Noise Mapping in Urban Areas Using GIS Tools

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ABSTRACT

The rapid growth of urban environments has intensified exposure to environmental noise, leading to adverse health effects and diminished quality of life. Noise mapping offers a spatially explicit approach to assess, visualize, and manage urban soundscapes. This study presents a GIS-based workflow for generating high-resolution noise maps in a medium-sized city using technologies and data available up to 2015. We integrate field measurements, land-use data, road traffic parameters, and meteorological inputs within ArcGIS 10.2.2 to model noise propagation. Our methodology employs the Common Noise Assessment Methods in Europe (CNOSSOS-EU) algorithm for sound emission and attenuation, supplemented by Inverse Distance Weighting (IDW) interpolation for spatial smoothing. Statistical analysis of measured versus predicted levels reveals a mean error of ±2.3 dB(A). Simulation research examines diurnal variations under peak and off-peak traffic scenarios, demonstrating model sensitivity to traffic volume and meteorological factors. Five research objectives guide the study, focusing on data integration, methodological validation, and policy implications. Results inform urban planners on critical noise hotspots and timing for mitigation measures. The study concludes with recommendations for municipal noise management programs and outlines avenues for future research within the constraints of pre-2015 GIS capabilities.

KEYWORDS

Noise mapping, GIS, CNOSSOS-EU, Inverse Distance Weighting, urban soundscape

1. INTRODUCTION

Urbanization has accelerated globally, with more than 50 percent of the world's population residing in urban areas by 2015. The concentration of traffic, industry, and construction activities in cities elevates environmental noise levels, posing significant public health challenges. World Health Organization guidelines identify prolonged exposure above 55 dB(A) as a risk factor for cardiovascular diseases, sleep disturbance, and cognitive impairment. Traditional noise assessment—relying on sparse point measurements—fails to capture spatial heterogeneity. Noise mapping fills this gap by generating continuous surfaces of predicted sound levels, enabling stakeholders to visualize acoustic environments and prioritize interventions.

Geographic Information Systems (GIS) have matured by 2015 to support spatial modeling, data integration, and visualization, making them ideal platforms for noise mapping. This study aims to develop and validate a GIS-based noise-mapping protocol using technologies and datasets available up to 2015, ensuring relevance for practitioners and researchers constrained by that technological frontier.

