

# The Use of Real Measurements and GPS Data for Noise Mapping of Riyadh City

M. A. Foda, K. A. Alsaif, M. M. ElMadany, and A.S. Aguib

**Abstract**—In this paper, the noise maps for the area encircled by the Second Ring Road in Riyadh city are developed based on real measured data. Sound level meters, GPS receivers to determine measurement position, a database program to manage the measured data, and a program to develop the maps are used. A baseline noise level has been established at each short-term site so subsequent monitoring may be conducted to describe changes in Riyadh's noise environment. Short-term sites are used to show typical daytime and nighttime noise levels at specific locations by short duration grab sampling.

**Keywords**—Noise mapping, Noise measurements, GPS, noise level.

## I. INTRODUCTION

THE Greater City of Riyadh comprises extended urbanized areas in all directions that have grown rapidly in the last years, and it is expected that this growth will continue in the future. In particularly, more and more people are choosing to live in Riyadh. With this fundamental shift in the demographic comes the potential between lifestyle and the intrusion of existing or future noise sources in the community. These lead to increase in noise pollution like big cities in other parts of the world. Environmental noise, caused by traffic, construction, industrial and recreational activities is among the main local environmental problems in Riyadh and the source of an increasing number of complaints from the public. Therefore, King Abdulaziz City for Science and Technology (KACST) has recently considered noise mapping of different cities in the Kingdom and noise monitoring and mitigation as part of its research-supporting priority. The European Directive 2002/49/EC [1] on the assessment and management of environmental noise requires drawing of noise maps of communities with more than 100,000 inhabitants and of the area near major transport infrastructures for the purpose of assessment of noise outdoors. Bento Coelho and Alarcao [2] presented case studies of large scale noise mapping drawn for

cities of Lisbon, Almada, Loures and Albufeira in Portugal. They discussed the problems encountered in collecting data, data management and optimization and its impact on the precision of the final maps. Bite et al. [3] have discussed the Budapest noise mapping project which was contracted by LARMKONTOV GmbH. Their aim was to assess the methods used to collect noise data and the splitting of Budapest city into six districts each was taken as a pilot area for a typical noise source. Ramos Pinto et al. [4] have developed the noise maps for two different areas in Portugal: Carregada area in Alenquer city and Queijas area in Oeiras city. The noise software MITHRA is used to predict the noise indicator  $L_{Aeq}$  in dB for day and night periods. Stapelfeldt et al. [5] studied the quality of noise maps of Birmingham and Bonn and pointed out that the maps require a fairly high standard of accuracy and the data must be reproducible and traceable and all the steps of drawing the maps should be clearly documented. Foda et al. [6] developed a noise map based on real measurements for the area enclosed by the First Ring Road in Riyadh City. Solea and Arghir [7] developed the noise map for pilot zone of the great city of Cluj-Napoca, Romania using actual measurements and calculation using Sound Plan. Wei et al. [8] studied the noise pollution in an area covers a range within 200 meters from both sides of the high ways and express ways in the center of Beijing city surrounded by Fifth Ring Road.

## II. RESEARCH METHODOLOGY

### A. Methodology for Gathering Noise Measurement Data

The methodology for gathering noise measurement data, reduction, and analysis is outlined below:

1. An extensive measurement program was launched for the purpose of compiling noise load distribution maps for the city of Riyadh, which showed contour lines of daytime/nighttime equivalent noise levels. The maps summarize results of short-term measurements. The information could, at a later stage, be used to develop computer simulation models, which help assess future noise levels as resulting from new noise abatement and road-building projects.
2. A sufficient number of short-term sites was selected, and then was used to provide the data necessary to fulfill the survey objectives. The short-term sites were continuously monitored for 20 minutes during the daytime hours and 20 minutes during the nighttime hours. The praying time and the rush hours were excluded.

M. A. Foda is with the Department of Mechanical Engineering, King Saud University, Riyadh, 11421, Saudi Arabia (phone: 966-14676824; fax: 966-14676652; e-mail: mfoda@ksu.edu.sa).

K. A. Alsaif is faculty at the Department of Mechanical Engineering, King Saud University, Riyadh, 11421, Saudi Arabia. He is now full time consultant at the national robotics center, King AbdullAziz City for Science and Technology, Riyadh (phone: 966-14676824; fax: 966-4676652; e-mail: alsaiif@ksu.edu.sa).

