Urban Noise Mapping: 
The Case of the City of El-Mina, North Lebanon

By Amal Iaaly-Sankari, Oussama Jadayel and Nicolas El-Murr
GIS Center, 
Faculty of Engineering, 
University of Balamand, 
P.O. Box: 100, Tripoli, 
Lebanon
amal.iaaly@balamand.edu.lb
oussama.jadayel@balamand.edu.lb
nicolas.murr@balamand.edu.lb

Abstract

Noise has always been a major environmental stressor in urban areas. The ability to measure ambient noise levels and represent them on a map should provide a powerful tool for spatially identifying noise sources, its spread, its impact and make decisions relating to its control and management. As such, geographical information technologies become very useful tools in noise mitigation.

The GIS Center at the University of Balamand has identified the city of El-Mina, North Lebanon, as a typical mixed-use urban environment in which noise sources are diverse. These range from road transport activities to small-scale industries to construction activities, in addition to road retail, social and recreational activities, etc. The Balamand team used noise sensors and global positioning systems in order to spatially construct the noise map of the city. A total of three hundred and fifty points were recorded, together with information relating to the causes and effects over the 3.5 km² of the town and over different times of the day.

Daily averages were taken and it was found that 68 % of localities experienced noise levels in excess of 70 dBA while the acceptable level should not exceed 55 dBA. Maps were drawn showing the spatial distributions of noise and classified by source. It was concluded that traffic was the main contributor to such type of pollution. The object of this paper is to report these measurements and discuss how the methodology may further be developed and extended to other sites.

Keywords: Ambient Noise, Noise Contours, Inverse Distance Weighted (IDW), Spatial Analysis

1. INTRODUCTION

Noise has gradually and steadily increased as civilization advanced and is considered among the most pervasive and frustrating sources of everyday annoyance. Noise is considered an environmental pollutant because of the danger it poses to health and the way it affects our well being and quality of life. It differs from any other forms of pollution since it is transient; once the noise stops, the environment is free of it.

Since noise has many spatial components, the use of GIS provides an attractive and appropriate platform for its mitigation. With advanced interpolation techniques in GIS it is now possible to obtain an accurate picture of the acoustic situation and Noise Risk Zones (NRZ) based on a finite number of sample points recorded using noise level meters.
The key aim of this work is to draw the noise map of the city of El-Mina. It also intended to ascertain the extent to which people in the city perceive noise to be a problem and identify which noise sources have the greatest effect.

2. BACKGROUND

2.1 El-Mina city Profile

El-Mina occupies a total surface area of 3.5 km². The city acts as a hub for merchants and cargo ships on the trade circuit between North Africa and Europe and has the second largest harbor in Lebanon. It encompasses a chain of road network and contains a small industrial zone located near the harbor. The city attracts many tourists due to its rich historical heritage.

Figure 1. A map of El-Mina city in Lebanon showing its various demographic aspects.

El-Mina contains both ancient and modern quarters vivid with commercial and industrial activities. The following figures give a general idea about the status of El-Mina city:
<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Street Length</td>
<td>64 km</td>
</tr>
<tr>
<td>Number of Buildings</td>
<td>1690</td>
</tr>
<tr>
<td>Number of Habitat ional Units</td>
<td>10150</td>
</tr>
<tr>
<td>Number of Commercial Units</td>
<td>1590</td>
</tr>
<tr>
<td>Number of Industrial Units</td>
<td>220</td>
</tr>
<tr>
<td>Number of Handicraft Units</td>
<td>630</td>
</tr>
<tr>
<td>Number of Banks</td>
<td>4</td>
</tr>
<tr>
<td>Number of Hospitals</td>
<td>3</td>
</tr>
<tr>
<td>Traffic Volume on El-Mina Roads</td>
<td>18,000-24,000 veh/day</td>
</tr>
<tr>
<td>Traffic Volume on Beirut –Tripoli Motorway</td>
<td>30,000 veh/day</td>
</tr>
</tbody>
</table>

2.1- Ambient Noise

Ambient noise is often referred to as environmental noise. It is the noise that one hears in day to day life and does not include workplace noise. The present study of El-Mina concentrates on the noise that people hear when about their homes. This is generally made up of noise from transportation, commercial activities, construction activities, out-door leisure activities, etc.