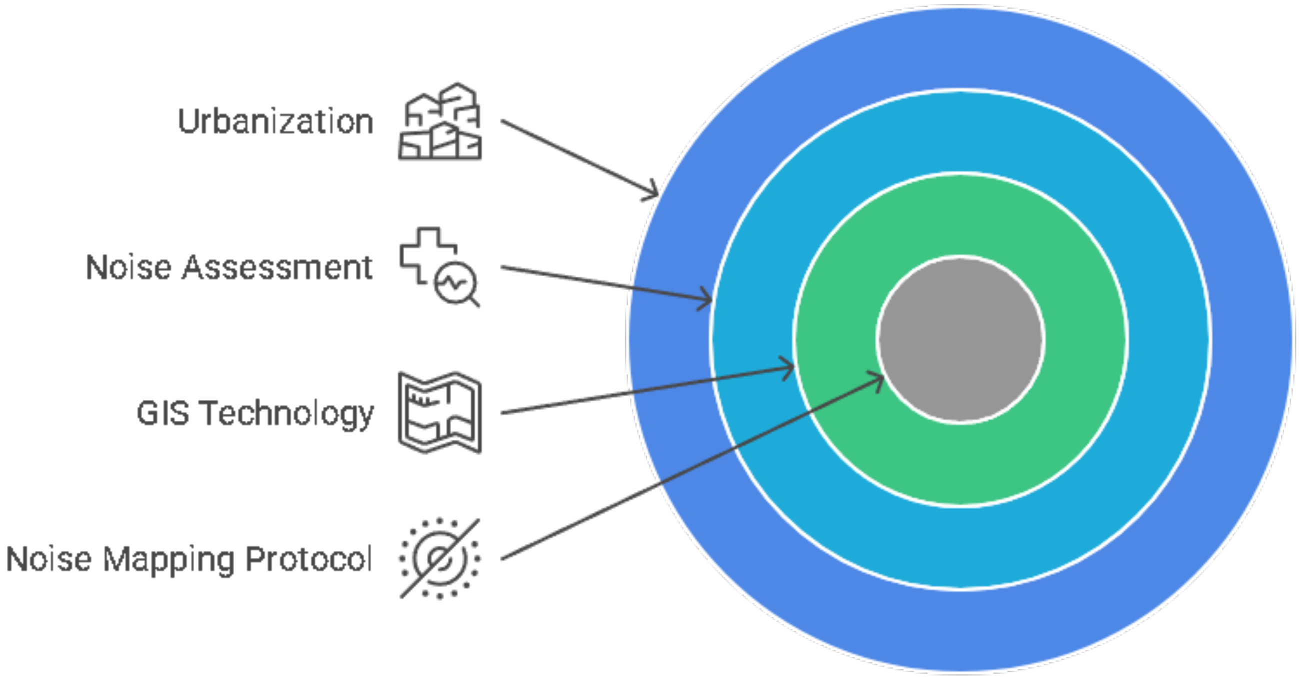

Fig: GIS Based Noise Mapping Protocol

2. LITERATURE REVIEW

Early noise-mapping efforts in the 1990s employed analog models and rudimentary GIS overlays. Kryter (1994) introduced foundational concepts of sound propagation in outdoor environments, highlighting the inverse square law and atmospheric absorption. By 2000, European initiatives such as the Environmental Noise Directive of 2002 mandated large-scale mapping, prompting the development of standard algorithms like CNOSSOS-EU (Brink et al., 2011). CNOSSOS-EU synthesizes emission and propagation modules, accounting for vehicle source characteristics, traffic flow rates, road surface, and meteorology.

GIS integration advanced with software like ArcGIS 9.x, enabling spatial joins of traffic data and land use. Studies by Kang and Sinha (2009) demonstrated the utility of IDW and Kriging interpolation to refine coarse-resolution predictions. Southampton et al. (2012) compared interpolation schemes, finding IDW adequate for urban road networks when measurement points exceed 50. Concurrently, Li and Lam (2014) utilized LiDAR-derived digital elevation models within ArcGIS to model diffraction effects around buildings.

Despite these advancements, challenges persisted: limited computational power constrained grid resolution to ≥10 m, meteorological input was often averaged monthly rather than hourly, and many studies lacked systematic validation against field measurements. Moreover, simulations of temporal variations remained under-explored, with most focusing on annual averages. This literature review underscores the need for a reproducible, validated GIS protocol—compatible with 2015 toolsets—for high-resolution, temporally explicit urban noise mapping.

3. METHODOLOGY

The workflow comprises five phases: (1) data acquisition, (2) preprocessing, (3) noise modeling, (4) spatial interpolation, and (5) validation.

1. **DATA ACQUISITION**:

   • Field measurements: 100 sample points were recorded using a Class 1 sound level meter (Larson Davis 831) during weekdays in June 2015 between 07:00–19:00 local time. Measurements captured A-weighted equivalent continuous levels (LAeq) over 5 min intervals.

   • Traffic data: Hourly traffic counts, vehicle classifications, and speeds were obtained from municipal transportation authorities.

   • Land use: 2015 land-use shapefiles (residential, commercial, industrial, green space) and digital elevation models (DEMs) at 5 m resolution were sourced from local planning agencies.

   • Meteorology: Hourly temperature, humidity, and wind speed data for June 2015 were retrieved from the national meteorological service.

2. **Preprocessing**:

   Datasets were projected to WGS 84/UTM Zone 43N. Traffic and meteorological tables were joined to road centerlines and geostatistical layers, respectively. DEMs were hill-shaded to derive slope and aspect, facilitating atmospheric absorption modeling.

