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ANALYSIS OF COMPLEX SCENARIOS IN THE NOISE MITIGATION OF MAIN INFRASTRUCTURES IN ITALY IN LIFE SILENT PROJECT

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ABSTRACT

Transportation infrastructures are responsible for most noise exposure in Europe. The Europe Environmental Noise Directive prescribes a cycle of noise mapping, citizen involvement, and action plans to reduce annoyance and sleep disturbance. In Italy, national regulation shares with END the aim to reduce noise, but is more focused on the definition, and respect, of noise limits rather than considering noise effects on citizens. In the case of multiple noise sources acting in the same area (complex acoustics scenario), Italian regulation asks transportation infrastructure managers to cooperate and share the mitigation costs. In these cases, without an integrated mitigation plan, acting on one source can lead to higher costs or, at worst, an increase in exposure. However, the regulation does not provide practical guidelines on how to manage this process, thus very little progress has been made in mitigating noise in those complex scenarios. The Life SILENT project aims to address this problem by developing a methodology for highlighting conflicts in complex scenarios and solving them, reducing total citizen exposure while minimizing costs and considering EU requests at the same time. The present work will describe a preliminary study conducted with this intent.

Keywords: *concurrent infrastructures, railway noise, road noise.*

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1. INTRODUCTION

Environmental noise is a significant health concern in Europe, identified as the second most critical environmental stressor in six European countries, according to the WHO's 2018 "Environmental Noise Guidelines for the European Region" [1]. Approximately 20% of the European population resides in areas where noise levels pose health risks, leading to substantial economic costs due to non-productive workdays, healthcare system burdens, and decreased property values [1].
The Environmental Noise Directive (END) provides essential tools, such as Action Plans, to develop effective noise reduction measures by integrating local and regional actions as per Member States' regulations [2].
Despite the establishment of national noise limits, challenges persist in implementing these Action Plans effectively considering also national legal framework. Fragmented responsibilities and a decentralized approach often delay noise mapping and Action Plan execution. Additionally, the absence of common guidelines for prioritizing interventions hampers the development of uniform methods, leaving decisions to local authorities based on health impact assessments and public consultations [2].
While there is a growing body of research on health impact indicators for prioritizing interventions, the mitigation of multiple noise sources in complex scenarios, particularly outside urban areas, remains underexplored. There is a notable lack of interventions and pilot projects that provide practical, verified examples for infrastructure managers.
In Italy, the Ministerial Decree 29/11/2000 (DM 2000) establishes that in case of limits exceeding due to concurrent infrastructures, the operators must proceed to a joint execution of the noise remediation actions. This scenario is likely to be spotted in the case of parallel infrastructures e.g. a highway that runs parallel to a railway

line, very common along the Italian costal lines. However, this approach was never applied to real cases, also considering END requirements, due to a lack in the definition of accountability and the procedure to be followed.
The SILENT Project (Sustainable Innovations for Long-life Environmental Noise Technologies) [3] aims to address these issues by developing mitigation proposals for population exposure to noise in complex scenarios involving road and rail sources. This project will explore the current state of Remediation Plans, identify critical issues, and propose regulatory measures to establish measurable and replicable intervention procedures in complex acoustics scenarios.
The first step towards this goal is to experiment with a simple case study to understand the critical points to be solved.
In the present paper, the case study of Italy, Fano (PU) will be presented.

2. METHODS

The test site of Fano covers a total area of 0,9 km^2 with a total resident population of 621 inhabitants. The site was selected due to exceeding noise limits caused by the combined effect of road and railway sources. The two infrastructures run parallel for all the length of the test site as shown in Fig. 1.

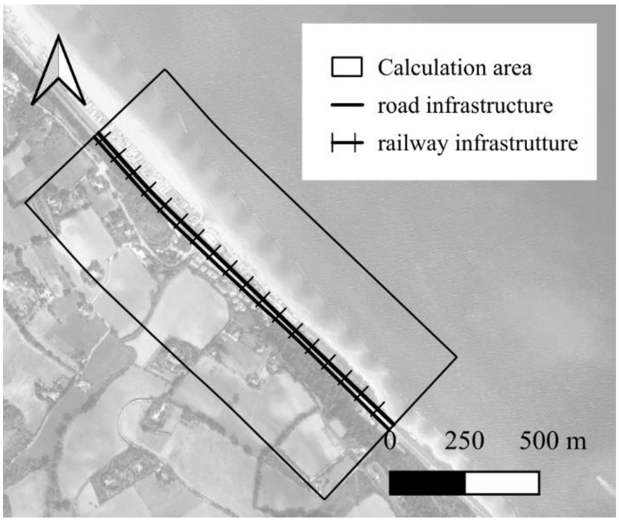

Figure 1. The test site of Fano.

