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## Sound exposure of a pedestrian going through an urban boulevard

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### Abstract

Exposure to noise may constitute a health risk examined in epidemiologic studies. Indeed, we do not get used to noise but cumulate its effects. Furthermore, noise with highly variable levels increases the negative impacts. In urban areas, such situations are common due to traffic dynamics.

On the other hand, in operational studies, one has typically to estimate the noise level at the building frontage, in application of French environmental noise regulation. In this work, we would like to adopt another point of view. We want to focus on the noise exposure of pedestrians during their displacements in urban areas, rather than the exposure of people when they are inside a building.

The case study is a section of an urban boulevard with six traffic lights. The method developed in this work relies on a predefined set of receivers and the calculation of the dynamic noise levels at such locations. We can then assess the whole exposure of the pedestrian during his route. Several routes have been analyzed and characterized using traditional and dynamical indicators.

*Keywords:* noise exposure, pedestrian, annoyance, health risks, dynamic noise assessment, urban environment, traffic dynamics

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### Résumé

L'exposition au bruit a une incidence sur la santé des individus, telles que le démontrent les études épidémiologistes. En milieu urbain, la situation est d'autant plus critique que la dynamique du trafic routier y impose de fortes variations des niveaux sonores auxquelles nous sommes sensibles et des niveaux sonores élevés pour lesquels nous cumulons les effets négatifs au cours de la journée.

D'autre part, les études d'impact réglementaires cherchent à estimer les niveaux sonores en façade des bâtiments afin de limiter l'exposition de leurs occupants, mais ne se préoccupent pas de l'exposition des piétons.

La méthode décrite dans cet article permet de déterminer la dose de bruit perçue par un piéton parcourant un boulevard urbain à partir d'une simulation dynamique couplée trafic – bruit, en s'appuyant sur un maillage de récepteurs prédéfini. Les résultats analysés nous permettent de caractériser l'exposition des piétons en fonction de leur trajet à l'aide d'indicateurs traditionnels et dynamiques.

*Mots-clé :* exposition au bruit, piéton, gêne, évaluation dynamique, milieu urbain

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## 1. Introduction

### 1.1. Noise exposure

Noise exposure may constitute a health risk as for instance hypertension or heart diseases. These health effects have been examined in epidemiologic studies (Passchier-Vermeer, 2000). The exposure settings are quite diverse, but a common environmental noise source is traffic. This is the reason why annoyance due to traffic noise is one of the major concerns of French people when it comes to their quality of life (INSEE, 2002). Moreover the health risk depends not only on sound pressure levels but also on the duration of the exposure. Indeed, we do not get used to noise but cumulate its effects. Thus annoyance is related to sound pressure levels, but also to the cumulated noise exposure. Furthermore, noise with highly variable levels increases the negative impacts. In urban areas, such situations are common due to traffic dynamics.

### 1.2. Proof of concept

The relation between traffic dynamics and dynamical noise levels was studied in (Leclercq and al., 2008). The modelling chain coupling (i) a dynamic traffic simulator Symuvia<sup>2</sup>, (ii) noise emission laws (Lelong and al., 2003) and (iii) the geometrical propagation model NMPB-routes-96 implemented in (Mithra, 2002), has been validated by a measure campaign in an urban boulevard (Lafayette, Lyon, France). Noise levels in buildings' frontage, as required by noise regulations for day and night periods, were dynamically assessed at each time step (1s).

Nevertheless, these indicators are describing the situation at one place. The focus of the study was to know if the same simulation could also describe the exposure of a mobile receptor. Indeed, as we said before, pedestrians in urban areas are quite exposed to annoyance due to noise.

We will present the method proposed to assess the whole exposure of the pedestrian during his route, from a predefined set of receivers and the calculation of the dynamic noise levels at such locations (the time evolution of the short-term sound level  $L_{Aeq,1s}$ ). One can assume that the sound exposure of the pedestrian can be assessed using the sound level of the nearest receptor.

For this, at each time step  $t_i$  (usually 1s), the following steps have to be achieved:

- (i) Searching the nearest receiver from pedestrian's position  $X_i$  using a nearest neighbour algorithm:  $R_{X_i}$ ,
- (ii) Extracting the sound level  $L_{Aeq,1s}(R_{X_i}, t_i)$ ,
- (iii) Assigning this sound level to the pedestrian exposure.

