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ANNOYANCE DUE TO COMBINED NOISE SOURCES

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ABSTRACT
The development of double infrastructures, a motorway and a high speed railway line for example, leads to an increasing number of residents exposed simultaneously to several noise sources, each one having its own characteristics and effects. However, nowadays, this kind of situation can't be precisely qualified in terms of annoyance. The objective of the present study is on the one hand to determine the effects of combined noise sources on the overall annoyance perceived by residents and in the other hand to study potential particular effects, such as for example synergetic effects from two different noise sources. The results show that a dose response curve, when assessed for one single source (road or railway) should take into account exposure to other sources.

1 - INTRODUCTION

When someone is exposed simultaneously to several noise sources, does he perceive the annoyance due to each noise source exactly as he would do if he was exposed to only one source after an other? How does he integrate the proper annoyances due to each source of noise in an overall annoyance? Exposure to combined or mixed noise sources as it is defined in this study only concerns situations in which residents are exposed to two different noise sources. This study focused on two particular traffic noise sources: road traffic noise and rail traffic noise. The first one is often continuous, with no high peak levels but persistent; the second is periodic with relatively high peak levels.

2 - METHODOLOGY

2.1 - Overall survey design

The survey took place during Autumn 1997. 62 sites were selected all over France. Criteria used for the site selection were as follows (Table 1).

Type of infrastructure	Motorway, highway, railway
Type of area	Rural, sub-urban (no site in urban area)
Traffic volume (V)	road traffic between 2 500 to 100 000 per 24h railway traffic between 66 to 200 trains per 24h
Traffic types	road traffic: large range of lorries % railway: high speed lines, mixed lines (freight and passenger)
Localisation of buildings/road − railway	between − same side

Table 1: Criteria for the site selection.

2.2 - Social survey sample
700 residents have been interviewed (52 % male - 48 % female). The distribution of ages is similar to the French one, 79% of the residents are living in individual houses.

2.3 - Social survey data collection
Face-to-face interviews were conducted at home. The length of the questionnaire was about 30 minutes. It was organised around 51 questions which deal with 3 topic areas:

- the historical part explaining their experience linked to their exposure to noise
- the description and the perception of the current environment
- their annoyance (global, activities disturbed, behavioural patterns) related to the different noise sources, separately, globally and according to different periods (day − evening − night).

The questionnaire included also 20 questions about the characteristics of the residents interviewed (age − gender...) and of the dwellings where they lived (type of windows...).

2.4 - Assessment of noise exposure
Measurements of L_{Aeq} (1 sec) were carried out, and most of them on 24 hours. Per site, at least two measurements were necessary to characterise the site on an acoustical point of view. This would help then to realise calculations with the software MITHRA-FER which is a complete calculation prediction model including parameters for emission and propagation.
Four periods have been considered for all the calculations: day (6h-19h), evening (19h-22h), night (22h-6h) and 24h. As well for the noise measurements as for the calculations, reception points are situated 2 meters in front of the facade and two meters from the ground.
For the following periods: day, evening and over 24h, results taken into account are the ones on the most exposed facade whereas for night period the facade of the bedroom is also considered.

3 - RESULTS
A general question at the beginning of the questionnaire was: Is there anything in your environment which you dislike and you would like to change in priority? 61% of the subjects answered: the noise of the infrastructure (road or railway). Nevertheless, considering the whole sample (i.e. without noise level classes considerations), 70% of the people declare being not at all or little annoyed by any of the two noise sources and 60% by the global noise.
We will first present an assessment of this annoyance depending on noise levels, then we will compare certain parameters of the two noise sources and finally a comparison of annoyance related to different periods will be exposed.

