inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 1.3

DEFINITION OF A PROPAGATION MODEL OF TRAFFIC NOISE IN SATURATION CONDITIONS

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Keywords:
TRAFFIC, SATURATION

ABSTRACT
This model of propagation here illustrated has been obtained through a regression model in traffic saturation conditions. In traffic saturation conditions the noise level does not follow a logarithmic curve but a quadratic curve in relation to the equivalent number of vehicles. In order to analyze this phenomenon a set of measurements has been carried out in the outskirts of Turin (Italy). The traffic flow has been analyzed at different times of the day, paying special attention to moments of traffic congestion. Two different charts have been drawn up: a logarithmic chart for the first measure points (in situation of normal traffic flow) and a parabolic one for the traffic congestion points. A mathematical function joining the two curves has been found, in order to have a complete description of the phenomenon. The theoretic figures have proved to be basically in accordance with the experimental ones.

1 - ANALYSIS OF NOISE IN CONDITIONS OF TRAFFIC SATURATION

In conditions of traffic saturation the amount of noise does not follow a logarithmic trend but it follows a quadratic trend in relation with the equivalent number of vehicles.
The level of noise created by road traffic strongly depend on the types of vehicles that flows along the road, on the number of vehicles, their speed, the composition of traffic, the road surface and the slope of the road [1].
Studying the course of vehicle speed along a road it is possible to find different types of flows: accelerating and decelerating traffic, smooth flowing traffic, saturated traffic, traffic with vehicles running at a high speed for a certain time and vehicles driving at a slow speed at another time.
We usually have the first condition in places where several stop signs are present, while the second is a normal condition and the third is typical of those roads with a prevalence of commercial vehicles. The last one can be measured along roads having synchronized traffic lights.
We are not going to consider the first and the fourth conditions, as a motorway or a bypass do not have traffic lights or crossroads regulating traffic. When we have a situation of smooth flowing traffic, vehicles do not interact in a significant way and so every vehicle can run at its own speed [2]: however there is a relation between the highest possible speed and the percentage of heavy vehicles: speed slows down when the number of heavy vehicles increase.
When the percentage of heavy vehicles or the volume of traffic increases over a certain level there is the level of saturation of the road and as a consequence the interruption of the flow [3].
In order to analyze this phenomenon a set of measurement has been carried out in the outskirts of Turin (Italy). The traffic flow has been checked at different times of the day, with a particular attention to moments of traffic congestion.
The expected trend for the noise level in relation to the number of vehicles foresees that the noise level reaches its peak with the growing up of the flow of vehicles and then decrease because of the reduction of speed. The peak of noise is not reached in condition of traffic saturation but when there is the *maximum number of vehicle* in transit, which varies according to the type of road examined [4].

The expected logarithmic trend of noise level is not correct when the maximum number of vehicles is reached.
In a situation of traffic congestion, all the regression models give levels of noise which are higher then those measured and so they do not describe exactly a similar condition.
The calculated and measured levels in conditions of traffic saturation are presented in the following table.

Distance [meters]	**Measured Flow in 10 min.**	**Measured Leq [dB(A)]**	**Leq CNR[1] [dB(A)]**	**Diff. CNR**	**Leq OMTC[2] [dB(A)]**	**Diff. OMTC**
18	**877**	**73.2**	**80.2**	**7.0**	**79.3**	**6.1**
18	**943**	**69.7**	**80.0**	**10.3**	**78.1**	**8.4**
18	**888**	**72.8**	**79.6**	**6.8**	**79.2**	**6.4**
68	**847**	**67.9**	**74.0**	**6.1**	**71.8**	**3.9**
68	**943**	**63.8**	**74.3**	**10.5**	**70.1**	**6.3**
68	**814**	**66.3**	**74.5**	**8.2**	**73.5**	**7.2**

	Leq G&L[3] [dB(A)]	**Diff. G&L**	**Leq Burgess [dB(A)]**	**Diff. Burgess**	**Leq our model [dB(A)]**	**Diff. our model**
	76.1	**2.9**	**72.5**	**-0.7**	**69.4**	**-3.8**
	76.2	**6.5**	**72.0**	**2.3**	**65.0**	**-4.7**
	75.9	**3.1**	**71.5**	**-1.3**	**70.5**	**-2.3**
	69.7	**1.8**	**60.8**	**-7.1**	**68.4**	**0.5**
	70.1	**6.3**	**60.9**	**-2.9**	**61.1**	**-2.7**
	69.8	**3.5**	**61.7**	**-4.6**	**63.0**	**-3.3**

Table 1: Comparison between theoretical levels predicted by different regression models in case of traffic saturation ([1] Consiglio Nazionale delle Ricerche (Italy), Cannelli et al., 1983; [2] Ontario Ministry of Transportation and Communications, Canada; [3] Griffiths & Langdon, 1976).

In order to analyze a condition of congested traffic, we have created a new model based on a relation of quadratic type between the noise level and the traffic flow.
In the following pictures we show the diagrams obtained from the two models: the first has been obtained using a logarithmic trend between the number of equivalent vehicles and the sound level, the second supposing a parabolic type relation between the above mentioned variables.

