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APPLICATION OF NOISE SOURCE PREDOMINANCE MAPS (NSP) TO AGGLOMERATES

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ABSTRACT

Environmental Noise Directive prescribes periodic strategic noise maps for agglomerates in order to evaluate citizens' noise exposure. They include a global map and individual maps for each individual type of source: railways, roads, airports, and industries. The Directive also requires informing the public, but the current representation does not facilitate the understanding. In a previous study, Noise Sources Predominance (NSP) and Intensity Noise Source Predominance (I-NSP) maps have been developed to offer better representation results for strategic noise maps. NSP shows, by means of polygons and colors, the predominant source at each point of the calculation grid of the strategic noise map, while I-NSP also adds the visualization of noise exposure levels by coloring the polygons according to a color-scale. As those new maps were only tested in port areas, the present work investigates their applicability in agglomerates.

Keywords: *Strategic noise map, noise limits exceedance, noise monitoring, environmental noise directive, sound sources.*

1. INTRODUCTION

Studies on health effects related with noise need precise noise exposure evaluation, which is generally remanded to average over a long time period, both simulated or measured [1, 2]. The day–evening–night level L_{DEN} from the European Environmental Noise Directive (END) 2002/49/EC [3] is the mostly used metric, and is generally gathered from the strategic noise maps. Introduced by the END as part of the noise exposure prevention plan, noise maps are tool that predict and represents the noise situation in a particular area. The visualization of noise levels is left to a graduation of different colors on 5 dB(A) intervals and different maps are produced for each individual source. They are then summed together for the overall noise exposure calculation. Territorial and building information are basic needs for the 3D environment, on which source specific data are needed. After computing the sources' noise emission, the sound waves are propagated in the space applying attenuation effects like distance, ground absorption and presence of obstacles. A grid with a point-to-point calculation is the final output and is generally performed with a commercial software implementing a mathematical model, which for the European Union is the CNOSSOS-EU [4].

Strategic noise maps are subject to a 5-year cycle of evaluation and information in order to reduce noise pollution while also involving citizens. Each member state is required to periodically send data to the European Community about the emission, and citizens' exposure, to the noise emitted by the main transport infrastructures and agglomerations. This includes roads with more than 3 million vehicles a year, railways with more than 30.000 trains a year, airports with more than 50.000 movements a year and agglomerations

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with more than 100.000 inhabitants. Industrial plants are mapped only inside the Integrated Pollution Prevention and Control or, as ports, only when they are inside or close to agglomerations. Even if not considered as transport infrastructure by the END, ports and ships' noise received lot of attentions in the last years [5-7]and has been recognized as a disturbing source [8, 9].

After being neglected for so long, the scientific community finally investigated a broader spectrum of sound exposure features. Thus, not only the annual average, but also peak level, variation over time, impulsivity of events, frequency distribution, psycho-acoustics are being investigated in relation to nuisance perception. Most importantly, citizens are more likely to complain about single high levels rather than average exposure [10]. Moreover, different reactions occur to noise produced by different sources, i.e., not all sources are disturbing for the same level of exposure. More complaints can then emerge where one source predominates over the others. For this reason, visualizing the information in an exploited way would be pivotal in understanding, foreseeing and prevent complaints and eventual negative health effects [11, 12].

Noise Source Predominance Map (NSP map) Intensity Noise Source Predominance map (I-NSP map) have been developed in order to solve these issues [13]. They have been originally tested in ports, as they are large areas with a great variability of different types of noise sources where responsible for exceeding are not easily detectable. A future development left open in the aforementioned paper was the application of NSP and I-NSP maps to be urban agglomerations and sources defined by the END. The present paper wishes to cover this lack and test the NSP and I-NSP as a visualization support in the noise exposure prevention process.

2. NSP AND I-NSP

NSP map have developed with the main purpose of an easier identification of areas where a specific port source dominates over the others. Such areas would be the best ones in where identify the contribution of a specific source and, consequently, where a direct responsibility can be assigned in case of limit exceedance. Furthermore, mitigation would be more efficient.

Also non-predominance areas' identification has the benefit of knowing, before performing a measurement, where distinguishing a specific source would be challenging. Moreover, no specific source will be particularly annoying to the citizens and mitigating the total noise would be more difficult.