M. M. ElMadany is with the Department of Mechanical, King Saud University, Riyadh, 11421, Saudi Arabia (phone: 966-14676666; fax: 966-4676652; e-mail: mmadany@ksu.edu.sa).

A S. Aguib is with the Department of Civil Engineering, King Saud University, Riyadh, 11421, Saudi Arabia (phone: 966-14673693; fax: 966-14805063; e-mail: aaguib@ksu.edu.sa).

3. Existing land data were obtained from the local authorities.
4. The following geographical data were obtained:
  - Ordnance Survey Landline digital map data.
  - A scale map of the city of Riyadh.

#### B. Selection of Measurements Locations

In choosing locations to perform measurements, some criteria have been set forth and met. These criteria are as follows:

1. The locations chosen must contain all zones included but not limited to residential, commercial, and industrial. These zones must be contained within at least one of the specified locations.
2. The locations must be adjacent to one another, so each location is somewhat relative to other.
3. For a block of building, the cornered area is measured.
4. Locations along busy roads and busy intersections that pass a high volume of traffic daily.
5. Locations are to be no more than 150 meters apart.
6. Each location must be able to satisfy the measurement process that explained in Section D.3.

#### C. Measurement Taking Protocol

Measurements for this study were taken as follows:

1. At each location, there were measurements at two shifts of the day for no less than 20 minutes a session during daytime shifts and no less than 20 minutes during nighttime shifts. These shifts are defined as follows:
  - a- Daytime shift: 7:00 a.m. to 12:00 noon
  - b- Nighttime shift: 6:00 p.m. to 12:00 p.m.
2. All measurements were taken on weekdays (working days): Saturday through Wednesday.
3. Each measurement was taken once, for the full 20 minutes, unless circumstances deem others, and the measurements were not taken during praying times.
4. The measurements taken at each site contained a real time dB (decibel) read out. The dB measurement was taken with A-weighting.
5. If there was abnormal noise at any location, the time history of that noise during longer periods was recorded for further analysis of its frequency content. In addition, a written description of the object(s) producing the noise was described.
6. The microphone was supported 1.5m above the ground at each measuring site.

#### D. Noise Mapping System

For the purpose of developing noise maps for Riyadh city, a system is introduced to easily produce a noise map using noise and GPS data measured simultaneously. The system consists of a sound level meter, a GPS receiver, a database program to manage the measured data, and a program to produce the noise map including a model of the area. All the components of the system have their own interface functions to transfer one or more measured data with minimal human interface. The system allows noise mapping for any quantities of sound pressure levels, in broadband and in one or one-third octave

bands, measured at user-defined irregular locations by importing all the concurrently measured items from the sound level meter and producing noise contour maps by ArcView-ArcMap software through the use of the Natural Neighbor method for interpolation. The produced noise map can be exported to SHP files, with other possible modeling items, for post-processing in GIS software.

##### 1. Sound Level Meter and GPS Receiver

The noise mapping system, in principle, allows using any sound level meter because the measured data can be registered manually. However, noise mapping based on measurement must include many measure points to obtain a complete picture of the noise situation. Hence, sound level meters that providing data storage and communication functions are preferred. Moreover, to automatically correlate the measured noise and position data, it is preferred that the sound level meter can interface with a GPS receiver. The selected sound level meter NL-32 provides such functions. It has an internal disk for storing its application software, user-defined set-ups and measurement data consisting of the measured sound levels, measurement time, and position data imported from a GPS receiver. Its memory size can be extended by attaching an external memory card, which allows storage of hundreds of measurement data. The sound level meter supports interfacing a GPS receiver. The spatial position of each observation point was determined using the hand held Garmin GPS with a precision of 5-10m in absolute point positioning. The coordinate of each observation point was recorded in geographic system (latitude and longitude) in the WGS84 global system.

##### 2. Measurement Database Module

The measurement data can be used for various purposes. Hence, one or more measurement data, prior to using them for noise mapping, are selectively imported to measurement database module from the sound level meter. The selected data stored in the sound level meter, including concurrently evaluated sound levels such as  $L_{Aeq}$ ,  $L_{AE}$ ,  $L_{Amax}$ ,  $L_{Amin}$  and other are imported with GPS data at once. In the database module, one can enter additional information/observations related to the measurement, as text, for the measurement point.

