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Technical note

Influence of the search radius in a noise prediction software on population exposure and human health impact assessments

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ABSTRACT

Engineering software products allow for quantifying environmental noise and a population's exposure to road traffic noise which can then be linked to human health damage. This paper investigates the impact of the search radius, a parameter used in emission and propagation models, on noise exposure results. The search radius is the threshold distance from which noise sources are not considered anymore in the exposure assessment. To understand the influence of this parameter on the evaluation of population's exposure, the search radius has been successively fixed to three different values (500 m, 1000 m and 2000 m) in four different geographical situations (village, industrial, suburban and inner city). The result of this investigation highlights several points. First, despite a search radius often fixed to 1000 m by noise prediction software users, going up to 2000 m shows significant increase in population's exposure. Second, the impact of a change in search radius is very dependent of the presence of preponderant noise sources. Third, increasing the search radius can quickly lead to an impractical calculation time. A solution to avoid underestimating the exposure without increasing too much the calculation time may be to only account for preponderant noise sources beyond a given distance.

1. Introduction

Noise is defined as an unwanted sound. The impact of environmental noise on human health has been abundantly discussed by scientific communities in the last decades. The World Health Organisation (WHO) has provided a comprehensive review of these studies [1]. The impacts taken into account are cardiovascular disease, cognitive impairment in children, sleep disturbance, tinnitus and annoyance. The WHO quantified the burden of disease from environmental noise on human health, finding a range of burden of 1.0–1.6 million disability-adjusted life year (DALYs) for Western Europe. More than 90% of this amount is coming from sleep disturbance and annoyance. This important burden of disease pushed the WHO to consider environmental noise as public health problem.

There are several sources for environmental noise, such as transportation (road, railway and aircraft traffic), industrial activities, construction work, energy resources (wind turbine), and leisure activities. Among them, transportation, especially road traffic, is predominant. For example, in France, it has been estimated that the health costs due to environmental noise are largely caused by road traffic (89%) [2]. For this reason, this paper focuses only on road traffic.

In order to assess the impact of noise on human health, it is necessary to evaluate the population's exposure. The European directive 2002/49/CE [3] requires the assessment and management of the environmental noise for major European cities. One of the fastest and most efficient ways to evaluate exposure is to generate noise maps with prediction software using simplified sound propagation models. There are various noise emission and propagation models that can be used, including the ones developed under the European projects IMAGINE or HARMONOISE and the French NMPB08 method [4–7]. NMPB08 has been preferred because it is more recent and more accurate than previous noise emission and propagation models, as described in Ecotiere et al. [8]. Engineering software products allow for quantifying exposure to environmental noise coming from road traffic for a given population (as well as noise coming from railway traffic and industrial activities). They also allow to take into account different scenarios such as the presence of sound barriers, absorbing grounds, changes in road surface characteristics, speed limits, and changes in traffic.

Once the exposure of the population has been calculated, it can be linked with impacts on human health by following the

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recommendations of the WHO [1]. In this paper, only the two major impacts will be calculated, *i.e.* annoyance and sleep disturbance. The link between exposure and human health is the percentage of highly annoyed (HA) persons, in the case of annoyance, and the percentage of highly sleep disturbed (HSD) persons, in the case of sleep disturbance. Knowing the exposure, the number of persons highly annoyed and/or highly sleep disturbed can be calculated using the dose response curves given, respectively, by Miedema and Oudshoorn [9] and Miedema and Vos [10].

When implementing this approach, several parameters have to be optimized, *e.g.* the search radius. The search radius defines a circle around a receiver point, where the sound sources inside this circle will be considered in the calculation while the sound sources outside this circle will be neglected. It can be seen as the allowed "maximum propagation distance". Studying the impact of this search radius on population exposure assessment is the main objective of this paper.

2. Material and methods

2.1. Population exposure assessment

In this study, a noise prediction software called CadnaA [11] is used. Among the calculation parameters of CadnaA, the so called "Max. Search Radius" is the parameter of interest for this paper. This parameter is also called "maximum path length" in the NMPB 2008 methodological guide [12]. For the sake of simplicity, this search radius will be referenced as d_{max}. When taking the point of view of a building, all roads within the d_{max} will be considered to evaluate the noise level at which this building is exposed. The value chosen for d_{max} can have a large impact on the noise level calculated on each building's facade.

Despite the sensitivity to d_{max}, there is no imposed or even recommended value for this parameter in the European directive 2002/49/EC [3]. In most cases, a typical value of 1000 m is used [13,14]. According to the NMPB 2008, the method used in this paper for the configuration of CadnaA, the d_{max} is valid up to 2000 m [12].

