FISITA 2004
World Automotive Congress
23 - 27 May, Barcelona, Spain

TECHNICAL PAPER FOR STUDENTS AND YOUNG ENGINEERS

- FISITA WORLD AUTOMOTIVE CONGRESS, BARCELONA 2004 -

TITLE:

Experimental determination of noise polution within a singalised intersection

Topic:

○ FUTURE AUTOMOTIVE TECHNOLOGY
○ INTELLIGENT TRANSPORTATION SYSTEMS
○ USER FRIENDLY AUTOMOBILE
○ ADVANCED PRODUCTION AND LOGISTICS
ⓧ VEHICLES & THE ENVIRONMENT

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National Society: ○ YES ⓧ NO

Name of the National Society:

Abstract:

The rapid growth of road traffic flows in the last decade that appeared in transitional countries - like Romania - due to the nowadays' undersized road structure, is translated into the increase in the level of pollutant emissions in general and noise pollution in particular.

The paper presents the experimental research developed as a part of Road Traffic Management laboratory classes. This research is focused on a signalized intersection, for which traffic congestions are often encountered.

Because this type of intersections are usually located within residential areas, the purpose is to identify the level of noise generated by mobile sources and the possibility of reducing noise levels through traffic flow optimization.

Place / Date:

Brasov, Romania / 4th of March, 2004

1. CONTEXT OF EXPERIMENTAL RESEARCH

Current research is focused on Brasov, a central city of Romania. From the geographical point of view, it resides on the passageway that links Transylvania to Bucharest. This positioning has lead to a development of a junction of national/european roads. All heavy/passenger car traffic has to be routed within the city as Brasov has no belt highway, causing a high volume of traffic flow on an undersized city road system.

Unavoidably, all this traffic has to pass residential areas, causing high values of noise pollution with negative impact over inhabitants' health.

Due to bad management of signalized intersections, causing a stop'n'go traffic flow regime, instead of a more smooth green wave, there are encountered high values of noise and chemical pollutants.

Considering the facts presented above, experimental research is focused on a very busy intersection placed nearby the municipal hospital, a highschool and many residential buildings.

2. DEFINITIONS

Sound - is a vibratory disturbance created by a moving or vibrating source, in the pressure and density of a gaseous, liquid medium or in the elastic strain of a solid which is capable of being detected by the hearing organs. Sound may be thought of as mechanical energy of a vibrating object transmitted by pressure waves through a medium to human (or animal) ears. The medium of main concern is air. (3)

Noise - is defined as (airborne) sound that is loud, unpleasant, unexpected or undesired, and may therefore be classified as a more specific group of sounds. Perceptions of sound and noise are highly subjective: one person's music is another's headache. The two terms are often used synonymously, although few would call the sound that emanates from a highway anything but noise. (3)

Frequency of a wave – is referred to as the number of times per second that the wave passes from a period of compression through a period of rarefaction and starts another period of compression. (3)

Threshold of audibility - the point at which sounds are barely detectable. In clinical hearing assessment, normal hearing falls within a range of 0 to 25 dB of the threshold of audibility. (2)

decibel (dB) - One decibel is the amount by which the pressure of a pure sine wave of sound must be varied in order for the change to be detected by the average human ear. The decibel can express an actual level only when comparing with some definite reference level that is assumed to zero dB (see SPL). (5)

SPL (Sound pressure level) - Sound pressures can be measured in units of micro Newtons per square meter ($\mu N/m^2$) called micro Pascals (µPa). The pressure of a very loud sound may be 200,000,000 µPa, or 10,000,000 times the pressure of the weakest audible sound (20 µPa). For this reason, sound pressure levels (SPL) are described in logarithmic units of ratios of actual sound pressures to a reference pressure squared. These units are called bels, named after Alexander G. Bell. In order to provide a finer resolution, a bel is subdivided into 10 decibels (deci or tenth of a bel), abbreviated dB. In its simplest form, sound pressure level in decibels is expressed by the term:

$$SPL = 10 Log_{10} \left(\frac{p_1}{p_0} \right)^2 dB \qquad (2.1)$$

Where:
- p_1 is sound pressure
- p_0 is a reference pressure, standardized as 20 µPa (absolute threshold of hearing in healthy young adults) (3)

A-Weighting - the A-scale approximates the frequency response of the average young ear when listening to most ordinary everyday sounds (figure 2.1). When people make relative judgments of the loudness or annoyance of a sound, their judgments correlate well with the A-scale sound levels of those sounds. Noise levels for traffic noise reports should be reported as dBA. (3)