According to the Italian law, when a regulatory limit exceedance is attributable to multiple sources, the relative responsibilities will be assigned by the calculation of the priority index (P_i) defined by DM 2000. The calculation starts by partitioning the total area of interest into several smaller areas in which the noise limits are uniform, the noise level does not change more than 3 dB (A), and the population distribution is the same. To obtain those A_i, the intersection between isophone areas (Figure 1), Census areas (Figure 2), and noise limits (Figure 3) must be done. In this way the priority index can be calculated as follows:

$$P_i = \sum R_i (L_i - L_i^*) \tag{1}$$

Where R_i indicates the number of resident inhabitants in the area A_i. The A_i are the areas in which the values L_i and the limit L^*_i are constant. For each A_i, the value R_i is obtained by multiplying the surface by the population density provided by the corresponding census area.
In order evaluate relative responsibility in the case of concurrent infrastructures it is of pivotal importance to have homogenous noise exposure data.
GIS approach is mandatory in order to obtain the priority index Pi.
The first step is to obtain the required geospatial and traffic input data:

- Terrain model [4],
- Buildings layer (with heights),
- Census areas [5] (Fig. 2),
- Infrastructures' map,
- Traffic data.

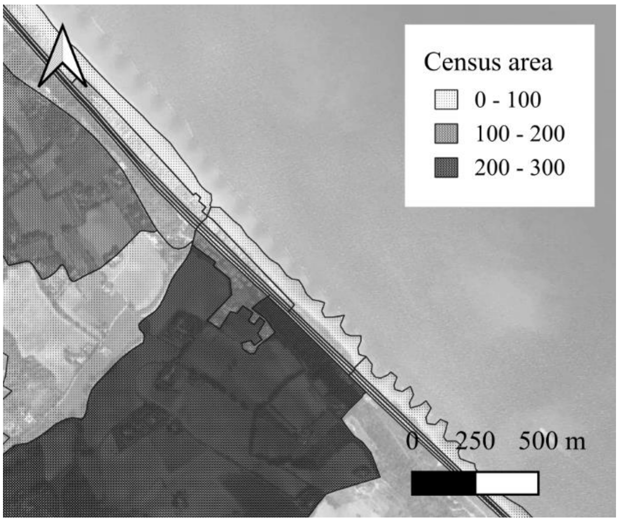

Figure 2. Number of residents per census areas in the test site of Fano.

Usually, all geospatial input information is provided by national or local authorities by open-data services. The unavailability of shared data can represent a significant issue in the process of identifying priority indices and subsequently undertaking shared acoustic mitigation paths.
The test site in Fano represents a case study in order to define a possible approach to overcome such problems.
The **building profiles**, lacking in public open data database, were extracted from OSM [6] and the height was extrapolated comparing the DTM and the Digital surface Model (DSM) provided by [4]. **Infrastructures' maps** and **traffic data** were provided by operators of the two infrastructures. This source of data is preferred to the OSM or other web service providers because it is more accurate in terms of number and exact location of the road lanes and railway lines.
ISTAT, the Italian National Institute of Statistics, provides **census areas** in shapefile (*.shp)* file format for all the municipalities with the number of people for different areas. From such information local population density can be computed. Finally, to calculate the required value R_i noise levels must be computed and compared with noise limits (Fig. 3).

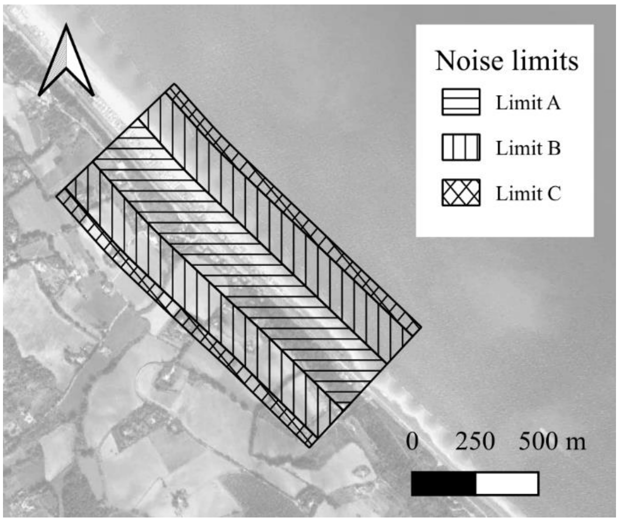

Figure 3. Noise limits for the test site of Fano.

