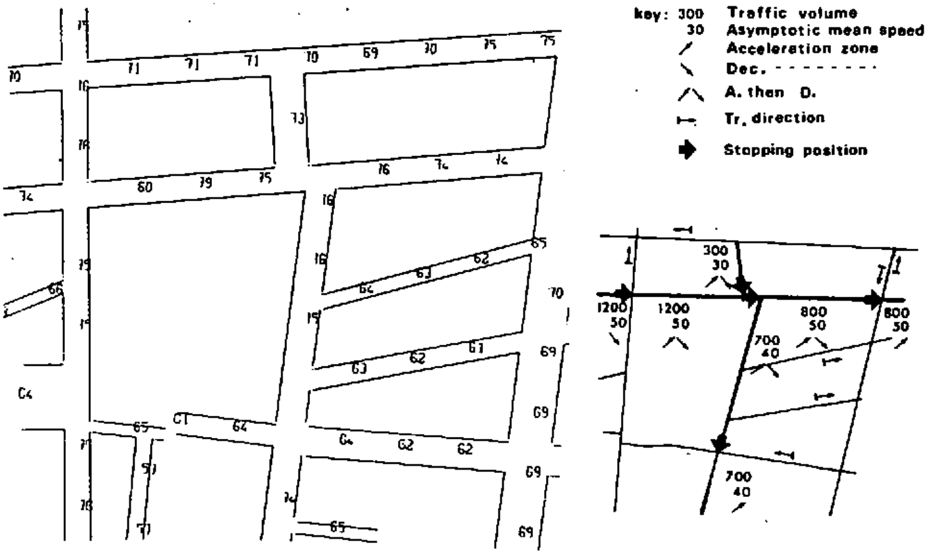

Figure 6 : Example of traffic noise (Leq) computation with computer program BURTIT

when the traffic parameters are correctly assessed. Furthermore, the "traffic lights effect" or "crossroads effect", as discussed in /1/, can be clearly demonstrated.

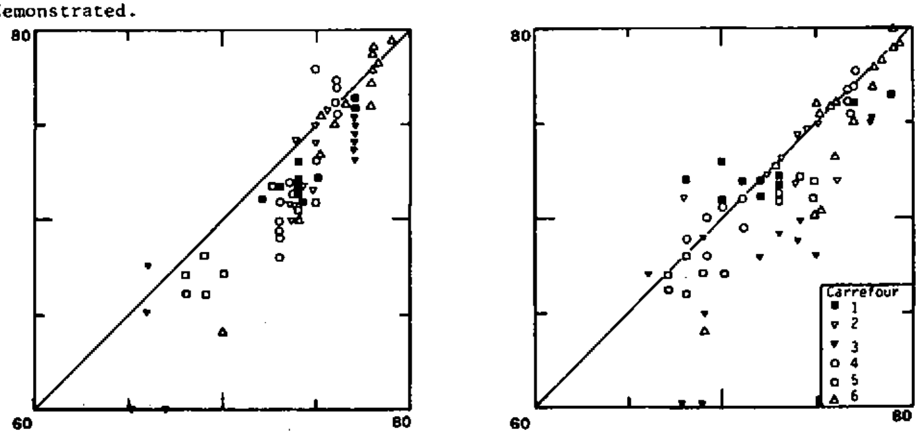

Figure 7 : Comparison between measured and computed Leq_A values for traffic noise under different conditions ; computed (left) from formula, (right) from computer program.

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