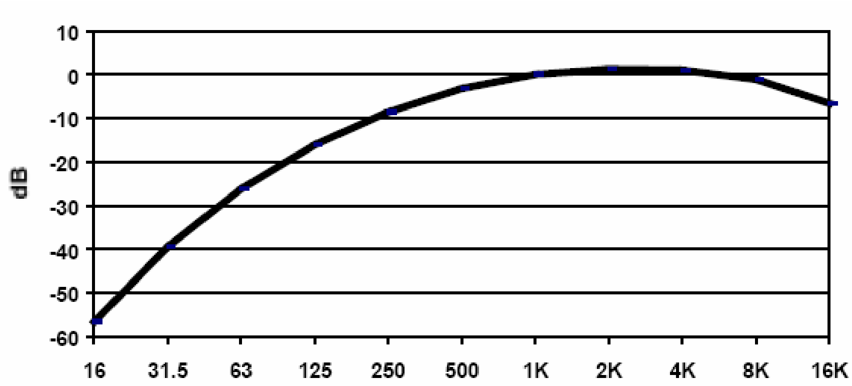

Fig. 2.1 A -Weighting Scale

3. EUROPEAN COUNCIL DIRECTIVES REGARDING NOISE

The EU noise control legislation, regarding motor vehicle category contains two directives. These directives establish the permitted sound levels for vehicles, their exhaust systems and silencers and also the requirements for measurement and testing:

· Council Directive 70/157/EEC of 6 February 1970 introduces limits on sound levels of road vehicles, and specifies procedures for measuring sound levels of exhaust systems and silencers. (Amended by 73/350/EEC, 77/212/EEC, 81/33/EEC, 84/372/EEC, 84/424/EEC, 87/354/EEC, 89/491/ EEC, 92/97/EEC and 96/20/EC). (1)

· Council Directive 97/24/EEC on certain components and characteristics of two or three wheeled motor vehicles of 17 July 1997 establishes limits for the permissible sound level of motorcycles, and requirements for exhaust or intake silencers. The directive also introduces harmonized testing procedures (The Directive replaces 78/1015/EEC of 23 November 1978 amended by 87/56/EEC and 89/235/EEC). (1)

It is necessary to establish the limit of noise level for motor vehicles. This can be accomplished by realizing tests and measurements. It is desirable that all these results to be reflected in the legislation. (1)

There has been an improvement of the Directive by several amendments. These amendments are progressively reducing permissible noise level emission. In the Directive 70/157/EEC, Annex 1 noise emission limit values are established (for eight types of passenger and goods vehicle) from 74 dB (A) to 80 dB (A). (1)

One of the Romanian laws, no. 137 from 1995 art.6 mentions:
“The protection of the environment represents an obligation for local and central public administration and for all persons and companies”, and this sufficient reason to act for minimize noise emissions.

3. NOISE EFFECTS ON HUMAN BODY

3.1. Hearing

Hearing as a human feature is defined as capacity of detecting sounds within the frequency range of 16-20000 Hz. Human hearing usual threshold lays between 0 and 26 dB. (2)

3.2. Noise Acceptance for Residential Areas

Literature specifies a day-night limit value for residential area sound level of 55dB in order to protect inhabitants from work interference, annoyance and fatigue. If the outdoor sound level exceeds 70dB, they are very likely to be severely annoyed and possibly lose their hearing. (2)

3.3. Indoor and Outdoor

Many outdoor noises annoy people more than inside noises do, and a typical reaction is to turn on indoor sources to cover up the outside noises, subjecting them to an even higher level of sound. (2)

3.4 Noise-Induced Permanent Threshold Shift (NIPTS)

NIPTS is a permanent shift in the hearing threshold (a lowering of the sensitivity) of the ears due to exposure to noise. It is not reversible. NIPTS can result from either a single exposure to high intensity impulsive noise such as blasts or explosions, or to longer exposures to lower, but still damaging noise levels. Typically, hearing loss due to noise exposure occurs first at the higher frequencies, particularly around the 4000 Hz level (3000-6000 Hz). For our study this means that we should pay more attention to noise in higher frequency range. (2)

3.5. Maximum Level of Noise Protecting General Population from Damage

Environmental noise to which an individual is exposed to 24 hr a day, 7 days a week, at the level of that person’s ear, should be limited to 75 dB (within margin of safety). However, annoyance and discomfort will appear much sooner. (2)

4. MEASUREMENT DEVICE

The sound measuring equipment used during the experimental research was Quest Technologies' Model 2800 Integrating Sound Level Meter (SLM) presented in fig. 4.1. This device is qualified to measure noise with Type 2 accuracy.