##### 3. Data Collection and Preparation

Data collection points had been distributed along the main roads within the study area. The points could be located sometimes on the edge of one side the road and sometimes on the island of the road wherever found. The total number of observed points (short-term sites) for this project was 5284, with each point was being occupied twice for noise measurements; one during the daytime and the second during the nighttime. The data collectors used the same observation point locations for day and night measurements in order to obtain precise comparison among the results. At the time of finishing the field work, all the data for the study area were collected in one file to be presented and mapped on Riyadh Map. The map used for presenting the noise distribution is a recent colored IKONOS image for Riyadh City obtained from

King Abdul-Aziz City for Science and Technology (KACST). The image has a 1m resolution and was acquired in 2008. The image was referenced to Ain AlAbd Datum of Saudi Arabia in UTM projection, therefore a transformation was applied to the image to the WGS84 system in UTM projection to be

consistent with the coordinate system of each field data point's position obtained from the Garmin GPS. The transformation was applied using the Earth Resources Data Analysis System (ERDAS) software.

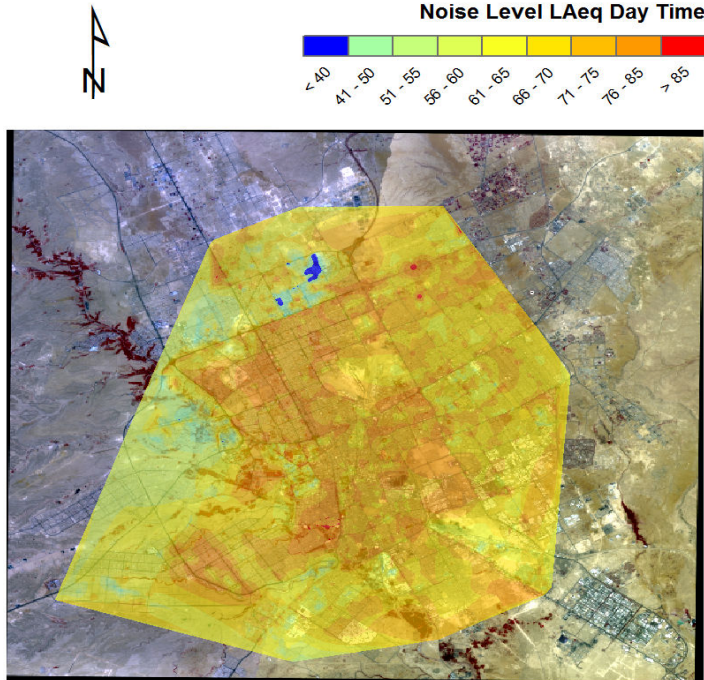


Fig. 1 Riyadh city noise map:  $L_{Aeq}$  (daytime)

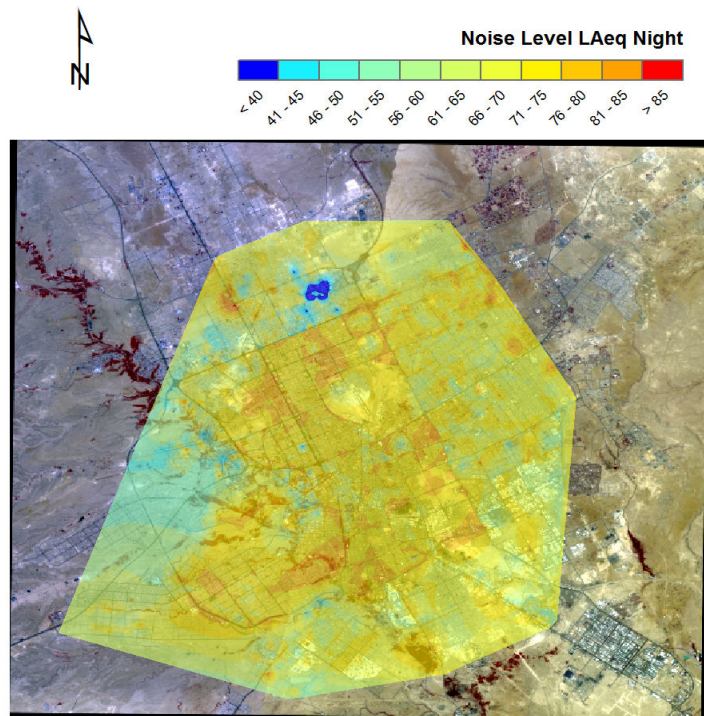


Fig. 2 Riyadh city noise map:  $L_{Aeq}$  (nighttime)

