AN ITS SYSTEM FOR MITIGATING NOISE INDUCED BY PORT-RELATED ROAD TRAFFIC

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Abstract

The SALPIAM project (Sostenibilità per l'ambiente e la salute dei cittadini nelle città portuali in Italia), funded under the PNC–PNRR framework, develops innovative solutions to reduce the environmental impact of port infrastructures, with a specific focus on mitigating noise generated by vehicular traffic. In the pilot case of the Port of Piombino, a fully open-source Intelligent Transport System (ITS) has been designed and implemented to manage traffic flow in compliance with the CNOSSOS-EU forecast methodology for the assessment and management of environmental noise. At the core of the ITS lies the integration of a SUMO (Simulation of Urban Mobility) traffic simulation model, a NoiseModelling acoustic model, and data acquired from intelligent cameras capable of vehicle classification according to CNOSSOS-EU guideline. By combining up-to-date traffic data and computing acoustic maps in near real time, the system can correlate vehicular flows along the various urban corridors with population exposure levels. This tool enables the proposal, assessment, and comparison of alternative traffic management scenarios, with the aim of identifying the most effective solutions for reducing noise exposure in critical areas. Once the optimal scenario for noise mitigation is selected, the system can inform drivers about recommended routes through Variable Message Displays (VMDs) and/or a dedicated mobile application, thereby contributing to a more environmentally sustainable management of traffic flows. A particularly critical phase of the project concerned the acoustic calibration of the model, which is essential to ensure the reliability and the consistency of the simulations. This calibration was conducted through a monitoring campaign employing four fixed stations and twenty-three mobile stations distributed across areas most affected by traffic entering and leaving the port. This allowed us to refine the acoustical parameters and validate the system's noise prediction performance under different operating conditions, including areas not strictly related to port activities.

Keywords: road noise levels, Intelligent Transport System, road noise modelling

1 Introduction

From an acoustic point of view, ports have long been neglected by European legislation [1], which classifies them as simple industrial areas, ignoring their specific characteristics as transport infrastructures. Ports are complex infrastructures including a wide variety of noise sources where maritime routes, road networks, and rail systems converge [2]. For historical reasons, they are often embedded in the urban context, creating a conflict between the development of port activities and the well-being of the population. Road traffic generated by port activities, when combined with existing urban traffic, is a major contributor to overall noise exposure.

DOI: https://doi.org/10.5592/CO/CETRA.2026.2013

Traffic generated by port activities is highly impulsive, since large numbers of vehicles enter the road network within a very short time during disembarkation operations. This characteristic can lead to substantial congestion across the surrounding road network. Deploying advanced traffic management systems can help mitigate these conditions and enhance the overall performance of the network. In the last decade, studies on port noise have increased. In the Italy–France cooperation area of the northern Tyrrhenian Sea, and within the Interreg Maritime European program, several projects have been carried out on this topic [3]. These projects have produced numerous results in the field of port-area monitoring systems [4], acoustic mapping [5, 6], and noise mitigation measures in port areas. Some of these results related to acoustic mapping have also shown their usefulness in broader contexts [7].
Within the L.I.S.T. PORT project, a traffic management system was implemented that is also capable of considering noise emissions [8, 9] through a simplified estimation of the generated acoustic impact. Building on the results achieved, the SALPIAM project aims to enhance this earlier ITS system [10] by integrating a noise-estimation methodology fully compliant with European legislation. The objective is to replace the previous simplified level-based approach with a robust and accurate assessment of noise exposure from road network using the European CNOSSOS framework.

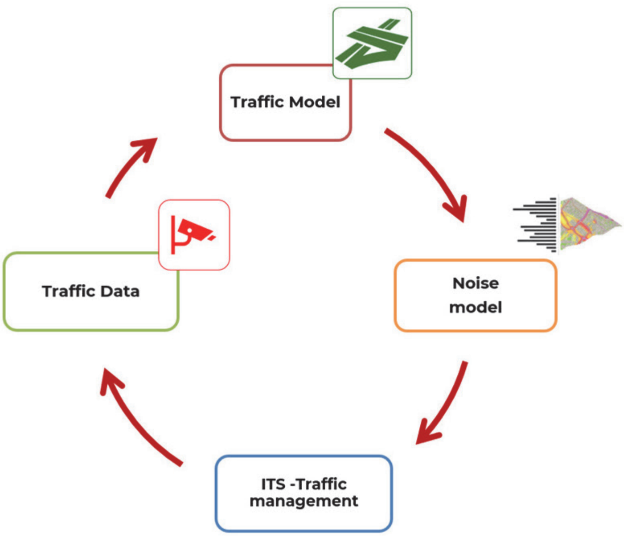

Figure 1 The SALPIAM ITS cycle

A distinctive feature of the SALPIAM project is the use of open-source software for the development of the ITS system (figure 1). In particular, the traffic model is implemented using the SUMO software [11], while the simulation used to generate the noise map associated with vehicular traffic is carried out with the NoiseModelling software (NM hereafter) [12]. As traffic data sources, it is also possible to use either historical datasets (databases) or real-time data acquired through advanced sensors capable of classifying vehicles in accordance with the CNOSSOS-EU methodology (figure 2). To enable these software tools to communicate with each other, so that traffic data produced by SUMO simulations can be provided as input to the NM simulator, a dedicated Python script has been also developed. This script ensures continuous operations and generates noise maps associated with building-level receivers at 15-minute intervals, as explained in [10].