On the one hand, a higher value for the maximum propagation distance implies that more sources will be considered in the calculation of the noise level on the studied façades. If the noise propagation software works properly and the simulation is well done, a result with a higher d_{max} should give a result more representative of the reality. On the other hand, the number of considered sources will grow at the same rate as the square of d_{max} since the number of considered sources is proportional to the surface taken into account in the calculation (assuming a homogeneous distribution of sources). Moreover, the d_{max} parameter also modifies the number of potential reflection and ray paths. Thus the calculation time can quickly become unpractical.

Since a value of 1000 m is the typical value used by people working on noise maps [13,14], a d_{max} value of 1000 m is chosen as a reference point. It may be interesting to compare two different changes in the value of the search radius to evaluate the benefits of fixing d_{max} at 2000 m instead of the mostly used value of 1000 m. As a result, it has been chosen to compare a doubling of d_{max} from 500 m to 1000 m and from 1000 m to 2000 m.

In order to study the impact of the search radius, Geographic Information System (GIS) data was used. It is given by a local French agency, Acoucité [14], and contains all the necessary information for the exposure assessment (roads, traffic, buildings, inhabitants, topography, ground characteristics, etc.). The area of the study is the Grand Lyon region that corresponds to the Metropolis of Lyon, a French territorial authority. The GIS data has been manipulated with a free and open-source software: OrbisGIS [15]. For the spatial scale of the study, a geographical mapping of the French territory called IRIS (Aggregated Units for Statistical Information - *Ilots Regroupés pour l'Information Statistique*) was chosen.

IRIS is the basic unit for the collection and transmission of statistical data coming from the French National Institute of Statistics and Economic Studies (INSEE) [16]. These geographical areas (16100 IRIS in France in total) are on a district scale and contain between 1800 and 5000 inhabitants. More importantly, IRIS are built in a way to ensure homogeneity among geographic and demographic criteria [17], and that is the main reason why they have been chosen for this analysis. Moreover, while IRIS are large enough to contain hundreds of buildings to be evaluated for each situation, they are small enough to allow for a lot of different calculations. This leads to a large amount of results which could be statistically analysed.

For each studied IRIS, all of the inhabited buildings in the area contained in the IRIS itself and an additional buffer of 1000 m have been evaluated for three values of search radius (d_{max} = {500 m; 1000 m; 2000 m}). The buffer was chosen to have a higher number of evaluated buildings to ensure a real "signal" and not just some "noise". The purpose of the buffer was to add more points in the studied cases by considering a larger area.

For each evaluated building, the noise level, L, is the maximum noise level found at four meters above ground and at two meters in front of all the façades of the studied building, following the standard of European directive 2002/49/CE [3]. The noise prediction software gives noise levels L_{day}, $L_{evening}$, L_{night} and L_{den}. L_{day}, $L_{evening}$ and L_{night} that correspond, respectively, to the noise level during day (6–18 h), evening (18–22 h), and night (22–6 h), while L_{den} is a day-evening-night equivalent level.

The few existing typologies for IRIS seem to be based on socioeconomic factors (*e.g.* [18]). To our knowledge, there is no existing typology based on environmental noise at the IRIS scale. There are some typologies based on noise for urban situations, but they are at the street scale [19,20]. Nevertheless, the aim of this paper is not to establish a noise typology of IRIS, but to show the influence of the search radius on different types of IRIS. The studied IRIS have been chosen to cover the different possibilities with a relatively low sampling rate. Four IRIS have been selected which are considered to be representative of the different types of configurations encountered in the Grand Lyon area. This choice regarding the geographical areas will be discussed in Section 4.1. For the sake of simplicity, a nickname is given for each of the four studied geographical area: *Village*, *Industrial*, *Residential* and *City*. It has to be noted that, as the four IRIS do not represent prototypes of any typology, the so-called *Village* is a geographical area which is not necessarily representative of every village.

In Fig. 1 representing the *Village*, the space between the two outlines is the 1000 m buffer. It means that the noise level in front of all the inhabited buildings contained inside the exterior outline will be predicted. All the black squares are buildings while the dark curving lines are roads. Finally, the grey lines are contour lines representing the topography. The noise prediction model will search for all the noise sources at less than d_{max} from the studied building.

The *Village* is centred on a small town in a hilly landscape. Within the buffer and the search radius, the considered area is more heavily urbanised than the IRIS alone, but it is one of the less densely inhabited areas in the Grand Lyon region. There is a railway line, but the road traffic is the only noise source considered in this work. There are no major roads in the area, so the environmental noise is expected to be low.

In the *Industrial* area, Fig. 2, most of the buildings in the IRIS are uninhabited. This is because it is an industrial area with big buildings and open space. Once again, railways are present but not taken into account. It means that most of the inhabited buildings that will be evaluated are not in the IRIS itself but in the buffer.