Then we will show the results in the urban boulevard we studied.

## 2. Method

### 2.1. Nearest neighbor and sound level associated

As exposed in the introduction, in order to assess the pedestrian exposure, we have to lean on the information we have, which is the dynamic noise level ( $L_{Aeq,1s}$  at each second) in buildings' frontage. In operational conditions, these receivers are placed 2 meters in front of each floor of the buildings, as imposed by French acoustic regulation. Consequently we make the following approximation: at every time step, the pedestrian is exposed to the sound level of the nearest receiver.

The first step of the method consists in looking for the nearest neighbor of the pedestrian's position. For this search, we used a nearest neighbor algorithm developed by Cao (1997), which gives good results in very short time.

We have then to pick up the appropriate sound level in the simulation results, in parsing the xml file, which contains at each second the sound level at each receiver.

### 2.2. Pedestrian exposure

Pedestrian exposure is defined as the sum of the levels to which the pedestrians are exposed through their route. Noise dose  $D$  was then computed using the following formula:

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<sup>2</sup> Symuvia is a dynamic traffic simulation tool jointly developed by IFSTTAR-ENTPE



$$D(T) = 10 \log [(1/T) T_n 10^{(L_n/10)}] \quad (1)$$

with

$T$  : total duration of the route (s)

$T_n$  : duration of the period  $n$  (in our case each period is 1s long)

$L_n$  :  $L_{Aeq}$  of the period  $n$  (dB(A))

### 3. Case study

#### 3.1. Dynamic noise simulation of the urban boulevard

The study concerns a section of an urban boulevard with six traffic lights and some bus lanes in both directions. The coupled simulation was produced in (Can and al., 2008a). This site has been described by 335 acoustic sources and 731 receivers (ground floor and in front of each building), as shown in fig.1(b).

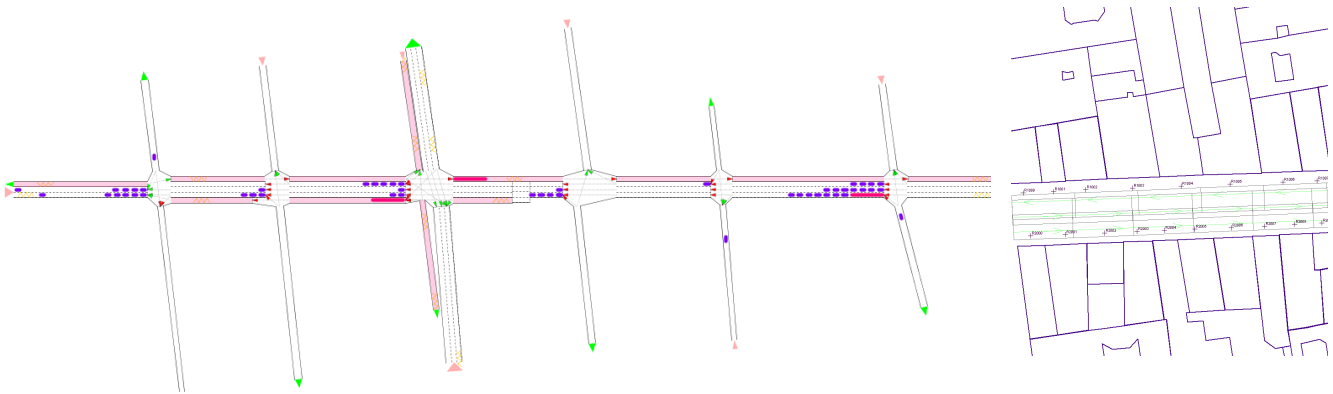


Fig. 1 Dynamic coupled simulation: (a) the traffic simulation in Symuvia (b) sources and receivers in Mithra

#### 3.2. Pedestrian trajectory

In this study, the pedestrian trajectory was quite simply simulated with the traffic model, as if it were a vehicle. However we had some constraints: (i) the mean speed is 1m/s (ii) the pedestrian walks on the pavement observing the traffic lights. As for the vehicles, the pedestrian position is estimated each second.

His route duration is approximately 10 minutes from one side of the zone to another. Different trips were simulated (same route; different beginning times). However, the sources do not change much, therefore pedestrian exposure during a mean time route is quite the same. This would probably not be the case in a larger zone, where various circulation conditions could appear.