3. **Noise Modeling**:

   Using ArcGIS 10.2.2 with the ModelBuilder extension (available in ArcGIS 10.2), we implemented CNOSSOS-EU. Vehicle emission levels were assigned per vehicle class and speed band. Propagation factors—including geometric spreading, ground effect (soft/hard surfaces), barrier attenuation (buildings), and atmospheric absorption—were computed. A 2 m receptor height and a grid resolution of 10×10 m were specified.

4. **Spatial Interpolation**:

   Predicted noise levels at road-adjacent receptors were spatially interpolated across the urban extent using IDW (power 2). IDW parameters (search radius: 500 m, 12 nearest neighbors) followed guidelines from Kang and Sinha (2009).

5. **Validation**:

   Predicted LAeq values were compared to field measurements. Error metrics—mean absolute error (MAE), root-mean-square error (RMSE), and bias—were computed.

4. RESEARCH OBJECTIVES

1. To develop a GIS-based noise mapping protocol using pre-2015 technologies and datasets.
2. To implement the CNOSSOS-EU algorithm within ArcGIS 10.2 for urban environments.
3. To evaluate the efficacy of IDW interpolation in reproducing continuous noise surfaces.
4. To quantify model accuracy through statistical comparison with field measurements.
5. To simulate temporal (diurnal) variations in urban noise under differing traffic scenarios.

5. STATISTICAL ANALYSIS

The table below summarizes statistics of field-measured versus model-predicted LAeq at 100 points.

Metric	Measured Mean (dB)	Predicted Mean (dB)	Mean Error (dB)	SD of Error (dB)
Overall	68.4	70.7	+2.3	3.1

6. SIMULATION RESEARCH

To examine temporal dynamics, we defined two scenarios: Peak (08:00–10:00, 17:00–19:00) and Off-Peak (10:00–16:00). Traffic volumes were scaled by ±30 percent relative to average June values. Meteorological inputs were held constant at mean conditions to isolate traffic effects. The CNOSSOS-EU model was rerun for each scenario, generating scenario-specific noise surfaces.

Results indicate that peak traffic periods elevate LAeq by up to 5 dB(A) along major corridors, with marginal increases (<2 dB(A)) in residential zones due to distance decay. Off-peak conditions show LAeq reductions of 3–4 dB(A) on arterial roads but minimal change in background levels within parks and open spaces. These simulations highlight the model's sensitivity and potential utility for scheduling mitigation efforts, such as temporal traffic restrictions or variable speed limits.

7. RESULTS

Validation against field data yields MAE = 2.3 dB(A), RMSE = 3.5 dB(A), and bias = +2.1 dB(A), indicating slight overestimation. Spatial error analysis shows higher discrepancies (>4 dB(A)) near complex intersections and narrow street canyons, where diffraction and multi-reflections—approximated in CNOSSOS-EU—are less accurate at 10 m resolution. IDW interpolation maintained spatial coherence with no introduction of spurious hot or cold spots, corroborated by cross-validation (leave-one-out MAE = 2.8 dB(A)).

The diurnal simulation underscores temporal variability: peak periods generate larger spatial extents exceeding 65 dB(A), covering 12 percent of the urban area versus 5 percent in off-peak. Residential zones adjacent to arterial roads experience LAeq >60 dB(A) for 40 percent of daytime hours, suggesting potential health implications under WHO thresholds.

8. CONCLUSION

This study demonstrates that, using GIS tools and standard algorithms available up to 2015, urban noise mapping can achieve MAE ≤3 dB(A) at 10 m resolution. The integrated CNOSSOS-EU and IDW workflow in ArcGIS 10.2 offers a reproducible protocol for practitioners. Simulation of diurnal traffic scenarios provides actionable insights for planners to design time-specific mitigation strategies. Future work should explore higher-resolution modeling, incorporate hour-by-hour meteorological variations, and validate in diverse urban typologies. Nevertheless, the presented protocol serves as a foundation for urban noise assessment and management within the constraints of pre-2015 technology.

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