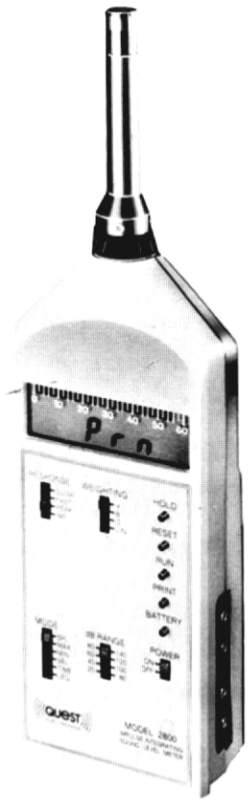

Fig. 4.1. Sound Level Meter

SLM 2800 has the following specifications:

- Standards: ANSI S1.4-1983, Type 2 and relevant sections of IEC 651-1979, Type 2(I) and IEC 804-1985
- Frequency Range: 4 Hz to 50 kHz, limited by the resonant frequency of the microphone, which is 41 kHz
- Minimum measurement: 35 dB
- Maximum measurement: 120 dB (4)

By connecting the SLM Print port to a laptop computer (fig. 4.2), hard copies of measured data may be kept.

4.1. SLM Placement

The sound meter should be placed in a relatively open area to minimize reflections. Placement against a wall or in a corner should be avoided. The microphone must be pointed directly to the noise source. (4)

Fig. 4.2. Sound Level Meter ready to record onsite

5. EXPERIMENTAL DATA

5.1. Experiment Conditions

Experimental research takes into account geometrical, traffic and signalization conditions of the intersection. With the aid of a digital image recording device the quality of progression that described the arrival type of vehicles, was identified.

The measurements were taken at a peak morning hour characterized by low performances of the intersection (maximum delays) and a period of time in the evening with medium traffic. Due to the high number of active population going to their workplaces in the town center from the surrounding neighborhoods, it can be observed that the predominant traffic flow at the peak hour period corresponds to the left 90 degree turn (fig. 5.1). Overlapping the high traffic flow through this road section, there may be observed that the rolling speed is mostly within margins of safety, cars partly losing adherence during cornering. The immediate result is an increased level of noise.

The methodology of recording data follows the standardized recommendations (STAS 6161/3-75)

Noise measurements where made in February 2004, on rainy days. This has some implications in the results obtained, but only up to a certain extent.

5.2. Experiment Measurements

In figure 5.1 you may see the intersection considered in the present study, and traffic flows are symbolized with small arrows through the intersection at the first measurement. Point MP1 represents measuring point one, location from which the first measurement was taken. Measurement direction is oriented towards the traffic flow entering the intersection through the section nearest to the observer.

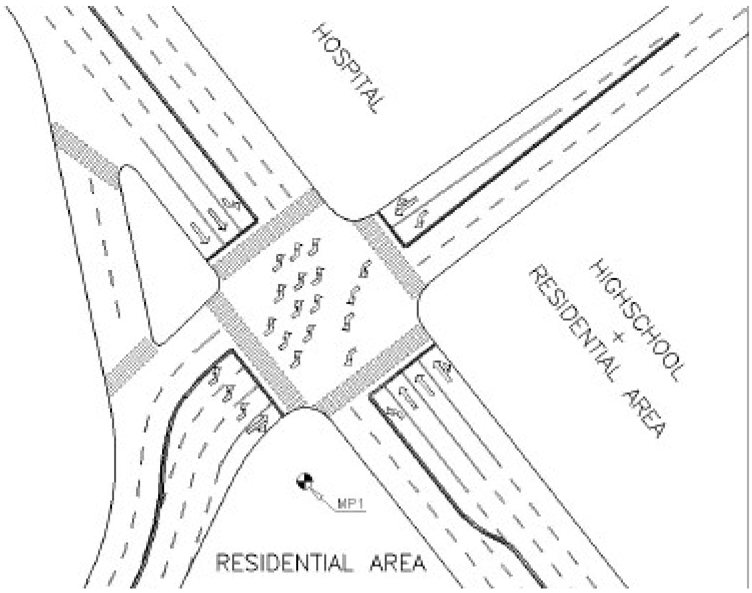

Fig 5.1. Targeted intersection; first traffic flow

The measurements were made at 08.30 AM, and the output of SLM was:

```
QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
 DATE:_______ SERIAL NO. _______ CALIBRATED: __________

   "A" WEIGHTING / FAST RESPONSE
LEQ(dB)   MAX(dB)   MIN(dB)   SEL(dB)    RUN-TIME     OL-TIME
 76.1      82.3      64.3      92.2        :00:41
```