I-NSP are upgraded NSP map showing also sound intensity, and thus, can be produced for both the L_{DEN} and L_{night} required by the END, as well as for other metrics.

Both maps are based on the predominance criterion, inspired by the requirement of UNI 10855:1999 [14] which requires environmental noise level to be at least 3 dB(A) greater than the background noise in order to correctly evaluate the specific noise source level. NSP and I-NSP maps are created applying this criterion for each point of the calculation grid to determine if any of the sources meets the requirement to have a corresponding background noise that is 3 dB(A) lower than the total noise produced by all the sources. This requirement is like checking if the specific source level is equal to or higher than the sum of the other sources then the NSP Map assign a specific colored symbol to each point of the calculation grid. The defined symbols legend for agglomeration is reported in Figure 1, together with the graded one for I-NSP. The color scheme follows Weninger one [15] in order to enhances the visibility for color blindness affected people and to improve the readability. The inclusion of Ship and Port sources is a consequence of the results provided by [13].

When the criterion is not met by any sources in the NSP, a white circle is associated with the grid's point.

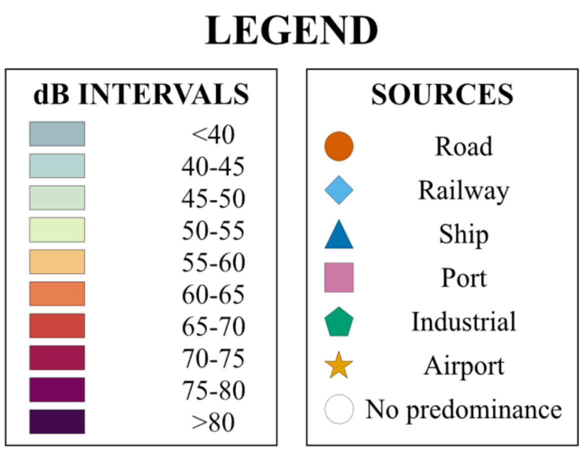

Figure 1. Legend for HSP (right) and colors for I-NSP (left).

3. APPLICATION TO LIVORNO

In this section, the maps of the Livorno municipality are reported as first application of NSP and I-NSP maps to agglomerations. Figures 2 and 3 depict respectively the NSP map of the L_{DEN} and L_{Night} indicators. Then Figure 4 and 5 report the I-NSP maps of Livorno for the L_{DEN} and L_{Night}

indicators respectively. In the municipality of Livorno are present all sources from Figure 1 except for the airport one. Unfortunately, the available map was produced in force of the current regulation, thus the sources inside the port area has been considered as mere industrial sources. Therefore, instead of the potential five sources, just three sources were available for the predominance evaluation: road, railway and industrial.

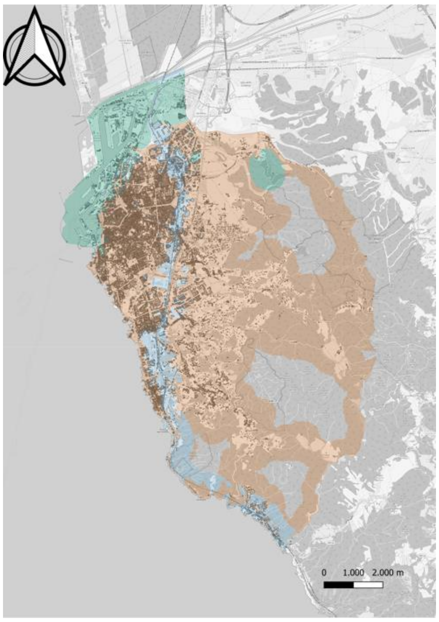

Figure 2. NSP for Livorno with L_{DEN}.