3.1 - Assessment of dose/response relations
The sample distribution (fig. 1) shows several exposure situations, we can assume that all the interviewed people are exposed to both noise sources but some are exposed to a dominant source and some to both sources at about similar levels.
For the 24h period which is presented here, sample sizes are the following: railway dominant: 126; road dominant: 282; no dominance: 256.
The objective here is to compare the evolution of annoyance responses in each kind of exposure situation. Within this study we considered three to five types of exposure situation according to the statistical analyses carried out. For the dose/response assessment, only three were considered to preserve large enough sub-populations: " railway dominant " (5dB(A) more than road), " road dominant " (5dB(A) more than railway), " no dominance " (difference inferior to 5dB(A)). The relation calculated on the whole sample is also represented.
Concerning the annoyance response, we took into account responses of the following question: " thinking about the 12 last months, which note would you give to the annoyance perceived inside your home due to road (railway) traffic noise for the following periods (day/evening/night/24h)? 0 *is not at all annoyed*-10 *is extremely annoyed*. A person was considered " quite or highly annoyed " if she gave a note superior to 5 on this 11 point scale.
Dose/response relations were achieved by logistic regression for each sub-population. Thus, what we assess is the probability of being, what we called, " quite or highly annoyed " according to noise levels.
Rappel of the logistic function:

$$F(x) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x)}} \quad (1)$$

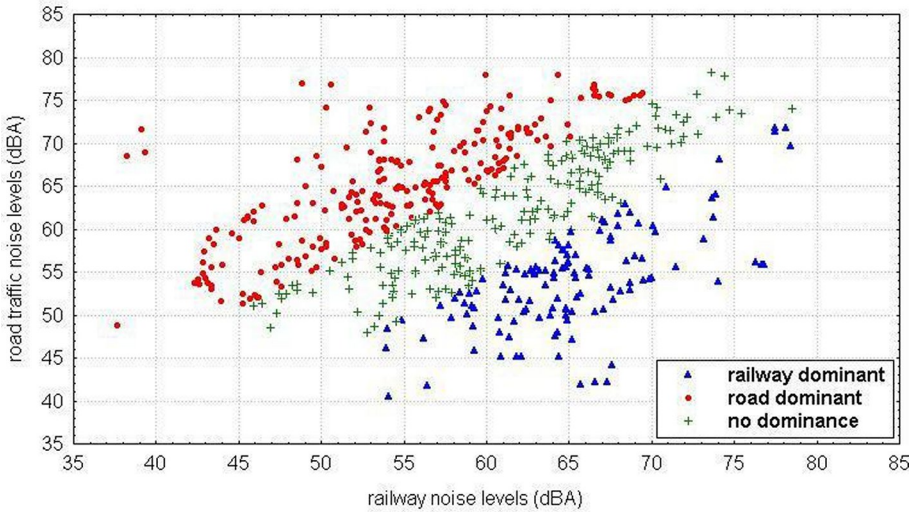

Figure 1: Noise exposure of the sample on 24h.

Each of the two following graphs is dedicated to one proper source and allows the comparison of the annoyance of this single source assessed for each of the three sub-populations described above and for the whole sample. The results are presented for the 24h period.
The reported dose/response relations are significant at 5 % and the confidence limits are in average within +/-0.07, which is quite large and only permit us to interpret tendencies.
The figures presented above show that annoyance allocated to one source depends on whether this source is alone or if the person is also exposed to an other source and in what proportion. When comparing fig. 2 and fig. 3, we can assume the following points:

- Whatever the annoyance considered is, the behaviour is dependent on the sub-population studied. Thus, the " railway dominant " sub-population always declare inferior annoyances than the " road dominant " or the " no dominance " sub-populations.
- The no dominance sub-population always express the highest annoyance for high noise levels (superior to 60 or 65 depending on the annoyance considered).

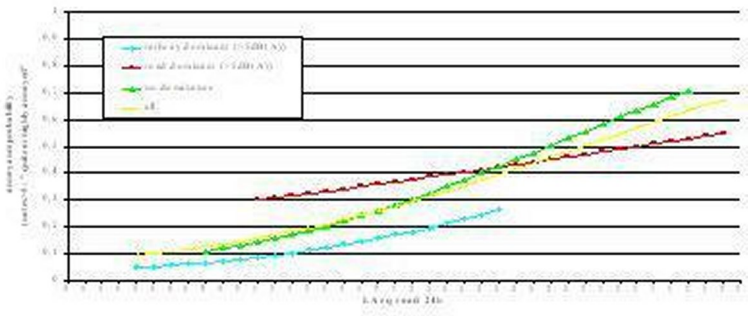

Figure 2: Annoyance due to road traffic noise on the 24h period.