At 09.15 PM in the same MP1:

```
QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
 DATE:_______ SERIAL NO. _______ CALIBRATED: __________

  "A" WEIGHTING / FAST RESPONSE
LEQ(dB)   MAX(dB)   MIN(dB)   SEL(dB)    RUN-TIME     OL-TIME
 63.1      72.6      54.2      83.4        :01:48
```

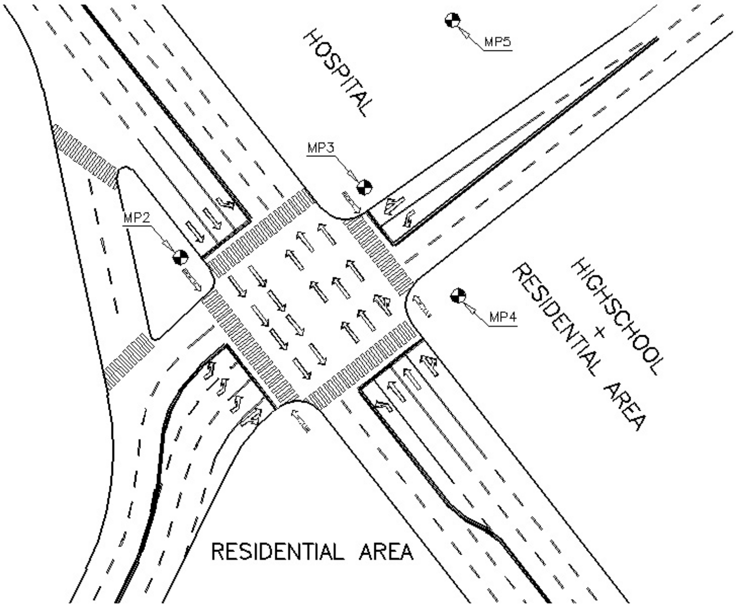

Fig 5.2. Second major traffic flow. Other measuring points

In Figure 5.2 the second major traffic flow is symbolized through small arrows. This traffic flow is measured from MP2, MP3 and MP4, while from MP5 is measured an overall noise level of the whole intersection, due to the relatively high distance (almost 150 m)

Recorded at 08.30 AM in MP2:

```
QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
 DATE:_______ SERIAL NO. _______ CALIBRATED: __________

  "A" WEIGHTING / FAST RESPONSE
LEQ(dB)   MAX(dB)   MIN(dB)   SEL(dB)    RUN-TIME     OL-TIME
 73.4      81.6      62.1      93.5        :01:45
```

At 08.30 AM in MP3:

```
QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
 DATE:_______ SERIAL NO. _______ CALIBRATED: __________

  "A" WEIGHTING / FAST RESPONSE
LEQ(dB)   MAX(dB)   MIN(dB)   SEL(dB)    RUN-TIME     OL-TIME
 73.6      81.2      64.3      94.1        :01:56
```

At 08.30 AM in MP4

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QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
 DATE:_______ SERIAL NO. _______ CALIBRATED: __________