### 4. Results

The results we obtained when we exploited the simulation on the urban boulevard allow us (i) to analyze the results, and (ii) to see the feasibility and the limits of this method.

#### 4.1. Fixed vs. mobile receiver

We first analyzed the results comparing the exposure of a pedestrian walking through the simulated zone and the exposure at one fixed point. We compared this exposure to two different receivers: (i) receiver n°495 situated near a bus station and (ii) receiver n°700 in a quieter zone, during the same period  $T$ .

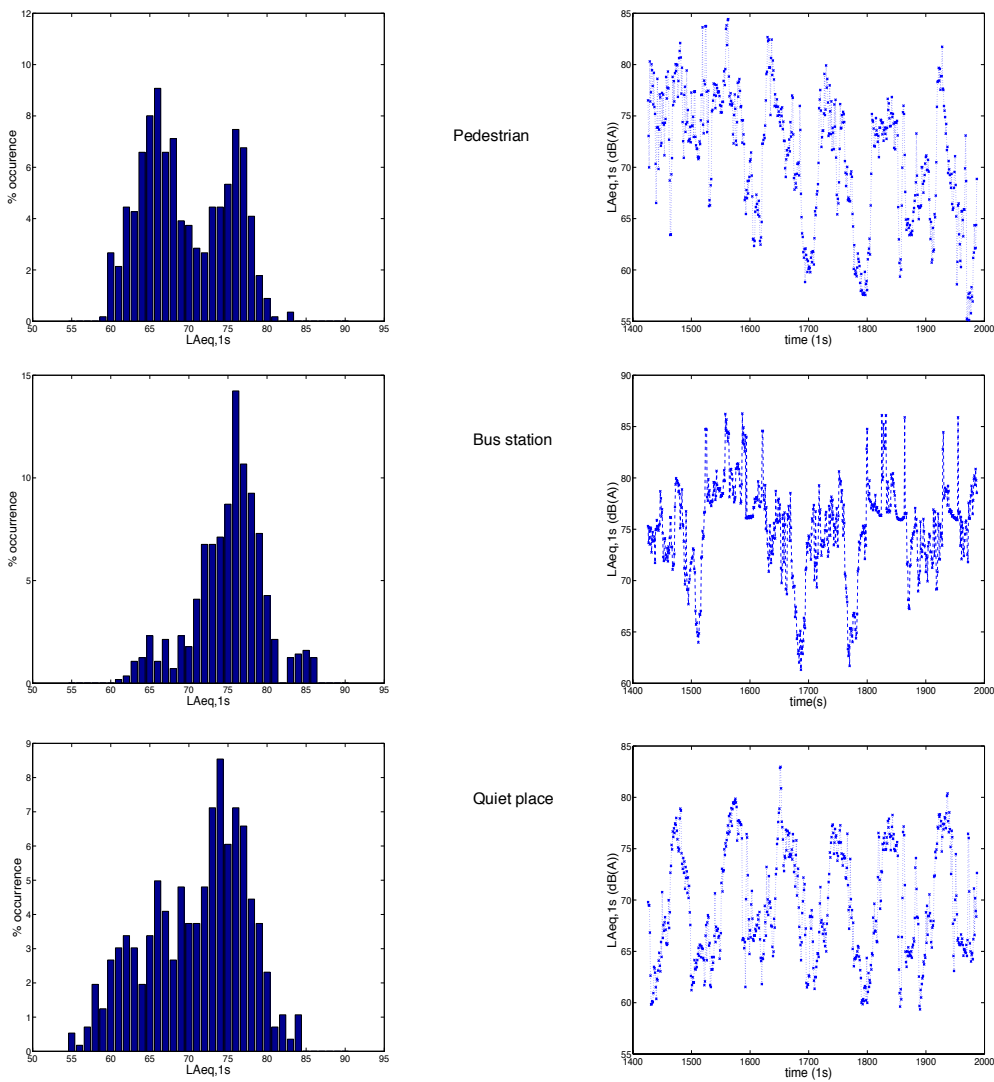


Fig. 2 Comparison between a pedestrian, a fixed point near a bus station and a quieter place (a) distribution of noise levels (b) noise levels time series

In each case, the noise levels are contained between 55 and 85dB(A), with numerous emergences due to the important traffic and the geometry of the site. However the distributions of  $L_{Aeq,1s}$  already announce that the nature of the exposure is different.

