Noise and city design

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Noise is a concept that, necessarily, implies a negative effect. There are no physical differences between sound and noise. It can be said that sound becomes noise if a reference value for a specific sound pressure level is exceeded. This depends on the effect under consideration. For example, restful sleep is impossible with ambient bedroom noise levels above 30 A-weighted decibels (dB(A)). Other effects of noise are cardiovascular and metabolic effects, cognitive impairment, adverse birth outcomes, hearing impairment and tinnitus, annoyance responses, mental health, etc. (WHO, 2018). The European Environment Agency estimates that noise is responsible for 12,000 premature deaths every year in Europe alone (EEA, 2020. EEA Report No. 22/2019).

According to the United Nations, the urban population in 2018 exceeded 55% of the world's total population and is expected to increase to more than two thirds by 2050 (WUP, 2018). Cities provide better living conditions for people. This means easier access to employment with higher wages and better basic services such as healthcare and education. Cities have many advantages for humans and the environment in general. Thanks to cities, more than half of humanity occupies only 4% of the arable land.

Naturally, this leaves land free for food production and wildlife development. In addition, for higher population densities, roads, sewerage and power lines are shorter and therefore use fewer resources.

However, this concentration of people also has negative effects. The need for mobility of people and goods to and from cities, as well as the need to move within cities, leads to a higher concentration of pollutant emissions in the urban environment and, logically, with an increasing number of people affected. One of these pollutants is noise, which is considered as one of the most important environmental risks to human health (WHO, 2018).

Urban planning, essential to facilitate the movement of people and goods, is also essential to minimise the adverse impact of transport infrastructures. Among the different means of transport (road, rail and air transport), it is well known that, under both temporal and spatial consideration, the most important source of noise in cities is road traffic. For example, according to the European Environment Agency, it is estimated that 113 million people (82 million inside urban areas and 31 million outside) are affected by long-term day-evening-night traffic noise levels of at least 55 dB(A). In comparison, 22 million are exposed to high levels of railway noise, 4 million to high levels of aircraft noise and less than 1 million to high levels of industrial noise (EEA, 2020. EEA Report No 22/2019).

For the development of urban noise studies, strategies based on measurements or calculation methods can be considered. The use of software, which implements models of the sound field behaviour, allows predicting the noise levels, taking into account the characteristics of the source of the noise, the terrain, urban planning and buildings. This is a useful tool to study future scenarios in urban development. In fact, it is recommended by the European Noise Directive for strategic noise mapping (END, 2002). But the use

of in situ measurements of noise is essential to validate the results derived from software simulation and the only way to know the actual effects of action plans for noise control. Brown and Lam (Brown and Lam, 1987) analysed different methods of sampling for conducting urban environmental noise studies through measurements. They conclude that "The design of urban noise surveys should take into account that the underlying structure of urban noise is largely determined by the disposition of transportation, and in particular, road traffic, noise sources". Similar conclusions had already been reached in the scientific literature decades earlier by (Purkis, 1964) and (Attenborough and Clark, 1976). The latter also proved that sampling by land-use category is an inefficient predictor of noise levels. These ideas began to be considered in the international scientific literature through the Categorisation Method (Barrigón et al., 2002), which, within the framework of urban design, uses the concept of functionality to classify urban roads according to their use as communication routes. One of the most important results of this method is that it has made it possible to verify the existence of a stratification of urban noise, with differentiated mean noise values between the defined strata. Subsequently, these papers have been used as a reference by other authors, with different approaches or fields of application.

All of the above leads one to think that there may be some relation between noise pollution and the variables that define the size of urban areas. Usually, population is the variable used for this purpose. Surface area is another variable that can be taken to measure the size of cities and, from both of these, comes the density variable, which allows the concentration of people to be measured. Density was the variable chosen by the United States Environmental Protection Agency (EPA) in 1974 to carry out a study on the relation between urban variables and noise in cities. This work was reviewed in 1999 (Stewart et al., 1999). In both studies, statistically significant relations were found

between these two variables, with explanations of the variability of 52% and 55%, respectively. This line of work was continued with the inclusion in 2010 of the variables population and surface area in the study of these relations and extended in 2021 by the same working group to more cities and including new variables, such as the total length of the city's streets or a new concept of population density, the linear density or number of inhabitants in the urban area divided by the total length of its streets (Barrigón et al., 2021). This study showed that the variables population, surface area and street length are variables of interest to analyse the relation between the size of an urban area and the noise level in its streets. It also revealed that linear density was found to have the best behaviour, with explanations of variability of more than 55%. Furthermore, this study also showed that if the categorization method was used, the coefficient of determination increased significantly, reaching explanations of variability between 75% and 87% for all street typologies in the city, except for neighbourhood streets, for the variables population, surface and total street length.

There are other approaches to study the relations between urban planning and noise levels in urban areas. One that is currently very attractive is the design of regression models for the estimation of noise levels using only urban variables (inhabitants, urban morphology, land use, urban road features, street environment, green spaces, etc.) or in combination with road traffic variables (flow, type of vehicle, etc.). Although only the variables associated with traffic explain a large variability in noise levels, progress is being made in obtaining models that, using only urban variables, make it possible to obtain good relations with sound levels. A good knowledge of these relations would allow an effective design of urban environments. In this way, the goal of finding a sustainable city could be closer, at least with respect to noise pollution.

Currently, there is a trend that aims not only to reduce noise pollution, but also to improve the sound quality of urban spaces. And urban design is an important tool for noise control and the development of action plans to improve the acoustic situation in an urban area. Action plans for the mitigation of noise pollution are essential, especially in urban areas where there is a high exposure of the population to noise (EEA, 2020. EEA Report No 22/2019). Some measures in this sense can be the creation of areas of restricted access to road traffic, the reduction of the number of traffic lanes or vehicle speed, the type of road asphalt, the development of ring roads away from residential areas where heavy traffic can be routed and the introduction of bicycle lanes and pedestrian zones. Restricting road traffic and pedestrianising central urban areas is one of the measures currently being developed in different cities to reduce road traffic pollution and improve the acoustic quality of the urban environment, but their effectiveness is linked to the implementation of efficient public transport. A further type of measure that can be applied in urban planning to reduce the impact of environmental noise on the population in cities is the creation of quiet green areas with high acoustic quality. Scientific literature shows that urban green spaces are associated with improvements in mental and physical health and well-being and are becoming recognised as a mitigation measure to reduce the adverse effects of urban living on health (Dadvand and Nieuwenhuijsen, 2018).

In summary, the concentration of people involved in urban areas has important benefits for people and the environment. But even if the emission of pollutants per inhabitant is reduced, pollutants may be concentrated in relatively small areas. This logically leads to more people being affected by the potential increase. Noise is one of the most important of these pollutants. This leads to the fact that noise pollution levels have to be known and research into strategies for conducting such studies becomes important. Furthermore, at least in those cases where pollution levels can be harmful to the human health, they must

be reduced to acceptable values, which leads to the importance of properly designed action plans. Urban design can be a very useful tool for the development of these action plans, as can be deduced from the results shown in all those studies in which significant relations are found between different variables, either related to the size of the urban areas or related to their design. Each of the aspects analysed in this document represents a promising field of work. Research is needed to improve urban noise sampling and analysis strategies, such as studies on the relations between city size variables and noise pollution, and studies on the relations between urban variables and noise levels. There is much research to be carried out and much new knowledge to be discovered and to be put at the service of improving the health and quality of life of the population.

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