Category	Name	Description	Vehicle category in EC Whole Vehicle Type Approval[1]
1	Light motor vehicles	Passenger cars, delivery vans ≤ 3.5 tons, SUVs[2], MPVs[3] including trailers and caravans	M1 and N1
2	Medium heavy vehicles	Medium heavy vehicles, delivery vans > 3.5 tons, buses, touring cars, etc. with two axles and twin tyre mounting on rear axle	M2, M3 and N2, N3
3	Heavy vehicles	Heavy duty vehicles, touring cars, buses, with three or more axles	M2 and N2 with trailer, M3 and N3
4	Powered two-wheelers	4a mopeds, tricycles or quads ≤ 50 cc	L1, L2, L6
		4b motorcycles, tricycles or quads > 50 cc	L3, L4, L5, L7
5	Open category	To be defined according to future needs	N/A

Figure 2 Tables of CNOSSOS-EU classification

1.1 Traffic flow measurement campaigns

Calibrating the traffic model, and subsequently the noise model, is an essential step for obtaining reliable prediction results [13]. To assess the consistency of the simulated noise levels at receiver points, we conducted multiple measurement campaigns in the city of Piombino (Tuscany, Italy), collecting both traffic and acoustic data. The monitoring activities used a radar-based traffic counter and four Class-1 sound level meters, deployed over five survey days across four fixed stations and twenty-three mobile measurement points (figure 3). Traffic flow assessment was carried out by classifying vehicles into the four CNOSSOS-EU categories (light, medium-heavy, heavy, and powered two-wheelers, as described in figure 2) using two approaches: automatic length-based classification from the fixed stations and manual identification and counting performed by field operators at the mobile positions. This procedure ensures input consistency and minimizing site-dependent bias through local calibration/validation against field data.

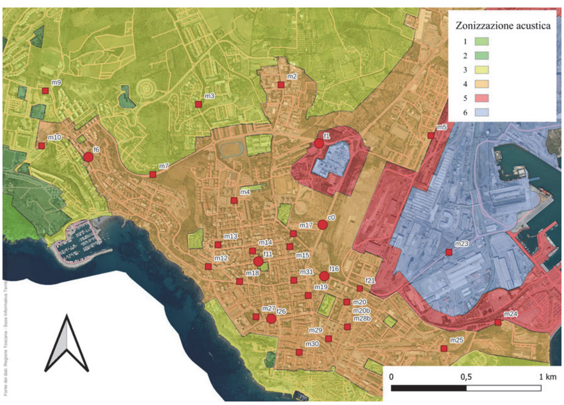

Figure 3 Position of the measurement points in the city of Piombino, superposed with the acoustic zoning

Preliminary results also indicate good agreement between the simulated and measured traffic patterns at the mobile locations, including areas not directly connected to the road network investigated during the measurement campaign. These additional findings are promising and are currently the subject of further investigation.

2 Acoustic calibration

The comparison between the measured data and those obtained from our predictive system is, in the first instance, assessable based on the difference over the time of the day between the measured and simulated value of sound pressure in dB. Two verification approaches were adopted: (i) a standard method that evaluates the effectiveness of NM engine against real, non-simulated traffic, and (ii) an extended method that assesses NM's performance when the traffic demand is simulated with SUMO over the road network. In both methods we inserted in the NM model all the details that we could provide: in particular we used the slope of the roads (derived from the SUMO net with heights extract from a 2m-DEM layer from an Italian M.A.S.E. project [14]) and the pavement parameters, included in the CNOSSOS framework.
In the standard method, the observed number of vehicles passing the road section under study is input into the model, and simulated noise levels are compared with the corresponding measurements. In the extended method, we run a simulation not only on the road link directly associated with the sensor but also – using SUMO with typical-day inputs – across the entire road network. Table 1 reports the mean difference and the standard deviation between simulated and measured noise levels: a positive difference indicates that the noise model overestimates the measurements.

Table 1 Comparison between real and simulated data

	Standard method		**Extended analysis**	
Sensor	**Mean difference [dB]**	**Standard deviation [dB]**	**Mean difference [dB]**	**Standard deviation [dB]**
STM6	-0.75	0.49	-0.74	0.49
STM33	-0.96	0.55	-0.91	0.56
STM34	1.30	0.60	1.52	0.54
STM35	-0.41	0.85	-0.12	0.84

As can be inferred from the table, applying the standard method already yields good results: while acoustic simulation models usually exhibit errors of about 3 dB, this procedure keeps the discrepancy within 2 dB in the worst case and 1 dB in all other cases. However, the extended method shows that including the nearby roads as a background noise has an impact on the final level sound at the receivers.