The other indicators used to compare these three sound exposures are explicitly given in table 1. The traditional indicators (equivalent noise level and statistical indicators) seem to show that the mobile receiver is a kind of mean situation between the two contrasted situations (R495 and R700). The interpretation is somewhat different if we look at the dynamical noise indicators that were defined in (Can and al., 2008b). The quietness and loudness are especially adapted in urban noise characterized by the rhythm of the traffic lights cycles. These criteria conduct us to qualify differently the pedestrian exposure  $D(T)$ : during 4% of the route time the pedestrian is confronted to “calm” situations, which is not the case in a fixed point in the site.



Table 1. Comparison of the pedestrian exposure PE and the receivers sound levels

	$L_{Aeq,T}$	L1	L90	Quietness <sup>3</sup> (%)	Loudness <sup>4</sup> (%)
D(T)	75	84	61	4	51
R495	77	86	68	0	71
R700	73	80	62	1	35

#### 4.2. Limits

After having analyzed the results obtained for various pedestrian's routes, we can conclude that the main sources can be identified. For instance, the emergences that result from the buses passing near the pedestrian or across the street are well reproduced.

However we can admit that the simulation could be improved. The number of receivers can probably be augmented without affecting the time calculation. Indeed in our case study, the distance between the pedestrian's position and the nearest receiver can be at most 20 meters. This is particularly due to the fact that there is (i) only one receiver for each building, no matter how big it is and (ii) no receiver in the crossroads. This lack of receivers can produce some anomaly: the presence of two emergences for only one bus passing near the pedestrian crossing the street.

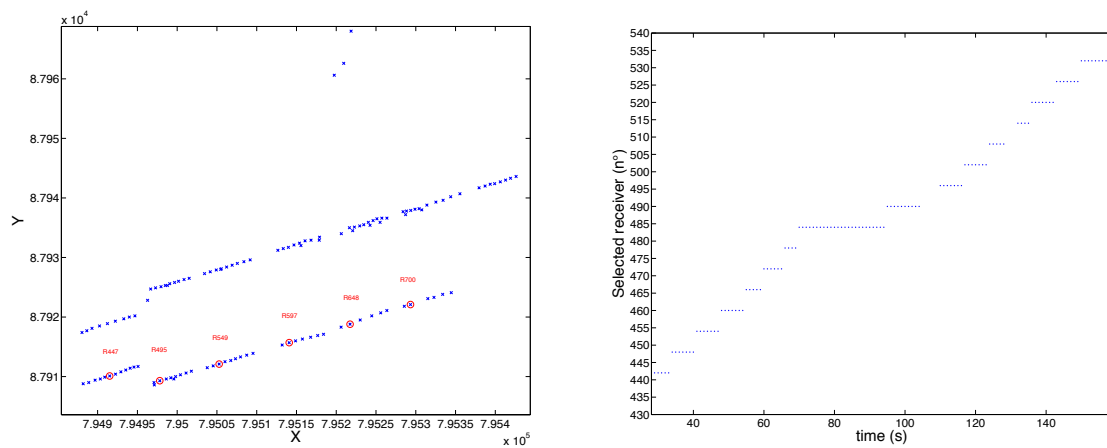


Fig. 3 (a) Position of the receivers (b) Example of selected receivers

### 5. Conclusion

The method described in this article gives the opportunity to assess the pedestrian exposure from a coupled dynamic simulation « traffic-noise » determined in only some locations in the site (positioned in regard to the French acoustic regulation).

We showed that it is worth looking at the pedestrian exposure because it has other characteristics than exposure in a fixed point. We also formulated some recommendations on the distance between the receivers (10m seems to be a good distance), which supposes that some receiver has to be added especially in crossroads. Another parameter could be tested: we could change the height of the receiver to see if a child is exposed to the same levels as an adult. This method will be further applied to a larger zone, an urban quarter, with more contrasted traffic conditions and a measure campaign.

<sup>3</sup> The quietness indicator is defined as the percentage of period of 4 seconds where the noise level is less than 60dB(A)

<sup>4</sup> The loudness indicator is defined as the percentage of period of 4 seconds where the noise level is more than 70dB(A)



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