We can thus assume the existence of interactions between noise sources in the annoyance expression relative to each source. This has to be completed with further analysis of the global annoyance in the different exposure situations considered here.

3.2 - Comparison of road and railway noise

Different types of questions were used in the survey, some of them allow sources comparison being made directly by the subject and not afterward by the researcher.
Considering first of all questions linked to noise sources characteristics, the results are the following: without considering noise levels, the noise from the railway traffic appears to be " intermittent ", " quite

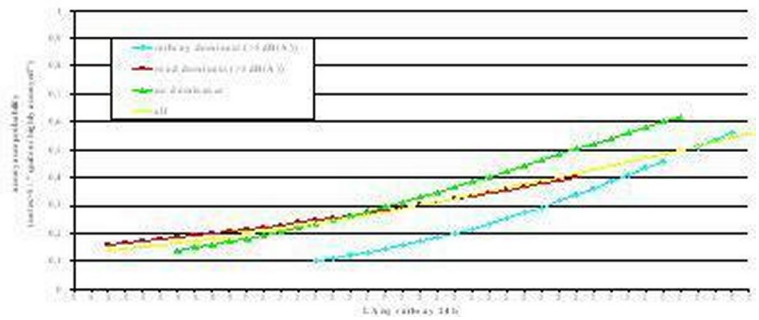

Figure 3: Annoyance due to railway traffic noise on the 24h period.

surprising " and " more acceptable " than road traffic noise. The road traffic noise is " permanent ", more " low pitched " than railway noise and " predictable ".
The item " I forget road traffic noise " evolves with the road noise levels and above 60 dB(A), about 40% " quite or totally agree " with it, whereas the item " I forget railway noise " is independent of the noise level and about 70% of the subject " quite or totally agree " with it.
The following figures 4, 5, 6 and 7 show results of question allowing direct comparison by the resident, results are represented relatively to exposure situations. In this case, 5 different exposure situations are considered: drailway 2 (railway strongly dominant, that is 10 dB(A) more than road), drailway 1 (railway dominant, that is 5 to 10 dB(A) more than road), no dominance (difference inferior to 5 dB(A)), droad 1 (road dominant, that is 5 to 10dB(A) more than railway) and droad 2 (road strongly dominant, that is 10 dB(A) more than railway). The relations between variables and exposure situations presented below have all been tested with a chi2 test and are all significant at 5%.
Figure 4 shows higher percentages of people agreeing with the proposal " What is unbearable is the mix of two different noise sources " for the categories: " no dominance " and " droad 1 " which are situations in which we can assume that the pauses between two trains are filled in with road traffic noise.

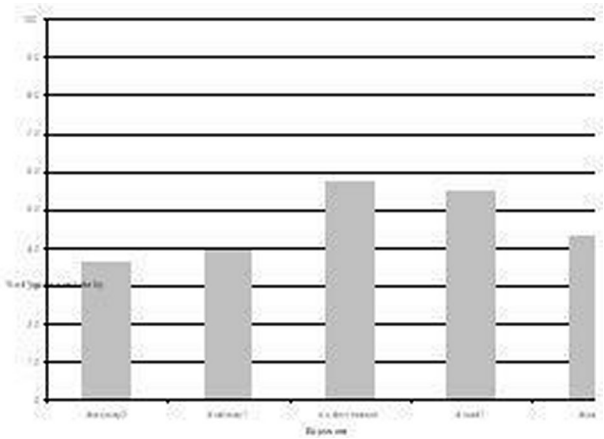

Figure 4: What is unbearable is the mix of two different noise sources.