With this aim, geographical and traffic data were used as input for commercial acoustic simulation software. The software allows us to calculate a noise map in accordance with the CNOSSOS-EU framework.

3. RESULTS

The present section will report the results for the test site of Fano. Noise simulation software produced a noise map for each infrastructure. In Fig. 4 the noise levels for the road infrastructure are reported as an example. The maximum calculated L_i overall is 79 dB (A), and the maximum for road and railways is 73 dB (A) and 79 dB (A) respectively.

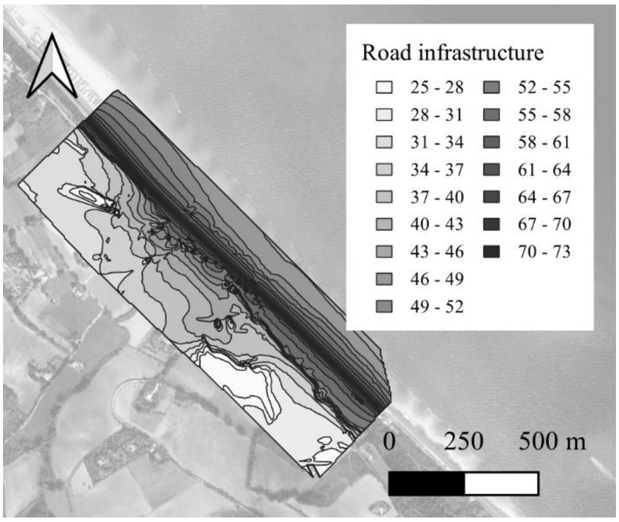

Figure 4. Noise isophones in dB (A) in the test site of Fano for the road infrastructure.

Those maps were then used to obtain the final A_i reported in Fig. 5 with the corresponding P_i value for the railway infrastructure. The results in terms of P_i for the test site of Fano are presented in Tab. 1.

Table 1. P_i calculated for the day (06-22) and night periods (22-06).

Source	**P_i Day**	**P_i Night**
Road	153	395
Railway	739	8564

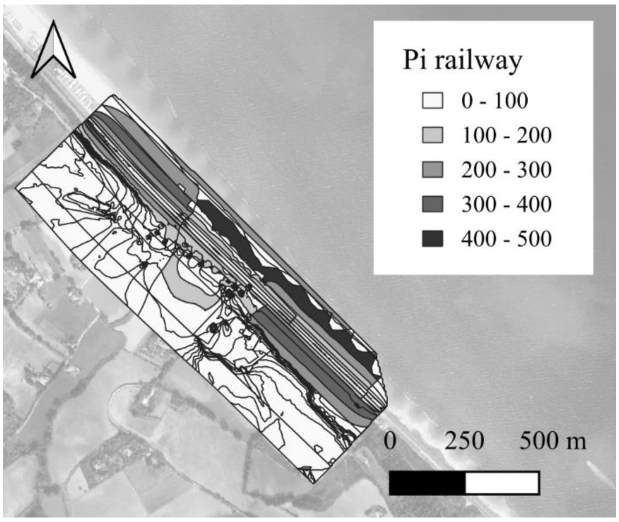

Figure 5. Priority values for the test site of Fano for railway infrastructure.

4. DISCUSSION

The results presented in Tab. 1 show that railway noise has higher priority both in the day and night period. The difference is more important during the night compared to the day, with a P_i for the railway almost 22 times bigger than the road one. This behavior can be ascribed to two independent causes: at night road traffic decreases consistently but railway traffic remains unchanged. At the same time noise limits L^*_i decrease by 10 dB (A) in the night period.
For the Italian regulation, both infrastructures would be remediated but they will be scheduled in different cycles of remediation plans due to the great difference in the priority levels. This causes an inefficient resolution of the concurrency, non-optimized spending and, in the worst case, an increase in population exposure. This could be the case of a noise barrier installed between the infrastructures to remediate the railway. The barrier, while remediating railway noise, will lead to an increase of almost 3 dB (A) of road noise due to unwanted reflection.

5. CONCLUSION

As we showed in this paper, Italian Regulation, especially the noise indices proposed, are not sufficient to resolve a (simple scenario with concurrent infrastructures like the case study of Fano (PU), where the two infrastructure runs parallel with no buildings in between and very few buildings in the calculation area, meaning little population affected by the traffic noise. The results underline the need for a different approach towards the resolution of complex scenarios. The Life SILENT Project will develop and test new indicators to better evaluate the concurrency and support the future remediation plan with more accurate and relevant information.

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