  "A" WEIGHTING / FAST RESPONSE
LEQ(dB)   MAX(dB)   MIN(dB)   SEL(dB)    RUN-TIME     OL-TIME
 63.8      73.7      54.6      81.1        :00:54
```

In order to determine the spectrum of noise emissions, an octave filter was used (of type OB-100 from the same producer as the SLM) which is capable of measuring in 1/1 regime (full octaves). It collected the following data:

At 08.30 AM in MP5 (In front of the Hospital)

QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
DATE:_______ SERIAL NO. _______ CALIBRATED: __________

"A" WEIGHTING / FAST RESPONSE

MODEL OB-100 OCTAVE FILTER SET - SERIAL NO. ______

FREQ(Hz)	LEQ(dB)	MAX(dB)	MIN(dB)	SEL(dB)	RUN-TIME	OL-TIME
31.5	36.3	42.2	30.9	47.2	:00:12	
63	49.9	56.1	44.1	60.8	:00:12	
125	51.0	56.8	47.1	61.8	:00:12	
250	52.4	62.4	43.7	63.3	:00:12	
500	52.5	59.1	47.4	63.3	:00:12	
1,000	53.8	59.8	48.9	64.6	:00:12	
2,000	59.5	63.9	52.7	70.3	:00:12	
4,000	55.5	69.9	45.6	66.3	:00:12	
8,000	48.1	53.4	37.3	52.7	:00:02	
16,000	38.2	44.1	26.1	49.1	:00:12	

For a section of road (SE of the studied intersection) with relatively constant traffic flow:

QUEST MODEL 2800 IMPULSE INTEGRATING SOUND LEVEL METER
DATE:_______ SERIAL NO. _______ CALIBRATED: __________

"A" WEIGHTING / FAST RESPONSE

MODEL OB-100 OCTAVE FILTER SET - SERIAL NO. ______

FREQ(Hz)	LEQ(dB)	MAX(dB)	MIN(dB)	SEL(dB)	RUN-TIME	OL-TIME
31.5	35.5	38.8	28.7	47.1	:00:14	
63	54.7	65.8	42.2	67.9	:00:21	
125	56.2	60.2	49.7	67.9	:00:14	
250	59.5	65.8	52.7	70.3	:00:12	
500	63.5	66.2	59.8	75.1	:00:14	
1,000	72.8	75.6	67.3	82.4	:00:09	
2,000	71.4	76.3	63.9	84.4	:00:19	
4,000	68.3	70.3	65.4	82.7	:00:27	
8,000	65.1	75.6	55.7	79.1	:00:25	
16,000	50.2	57.2	44.1	61.9	:00:14	

A graphical representation of the noise spectrum is given in figure 5.3.

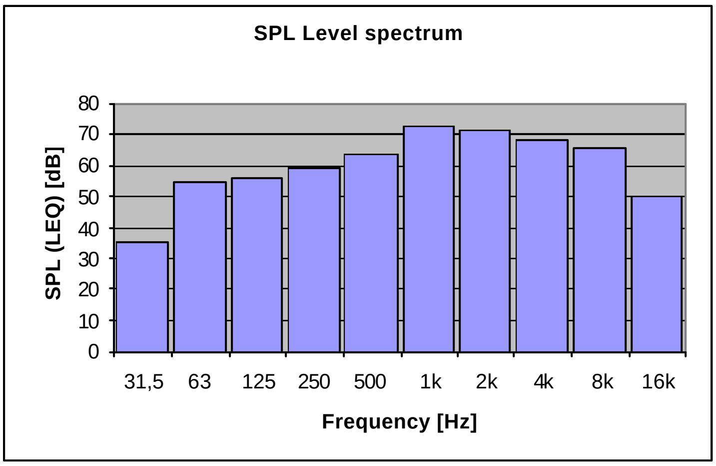

Fig. 5.3. Frequency spectrum

It can be noticed that the noise recorded has the tendency of having higher values for higher frequencies, which is most un-recommended (see chapter 3.4). One explanation for this phenomenon is the rainy weather, but still, the relatively low levels of noise compensate this tendency.

6. ANALYSIS AND CONCLUSIONS

6.1. Fact

a) As it can be observed from the measured data, in general the allowable value (of the noise environment in which a person should live), of 65dB is exceeded. The surplus of decibels disturbs a normal conversation, the sleep and even normal process of thinking. Noise is a main cause in migration of population from the city to the rural areas.
b) First traffic flow, presented in figure 5.1, is produced mainly by local/daily migration of workers to their workplaces
c) Traffic flow presented in figure 5.2 is mostly generated by passenger cars traveling through Brasov going to or coming from Predeal mountain passage. Fortunately, heavy traffic is not allowed in this area, being rerouted through another set of streets (Saturn street), also within Brasov.
d) Higher values of noise where obtained for higher values of frequency (fig.5.3)

6.2 Solution

In order to reduce the number of vehicles that this intersection has to serve, the authors propose two simple solutions:
- To avoid an increased traffic flow in the morning it can be useful to have different starting hours for schools and other companies.
- To re-route "outside" traffic through a belt highway around the city, which would also greatly reduce heavy traffic through other sites in Brasov.

The explanation for the higher values of noise for higher frequencies is that wet pavement produces an increase in tire noise and a corresponding increase in frequencies of noise at the source. On the other hand, traffic generally slows down on rain (or snow), decreasing noise levels and lowering frequencies. When wet, different pavement types interact differently with tires than when they are dry.
In general, to reduce the level of noise emissions caused by the urban traffic, it is necessary to apply a series of actions which refers to noise sources, transmission path (by modifying the type of noise propagation), receiver environment and public transport.

References

(1) European Commission (DG ENV) and the Phare- funded DISAE program, "Handbook on the Implementation of EU Environmental Legislation"
(2) Office of the Scientific Assistant Office of Noise Abatement and Control U.S. Environmental Protection Agency, "Noise Effects Handbook"
(3) Hendriks, Rudy, "A Technical Supplement to the Traffic Noise Analysis Protocol"
(4) Quest Technologies, "Sound Level Meter"
(5) www.yung-li.com.tw/EN/info/Glossary_list.htm, "Definition of decibel"