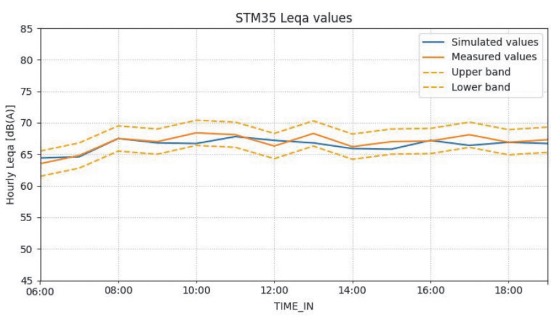

Figure 4 Hourly L_{EQ}[A] values for the STM35 sensor in the standard method; the blue line represents the simulated values while the orange one represents the measured values with a band of 2 dB error by side (dotted)

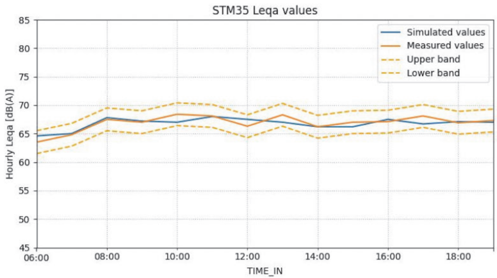

Figure 5 Hourly L_{EQ}[A] values for the STM35 sensor in the extended method; the blue line represents the simulated values while the orange one represents the measured values with a band of 2 dB error by side (dotted)

In this scenario the effect is almost neglectable due to the length of the SUMO edges, therefore the noise produced by the other roads is attenuated below the noise produced by the edges we are interested in. We report in figures 4 and 5 the shortest of the edges with the first and second method respectively. The effect in that location is also amplified because the street is positioned between two near tall buildings.

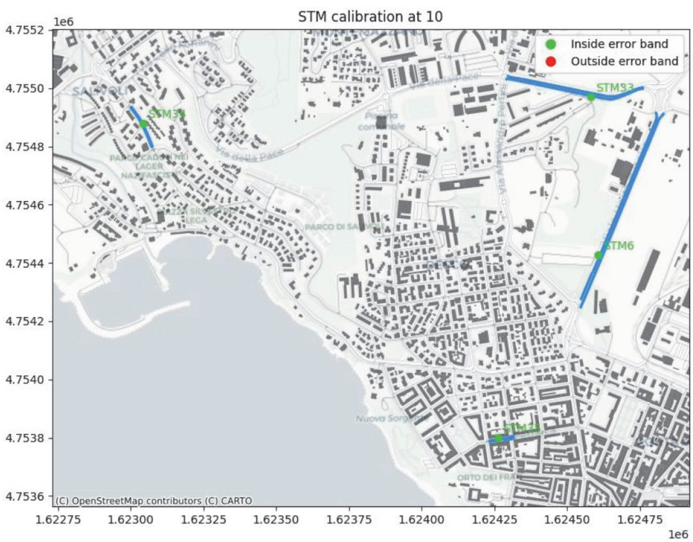

Figure 6 Acoustic calibration results, simulated with traffic measurement at 10 AM in the site; green dot means that the simulated value lies between a 2 dB range from the measured value; in blue are highlighted the roads under study

3 Conclusion

The aim of the study was to obtain reliable traffic data on which noise exposure levels could be modelled to build dynamic maps that would allow for network intervention to minimize exposure. The model's reliability has been demonstrated by other articles [15], enabling traffic levels to be estimated in areas without measures. At points where no measures are available, using a traffic model increases the accuracy of traffic estimates [16]. In fact, traffic level forecasting methods based on road categorization and attributing the same traffic values to defined groups of roads are unable to assess traffic evolution during the day, which is strongly influenced by the local scenario of a port city.

This paper demonstrates that our pipeline is effective and produces sound levels that are consistent with measurement (and therefore with actual traffic noise), which highlights the significance of utilizing traffic distributed across all the road network. In our scenario, the observed little difference with the measured values could be related to the long length of our roads, but it could be more important in shorter streets as shown above in the sensor STM35 case.
Further investigation is necessary for low traffic volumes, particularly at night, when traffic conditions change with an increase in transit speed and their sparseness in time. Under such conditions, speed estimates are affected by driver behaviour and local road conditions, and noise models themselves have difficulties reproducing the measurements in this condition.

Acknowledgements

The present work has been developed as part of the national project PNC - PREV-B-2022-12376988 - CUP E55I22000370001 - “Sostenibilità per l’ambiente e la salute dei cittadini nelle città portuali in Italia” (SALPIAM), under the Italian PNC-PNRR financial framework.

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