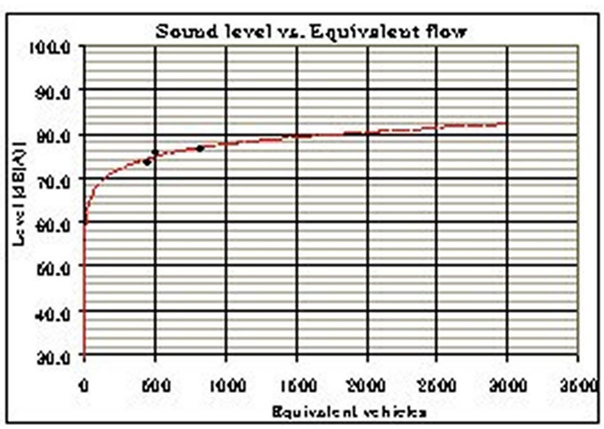

Figure 1: Logarithmic model with measure points.

As far as the first measure points are concerned, the logarithmic type diagram is the most suitable. It can be seen in the second diagram how the quadratic curve actually approximates the experimental values in condition of traffic congestion.
We have thought of looking for a mathematical function which can join the two curves, in order to have a complete description of the phenomenon.
These are our equations:

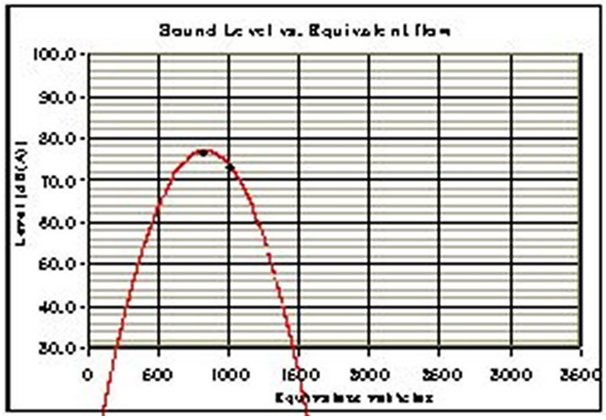

Figure 2: Quadratic model with measure points.

$$\begin{aligned} Y_1 &= \alpha \log_{10} Q + \beta \\ Y_2 &= aQ^2 + bQ + c \end{aligned} \tag{1}$$

When the coefficients of the first and of the second curve are known, we have found, through a numerical analysis, the value of equivalent vehicles Q for which the two equations Y_1 and Y_2 had the same value and the same first derivatives.
Formulating the problem with the following parameters: a=-12E-5, b=0.2, c=-6.14, α=9.34, β=49.25, we have obtained for Q the value of 871 equivalent vehicles in ten minutes. In this way we have obtained the following diagram:

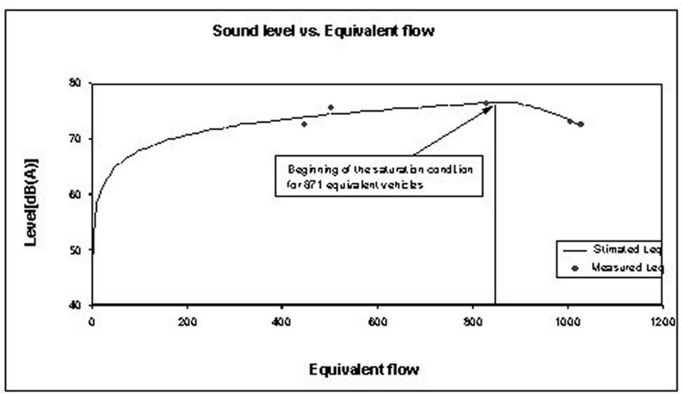

Figure 3: By time trend of the sound level in the stretch of road "Venaria- Corso Regina" (Turin north bypass) in a situation of traffic congestion.

It is clearly evident how, after the condition of saturation, the level starts to diminish.
Beyond the last point, the diagram represented in Fig. 3 has only got a mathematical significance and not physical, as it shows the second part of an equation curve of this type:

$$\begin{cases} Y_1 = (9.34)\log_{10} Q + 49.25 & \text{per } 0 < Q \leq 871 \\ Y_2 = \left(-12E^{-5}\right) Q^2 + (0.2)\, Q + (-6.14) & \text{per } Q > 871 \end{cases} \tag{2}$$

This consideration is pointed out by the fact that, considering the trend of the curve in the diagram, the noise would disappear with the increase of the number of vehicles, a thing that in fact does not happen. Proof of this is the fact that in those measurements done during the period of traffic congestion, the noise level, at a distance of 18 meters, was of about 72 dB(A).
We have noticed that the level of noise is almost unchanging (uniform) as far as vehicles are queuing, and it starts to change again when the vehicles start to flow again.
In the table 2 we sum up the results we have got at the variation of traffic flow, using the above mentioned relation.

It is easy to notice that there is a satisfactory agreement between the theoretical and the experimental values [5].

Equivalent flow (10 min.)	**Measured Leq [dB(A)]**	**Estimated Leq [dB(A)]**	**Difference of Levels**
446	74.0	73.1	0.9
502	74.5	75.6	-1.1
828	76.5	76.3	0.2
828	76.9	76.3	0.6
1007	73.3	73	0.3
1028	72.3	72.8	-0.5

Table 2: Comparison between levels with parabolic model.

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