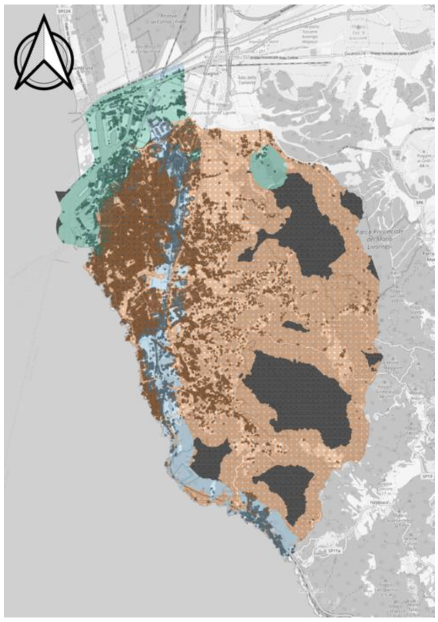

Figure 3. NSP for Livorno with L_{Night}.

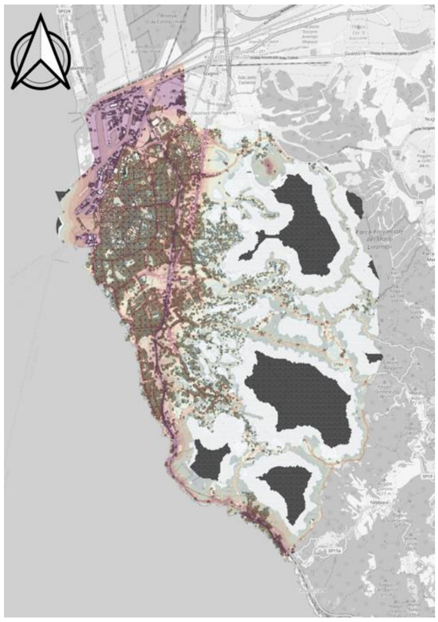

Figure 4. I-NSP for Livorno with L_{DEN}.

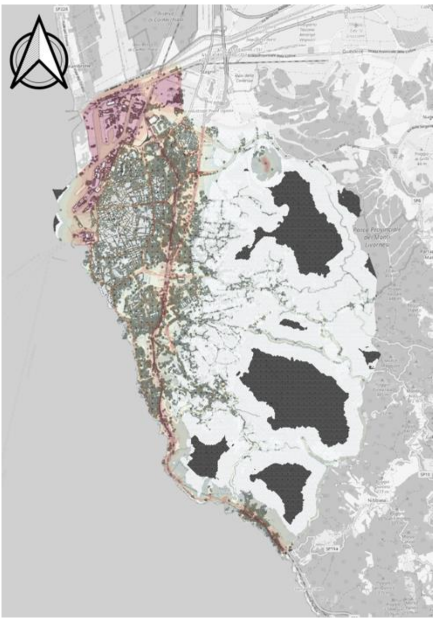

Figure 5. I-NSP for Livorno with L_{Night}.

As it was already pointed in [13] the NSP map allows for fast identification of the predominance of the different sources. On the other hand, on the surface, the I-NSP map looks like a regular strategic map. Nevertheless, it has embedded information about the predominance and can be used for in-depth analysis of the results.

From Figure 2 and 3, most of the city surface is affected by road predominance, while industrial predominance is restricted to the proximity of the port area and railways predominance is concentrated around a small area alongside the track of the main railway infrastructure.