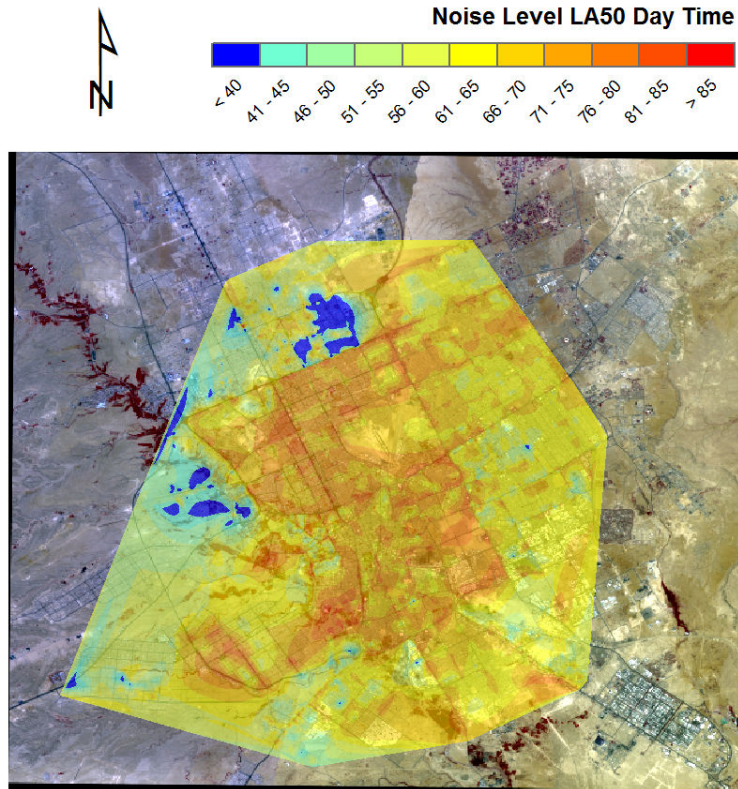


Fig. 3 Riyadh city noise map:  $L_{A50}$  (daytime)

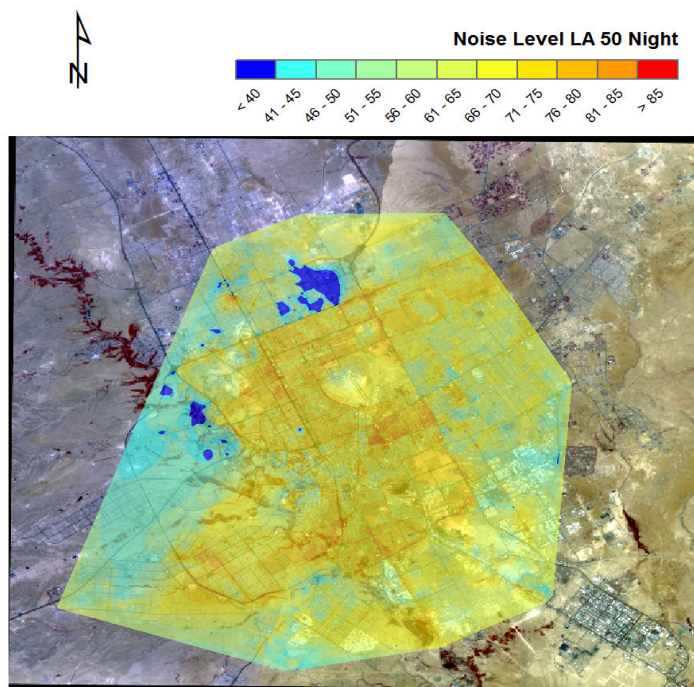


Fig. 4 Riyadh city noise map:  $L_{A50}$  (nighttime)

#### 4. Noise Mapping Module Using Measurement Data

The noise and GPS data measured are imported from the measurement database module. Then, choosing one of acoustic parameters measured generates a noise map of the area as color-coded maps by using the ArcGIS9 software, particularly ArcMap version 9.2. The IKONOS image of Riyadh was set as a backdrop while the data of observation points were put on top of it using its global coordinates for positioning as X, Y coordinates and the sound level observations as Z values. These points were located along the main roads. Distribution of the noise levels in areas among the main observed road was made using a module named 3D Analyst that is an extension to ArcView-ArcMap software. The Natural Neighbor method [9] is used for interpolation. This method finds the closest subset of input samples to a query point and applies weights to them based on proportionate areas in order to interpolate a value. Its basic properties are that it is local, using only a subset of samples that surround a query point, and that interpolated heights are guaranteed to be within the range of the samples used. It adapts locally to the structure of the input data, requiring no input from the user pertaining to search radius, sample count, or shape. It can be considered that the noise distribution maps produced from this research work are highly representing the actual noise levels at the close surroundings of measured roads and to a less degree for farther areas.