2.2- Noise Quality Criteria

A large degree of international consensus has emerged over the years as to what constitutes unacceptable levels of noise exposure. At the international level the World Health Organization (WHO) together with the Organization for Economic Co-operation and Development (OECD) are the main bodies that have collected data and developed their own assessments on the effects of exposure to environmental noise. On the basis of these assessments guideline values for different time periods and situations have been suggested.

In the mid 1980s the OECD reported the thresholds for noise nuisance as equivalent average sound levels (LAeq) measured in day-time:

- At 55-60 dB(A) noise creates annoyance;
- At 60-65 dB(A) annoyance increases considerably;
- Above 65 dB(A) constrained behavior patterns, symptoms of serious damage caused by noise arise.

The World Health Organization has suggested a standard guideline value for average outdoor noise levels of 55 dB(A), applied during normal daytime (16 hours) in order to prevent significant interference with the normal activities of local communities, and is considered as serious annoyance, while a value of 50 dB as moderate annoyance.

The following table shows the WHO Guidelines values for Community Noise listing also critical health effects ranging from annoyance to hearing impairment.
Table 2. WHO guidelines for community noise.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Critical health effect</th>
<th>Sound level dB(A)</th>
<th>Time hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor living areas</td>
<td>Annoyance</td>
<td>50 - 55</td>
<td>16</td>
</tr>
<tr>
<td>Indoor dwellings</td>
<td>Speech intelligibility</td>
<td>35</td>
<td>16</td>
</tr>
<tr>
<td>Bedrooms</td>
<td>Sleep disturbance</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>School classrooms</td>
<td>Disturbance of communication</td>
<td>35</td>
<td>During class</td>
</tr>
<tr>
<td>Industrial, commercial and traffic areas</td>
<td>Hearing impairment</td>
<td>70</td>
<td>24</td>
</tr>
<tr>
<td>Music through earphones</td>
<td>Hearing impairment</td>
<td>85</td>
<td>1</td>
</tr>
<tr>
<td>Ceremonies and entertainment</td>
<td>Hearing impairment</td>
<td>100</td>
<td>4</td>
</tr>
</tbody>
</table>

3- URBAN NOISE SURVEY METHODOLOGY

Since noise is transient, the noise levels over an area will be varying all the time. In the slightly longer term, ambient noise levels may be higher in peak periods and lower in off-peak periods; therefore an average value must be taken over a long period of time. To achieve this, the GIS Center recorded noise levels at various sites in El-Mina.

Field work was carried out, in March-June 2007 within the 3.5 km$^2$ of El-Mina. All measurement was carried out at five minutes intervals through eight hours for one day at each measurement point (average value was used in the GIS calculation). Main junctions of the city were selected as major sampling points. Within the radius of these sites, the team recorded the geographical location using a GPS along with the noise level. A survey with a comprehensive yet brief questionnaire was conducted. The survey sheet contained questions about all major effects of noise on people and all predominant sources of community noise.

It must be said that the survey did not emphasize the evaluation of any single noise source, but specifically intended to record ambient noise level and assess community reaction over broad ranges of noise exposure conditions.

Thus, the data offer a general comprehensive assessment of public reaction to noise exposure. A total of one hundred and ten interviews of randomly selected respondents were conducted at the sites of measurement.

4- GIS NOISE MAPPING

The aim of this work is to create a Noise Map of El-Mina City in order to identify any NRZ. In order to achieve the El-Mina Noise map, a clear methodology had to be adopted. Such methodology comprised the following steps:

• Step 1: Mapping of GPS collected data along with noise levels, taking the average noise level value as a reference.
• Step 2: Designing a spatial database for noise effect studies based on the noise survey sheet.
• Step 3: Spatial modeling and application of advanced interpolation techniques in GIS to obtain an accurate picture of the acoustic situation based on a limited number of sample points in addition to isonoise.
• Step 4: Set noise risk criteria in order to spot noise risk zones.
4.1 GPS Data Mapping

The data collected was mapped into the GIS and displayed on the cadastral map of the city. The distance between points varied from 50 m in highly populated area to 150 m in less populated regions.