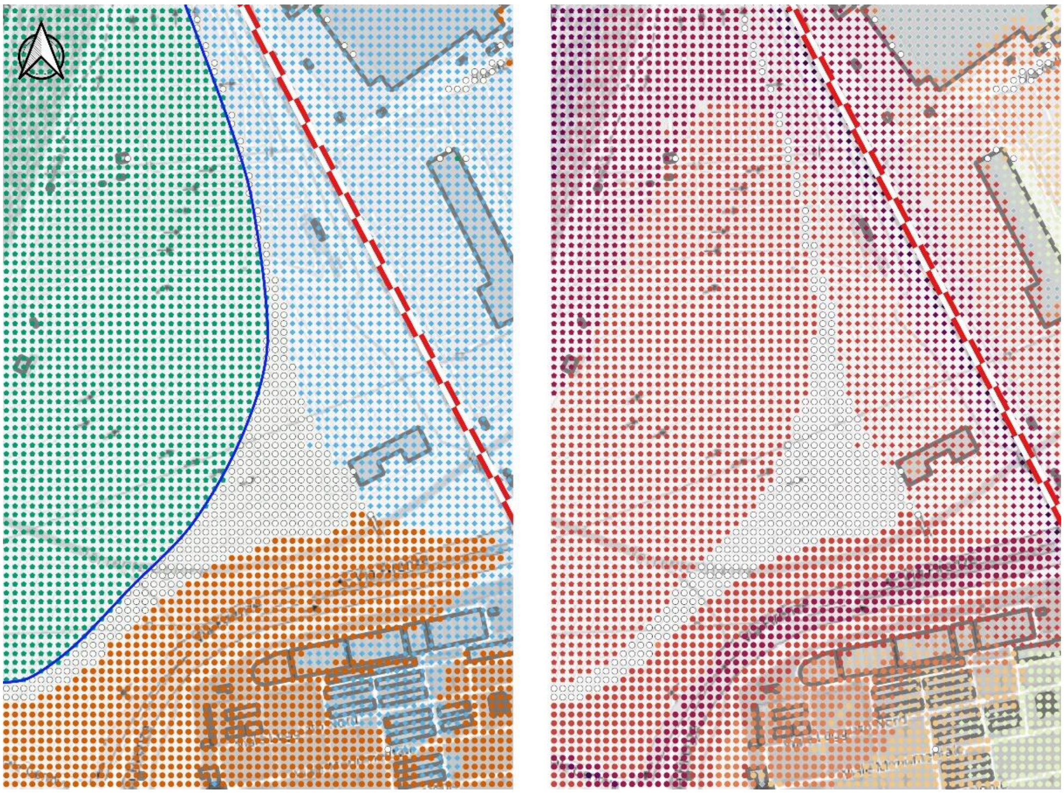

Figure 6. Zoomed L_{DEN} NSP map (left) ad I-NSP map (right) near the port area of Livorno. In blue the boundary of the port predominance area. In red and white the railway infrastructure.

The Figure 6 presents a zoom from the map of Livorno regarding the L_{DEN} indicator. On the left side of the Figure 10, there is the NSP map, while on the right side, the I-NSP map of the same region. Green pentagons in the upper left side of the map indicate industrial noise predominance, which in this case is generated by the port. The light blue rhombuses on the right side of the map reveal the predominance of railways noise produced by important railways, depicted in red and white. The orange circles denote road noise predominance due to the urban traffic. In the central region, white circles are present and indicate no predominance. This area is like a buffer area between two or more predominance areas, in which no one of the three sources predominates over the other. Looking at how this area moves between L_{DEN} and L_{Night} maps is an easy way to interpret the map and the relative variation between the noise levels produced by different sources. Indeed, comparing L_{DEN}'s results to L_{Night}'s results reported in Figure 7, the non-predominance area moves towards the south. Thus, the surface corresponding to road noise predominance decrease and yields ground to industrial noise predominance. This phenomenon is likely to ascribe to the fact that port activities reduce to a lesser extent than road traffic during the night.