### III. RESULTS

The total numbers of measurements is 5284 during the daytime and a similar number of measurements during the nighttime are used to develop noise maps for the city of Riyadh. Typical  $L_{Aeq}$  noise maps are shown in Figs. 1 and 2 for daytime and nighttime, respectively. Noise maps for  $L_{A50}$  are depicted in Figs. 3 and 4. Noise levels, in general, remain over 50 dBA in the daytime and nighttime. It can be observed that the average noise levels during daytime and nighttime are comparable. In addition, one can intuitively observe that severe noise over 70 dBA mainly occurs at the nearside of major roads and highways. Several hot spots with high level of noise can be identified. The area in the north-west (Al-Olyya District), downtown area, is subject to a high level of noise with  $L_{Aeq}$  of over 75 dBA daytime and nighttime. This area is characterized by the intersections of several main roads, including King Fahd road, Imam Bin Abdullah Bin Saud road, and King Abdullah road. The area in the mid-south west (Al-Shemaysi and Al-Bat'ha Districts), "downtown" which also contains an industrial zone, is exposed to noise level  $L_{Aeq}$  above 75 dBA. An area of high noise level is also observed at the northeast that is characterized by the intersections of four main roads.

### IV. DISCUSSION AND CONCLUSIONS

A noise mapping system using measured noise and GPS data are introduced and applied for producing the noise maps for the city of Riyadh; the area enclosed by the first and second Ring Roads. The system consists of a sound level

meter, a GPS receiver and software modules. It imports and manages measured data and produces a noise map, using any noise quantities measured over the enclosed area. The quality of developed noise maps depends on the number and accuracy of the measured data. The functionality and capability of the developed system have been demonstrated through the production of the noise maps. The results revealed that Riyadh city, in general, suffers serious noise pollution. In this exercise, road traffic is identified as the dominant source of noise followed by industrial, leisure, and then rail sources. Therefore, action in respect of these sources, if practicable, offers the prospect of the greatest improvements.

### ACKNOWLEDGMENTS

The National Plan for Science and Technology (NPST-KSU), the Kingdom of Saudi Arabia has supported this work under Grant number: ENV1182-02. These supports are greatly appreciated.

### REFERENCES

- [1] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, L 189, 2002, pp.12-25.
- [2] J. L. Bento Coelho and D. Alarcao, "Noise mapping in large cities in Portugal", *Twelfth International Congress on Sound and Vibration*, Lisbon, Portugal, July, 2005.
- [3] P. Bite, M. Bite, M. and I. Dombi, "The Budapest mapping project", *Twelfth International Congress on Sound and Vibration*, Lisbon, Portugal, July, 2005.
- [4] P.F. Ramos, M. Guedes and M. J. Leite, "Case-study for the development of noise maps at different scales", *Twelfth International Congress on Sound and Vibration*, Lisbon, Portugal, July, 2005.
- [5] H. Stapelfeldt, E. H. Banda and D. Manvell, "Quality assurance for the calculation of large noise maps", [www.harmonoise.org](http://www.harmonoise.org), 1999.
- [6] M. A. Foda, M. ElMadany, K. A. Alsaif and A. Aguib, "Noise mapping of Riyadh city using measured noise and GPS data", *Internoise 2010*, Lisbon, Portugal, 2010.
- [7] G. Solea and M. Arghir, "Obtaining of noise map of great city of Cluj-Napoca: Step by step", *PAMM · Proc. Appl. Math. Mech.* Vol.9, pp. 499-500, 2009.
- [8] Z. Wei, B. Zhang and M. Xu, "The investigation and analysis on traffic noise in Beijing", *Internoise 2010*, Lisbon, Portugal, 2010.
- [9] R. Sibson, "A brief description of natural neighbor interpolation", in Barnett V., ed., *Interpreting Multivariate*, John Wiley & Sons, 1981.