![Figure2. Noise measurement points in El-Mina city.](image)

Each point contains the following attribute data:
1- Geographical coordinates
2- Location
3- Date and time of collection
4- Duration of collection
5- Maximum recorded noise level
6- Minimum recorded noise level
7- Average noise level
8- Major source of noise

4.2 Spatial Database Development

To support noise effect studies a simple spatial database with the relevant geographical information was designed. This database was based on collected information and the results are sensitive to the level of details collected in the survey. This spatial database is made of four tables:
1- GPS Noise Location: contain the geographic location of points where noise levels were recorded. It contains a location ID (LID) that is used as a geographical indicator to link the database all together.
2- Noise level readings: contains noise readings in dB.
3- Noise sources: contains survey information concerning major noise sources.
4- Noise Impacts: contains survey noise impact on human health and behavior.
4.3 Spatial Modeling

There are a number of spatial modeling methods available with respect to application, by virtue of effective GIS tools. Here the purpose of building spatial models is to identify the spatial distribution of the noise pollution.

4.3.1 Surface interpolation via IDW

Surface interpolation uses a defined or selected set of all the samples to estimate each of the output grid cell values. Inverse Distance Weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. IDW allows controlling the influence of known points, upon the interpolated values, based upon their distance from the output point. This method provided accurate weighted interpolated surface grid.

4.4 Risk Evaluation Criteria

For the purpose of spotting Noise Risk Zones (NRZ) in El-Mina City, the following evaluation criteria was adopted which resulted Six Zones based on noise intensity levels.

<table>
<thead>
<tr>
<th>Intensity of Noise in dB(A)</th>
<th>Safe</th>
<th>Tolerable</th>
<th>Low Risk</th>
<th>Moderate Risk</th>
<th>High Risk</th>
<th>Extremely High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66 – 71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>71 – 76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76 – 81</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81 – 86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater than 86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. RESULTS AND DISCUSSION

As shown in the following figure, noise level in the urban center (core city) was unbearable. The internationally accepted tolerable range of 60 to 70 dB (A) had been far exceeded. Traffic congestion points as well as the industrial zone are highly noisy depending on the source of noise emission.

![Figure 4. Noise Risk Zones in El-Mina city.](image)

Triangulated Irregular Networks (TIN) datasets was derived from the IDW noise surface using 3D analyst tools. The TIN datasets contain irregularly spaced points that have a z-value that describes the noise intensity at that point. The resulting triangular mosaic forms a continuous faceted surface, where each triangle face is shaded by noise level intensity.

![Figure 5. Raster TIN of noise intensity in El-Mina city.](image)

In order to generate noise contour lines or isonoise, it is preferable to use TIN surface noise model rather than the IDW noise model. One disadvantage with grid-based contours (i.e.
IDW) is that control point data may not exactly fit the contours, because the contours are based on the calculated cell values that are one step removed from the control data. In contrast, contours from a TIN surface model are based on the irregularly spaced control data.

![Figure 6: Isonoise or noise contour lines in El-Mina city.](image)

The following chart shows the percentage of sites in each noise risk zone based on the maximum recorded value:

![Figure 7. Noise risk sites percentage. (Values in dB (A))](image)
As shown in the following figure, it was found that the major source of noise pollution comes from traffic flow in 86% of the noise measurement sites.

![Figure 8. Major source of noise pollutant.](image)

Based on the survey, all questioned citizens living in El-Mina were annoyed by the noise, which affects each individual differently. The following figure shows the public reaction of the extent to which noise affects social behavior, psychology and health.

![Figure 9. Noise impact assessment](image)

6. CONCLUSIONS

In this paper, it may be seen that GIS provided an ideal tool for identifying NRZ. The work provided a basis for a comprehensive study of noise pollution and a proper platform for result interpretation. Ambient noise levels recorded were seen to be much higher than acceptable standards. The methodology developed herein could easily be applied in similar urban settings.

Further work could be carried out in order to investigate the temporal variation of noise levels, whether on daily, weekly, or even monthly bases. Additionally, assessment of noise impact on residents could benefit from further assessment and correlation with other social and environmental stressors.
Acknowledgements

The authors would like to thank the following organizations and persons:

• The El -Mina Municipality for approving and supporting survey field work.
• The University of Balamand for providing its facilities for the success of the present work.
• Students of the University of Balamand who, through their dedication and enthusiasm, made this work possible.

References

http://www.nonoise.org/library/eunoise/greenpr.htm
http://www.who.int/mediacentre/factsheets/fs258/en/