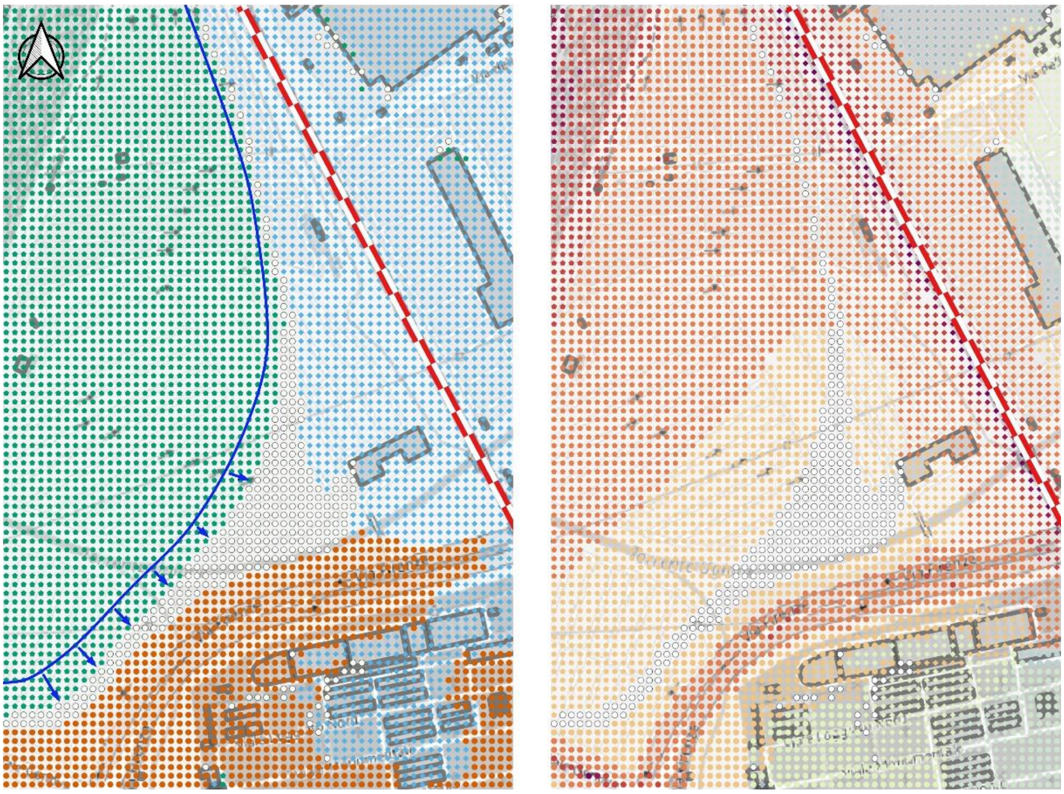

Figure 7. Zoomed L_{Night} NSP map (left) ad I-NSP map (right) near the port area of Livorno. In blue the boundary of the port source predominance area from the L_{DEN} map in Figure 6. In red and white the railway infrastructure.

A similar scenario is spotted paying attention to the boundary between industrial and railways predominance areas that, for the L_{Night} indicator, move toward the railways, indicating that railways noise reduces more than port noise during the night. This type of observation is easier in areas characterized by near-free-field propagation, where little to no obstacles are present. However, it is still possible to make similar assessments in areas dense with buildings.

4. APPLICATION TO PADOVA

In the present section NSP (cf. Figure 8 and 9) and I-NSP (cf. Figure 10 and 11) of the Padova agglomeration are also reported as a second example. In Padova just road, railways and industrial noise sources are present, thus the predominance evaluation is restricted to those three sources. As in the case of Livorno, also for Padova most of the surface is characterized by road predominance, while railways and industrial predominancies are more restricted. Looking at the railways predominance areas it can be see that there is a hard edge along the rails track. This can be ascribed to two different reasons. The first may be the absence of obstacles in the propagation. Thus, at a certain distance the rail noise level falls below the background level of urban street noise and the predominance changes. The other hypothesis is that those edges are due to a defect in the production of the map itself. In fact, the map was made by aggregating a map provided by the railroad operator to the road map made on behalf of the municipality. The railroad infrastructure map was made only within a fixed distance from the center of the track. This causes that beyond this distance predominance cannot be properly calculated because of no noise level available.

The solution came from the I-NSP map that show how hard edges are present also in terms of levels. This evaluation can also be done with the regular strategic noise map, but the NSP map can highlight it in a clearer way, allowing also to spot the responsible source.

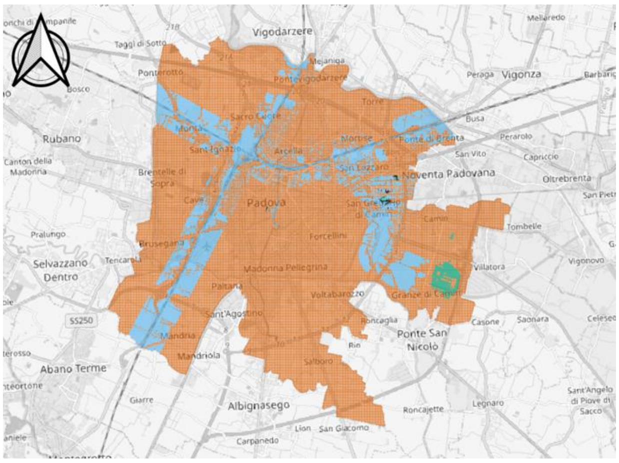

Figure 8. NSP for Padova with L_{DEN}.