Figure 5 gives an advantage to the rail as 60% of the subjects of the higher railway dominant situation (drailway 2) think that the railway noise alone would be totally bearable compared to 30% of the people who are in the higher road dominant situation (droad 2). The same tendency appears in figure 6 as in the higher railway dominant situation, 30% don't agree with the proposal and still think that railway noise isn't louder whereas the higher road dominant situation in which 15% think that the road is not louder even if the noise is more than 10 dB superior.
The last figure (fig. 7) shows the results of a scenario which was suggested to the people interviewed, we asked them to try to imagine different situation and one of them was to choose between the two following proposals: suggestion 1- " the railway traffic has doubled and the road has been covered and you don't hear anything left coming from the road traffic "; suggestion 2-" the road traffic has doubled and the railway line has been buried and you don't here anything left coming from the railway traffic ". This scenario gives some preference to railway as in a " no dominance " situation they prefer a scenario in

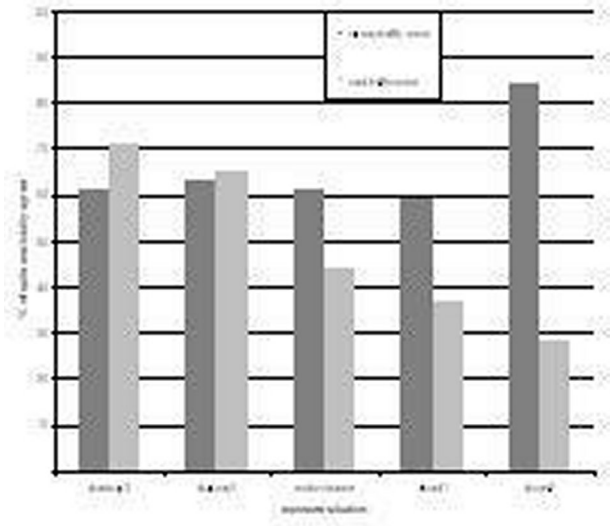

Figure 5: Road/railway noise alone would be totally bearable.

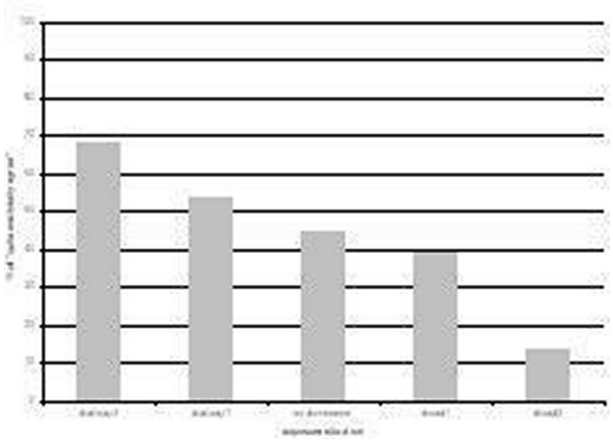

Figure 6: Railway traffic is louder than road traffic noise.

which the traffic would double and road traffic noise would be cancelled and since even nearly 50% in the a railway dominant situation (drailway 1) also prefer to increase the railway traffic.

3.3 - Comparison of global expressed annoyance for different periods

As explained in paragraph 1, we asked people to give annoyance's notes on a " zero to ten " scale for each single source and considering the two sources together on one hand but we also asked the same for the periods of the day, the evening, the night and on 24h. Logistic regression curves obtained on the whole sample and for the global annoyance are presented below.

For all the curves reported here, dose/response relations are significant at 5 % and the confidence limits are in average within +/-0.1, which is quite large and only permit us to interpret tendencies.

On figure 8, we see that curves related to 24h, day and evening periods are similar whereas the night dose/response is lower than the others and is not increasing a lot with noise levels. This is not in line with the assumption made for the LDEN evening and night penalties.

For noise levels superior to 60 dB(A), the LDEN curve is approximately parallel to the day curve but moved forward of about 5 dB(A), which suggests that LDEN limits should be increased compared to day ones.

The following graphs (fig. 9 and fig. 10) present responses to night period disturbances calculated on the whole sample.