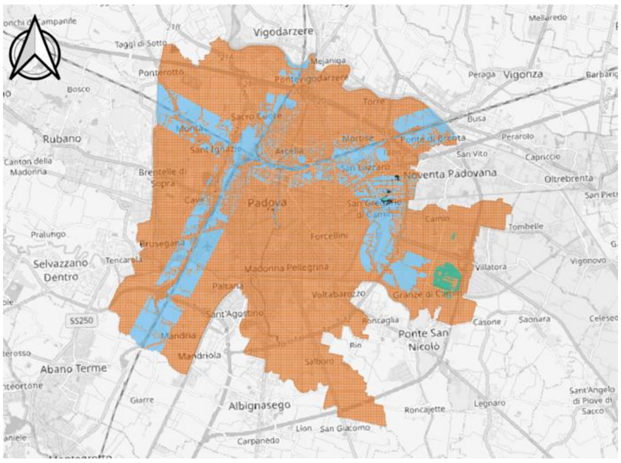

Figure 9. NSP for Padova with L_{Night}.

Those type of errors, cause not only uncertainties in the calculation of the sources' predominance area, but also an erroneous evaluation of citizen's exposure to noise. This aspect is critical in term of the current European regulations and nullifies the investments profuse in realization of maps.

5. CONCLUSIONS

In this work the NSP and I-NSP maps, previously defined only for the port areas, have been applied to the agglomerations. Livorno and Padova were used as case studies. These tools revealed to be valid support in the noise prevention and control process outlined by the END, as they make it easier to see which source predominates over the others. This allows an easier choice of the positioning for

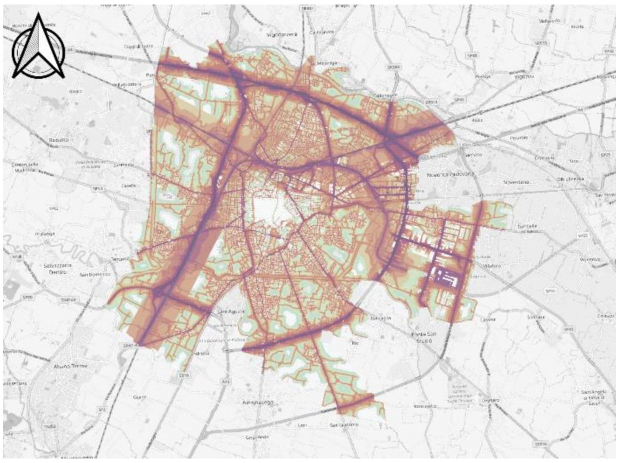

Figure 10. I-NSP for Padova L_{DEN}.

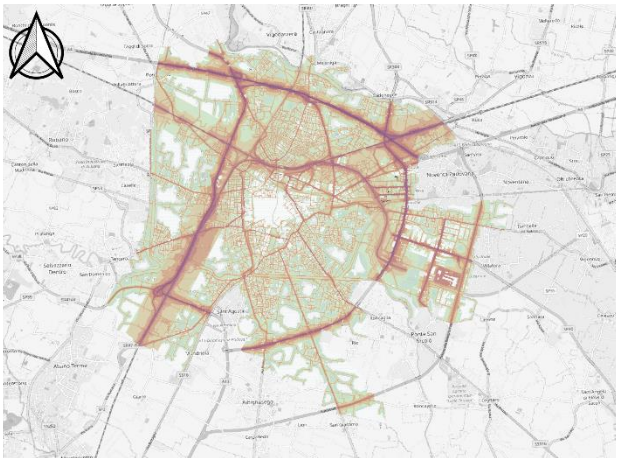

Figure 11. I-NSP for Padova with L_{Night}.

noise monitoring units, or to highlight the responsible for the higher sound levels or eventual limits exceedance.
The maps applied to the case studies confirm, in a visually easier way, that road traffic is the source most impacting citizens and that it is the one that spreads most throughout the territory. At the same time, criticalities and higher levels can occur in the vicinity of other sources, which are often the most neglected. Certainly in the case of agglomerations, the size of the area does not play in favor of visibility and targeted zooms of the areas of interest are needed to show the differences obtained with the standard map.
The L_{DEN}-L_{night} comparison showed how different types of sources, with different hours of operation, can lead to different boundary lines between the predominance in different periods of the day.

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