For railway noise, the proportion of "quite often or always" is not dependent of the noise level, whereas, for road traffic noise, significant tests show that when noise level increases, people are more disturbed during their sleep. Whatever the night time perturbation is, the percentages of "quite often or always"

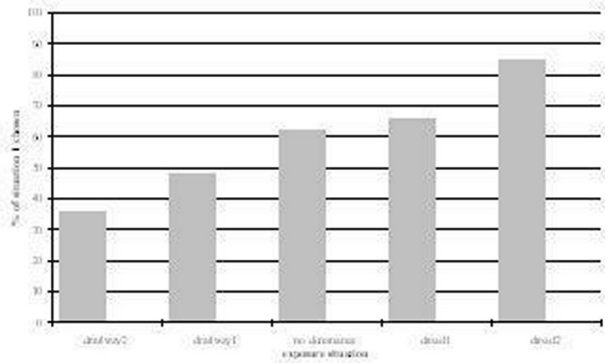

Figure 7: SCENARIO (Situation 1: railway traffic doubled, road traffic cancelled).

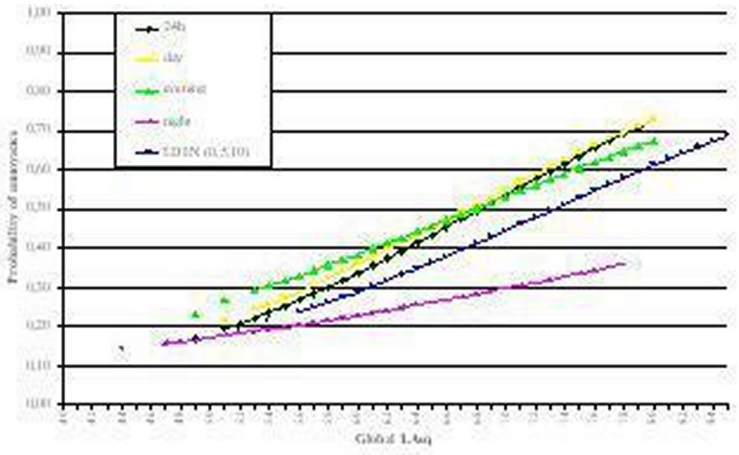

Figure 8: Global annoyance declared for different periods.

are extremely low and stay below 30% even for high noise levels for road and below 15% for railway.

4 - CONCLUSIONS

Dose/response curves presented in this paper show the existence of interactions between road and railway noise sources. This leads to suggest the assessment of several dose/response curves allocated to one particular source according to exposure to other sources. This has to be cleared up by studying the modelling of global annoyance. The road/railway comparison made directly by the residents express less annoyance to railway noise. Then, night annoyance assessed from the residents answers is really lower than annoyances relative to other periods which looks contradictory to the assumptions made for the LDEN (evening and night penalties).

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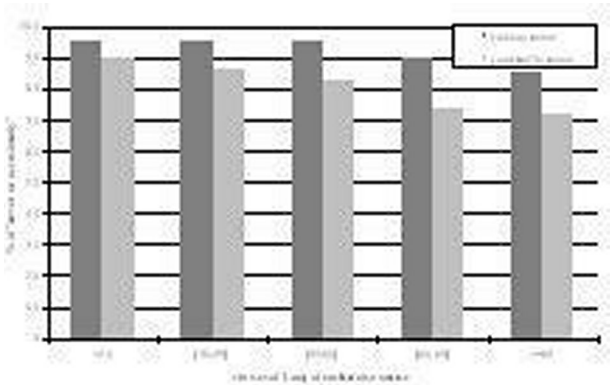

Figure 9: The noise of ... prevents me from sleeping.

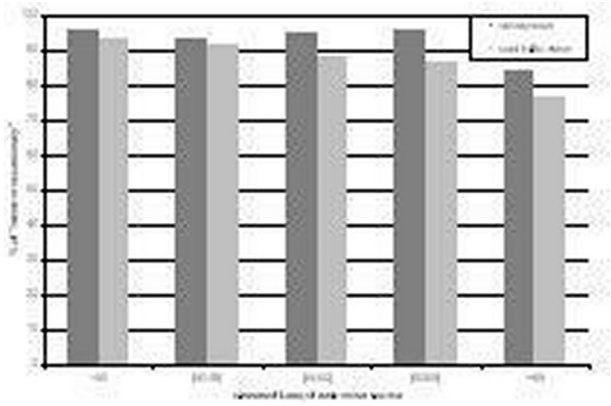

Figure 10: The noise of ... wakes me up during the night.