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The Use of GIS in Studying and Modeling Traffic Noise and its Relationship to Land Uses in Riyadh

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Abstract. This study aims to monitor, analyze and model spatial relationships of traffic noise and its intensity in major streets of Riyadh and surrounding residential areas. We shall adopt a mathematical model to obtain noise intensity level from the average number of passing vehicles in the road, their average speed and the percentage of trucks. By using methods of spatial data insertion in GIS system, it was possible to prepare noise maps (continuous area) which shows the nature and pattern of noise distribution in roads and surrounding areas, one set throughout the day and another through peak hours.

These maps are useful for delineating areas with high noise level and areas of low noise levels. This information, in turn, is useful for selection of sites for land uses that require low level of noise, such as health facilities, schools, public libraries, etc.

By analyzing the relationship between noise and land use of areas surrounding roads, it was possible to know the relationship between the activities and land uses of areas adjoining road, and the level of noise in the roads. The spatial analysis was also useful in understanding the factors that lead to the high noise levels in some roads.

The conclusion contains recommendations and planning criteria that may help planners and decision makers to reduce noise levels down to allowable levels, to preserve people's health and comfort and conserve the environment.

1. Introduction

The population of Saudi Arabia has increased two and half times between 1940 and 1992, as the annual population growth rate reached 5.2% (Al-Shareef, 1422H.). Riyadh is one of the fastest growing cities in the world. Its population reached 5 million inhabitants in 1425H. Riyadh's developed area reached 2000 square kilometers. If current growth rates are sustained, it is possible that Riyadh's population will reach 17 millions in 2021. (RDA, 1425H).

Although this phenomena can be considered positive with regard to development, this high growth rate can cause some problems with regard to housing, traffic bottlenecks, pollution, and environmental damage. One of the consequences of population overcrowding and high traffic density is the increase of noise pollution, which is an invisible from of pollution that need to be studied, analyzed and resolved.

Noise pollution is directly linked to level of vehicle traffic, which varies according to the day, week, month and year. To analyze this problem we need to use suitable and precise mechanism, such as Geographic Information System (GIS), which is now widely used to study such problems world-wide, especially in developed countries.

2. Research Topic and its Importance

Noise pollution is one of the main challenges facing the world. In Saudi Arabia the continuous increase in population and the growth of urban centers increased the number of trips within each center and the number of vehicles. In Riyadh, the number of cars in 1422H. (2001) was estimated to be 211,000 cars; i.e. 211 cars per 1000 inhabitants. Ten years earlier, it was less than 10 cars per 1000

inhabitants. (Al-Mutair, 1426H.). Daily trips, according to Riyadh Development Authority (RDA) reached 5 million, compared to one million twenty years ago (RDA, 1427H). RDA studies indicate that by 1442H (2021) daily trips in Riyadh will be more than 15 million (RDA, 1424H.), 92% of which will be by private cars.

High traffic noise level is a result of the increasing dependence on cars for transportation. It has a dilapidating effect on human health and comfort. It interferes with the ability to concentrate, learn, sleep, and rest. It has negative effects on the auditory and nervous systems which, in turn, affect the heart, increasing its beats. It also affects the digestive system. All of this lead to headaches, lack of concentration, high blood pressure and other heart problems, and nervousness (Obaid, 1420H).

One of the useful tools to solve this problem is to identify the spatial and temporal aspects of this phenomena through the use of GIS for spatial analysis.

The value of this study lies in the analysis of the relationship between traffic noise level and land use. This helps in choosing the proper location of facilities that require low noise level, such as hospitals, medical centers, schools and libraries.

3. Study area

This study is concerned with the city of Riyadh, the capital of Saudi Arabia, located between 45° 57' O"$_E$ and 47° O' 3"$_E$ longitude and between 24° 15' O" and 25° 12' O' North Latitude, at 600 meter altitude. Riyadh's area is 4900 km^2 and its population was 4.26 millions in 1425H (2004). Riyadh's Municipality include 15 sub-municipalities in addition to Der'eya district. There are 209 neighborhoods in Riyadh (RDA 1426H).

This research will study traffic noise in the network of main roads and highways, shown in Fig.1, and monitor the traffic noise level, in these roads and highways.

4. Research problem

Riyadh is suffering from a high of noise level, which comes from factories, workshops, traffic, roadwork, construction and other activities. Traffic noise accounts for a large portion of the total noise.

The Research problem is mainly to study and evaluate traffic-noise level in Riyadh within the limit of ringroad system using GIS.

5. Research objectives

Evaluation of traffic noise level in Riyadh's roads, its spatial relationships and distribution pattern, using a mathematical model based on traffic data and GIS, and its representation in acoustical maps.

6. Research Methodology

Research methodology depends on an applied study using a mathematical model to measure traffic noise based on number of passing vehicles, their speed and percentage of trucks. This model is linked to GIS which translate noise in the form of noise maps containing graphics and data.

Previous studies

Stoter (1999) showed that design and development of large scale projects such as railroads and freeways requires an efficient environmental management to mitigate their negative environmental impact. Noise is one of the factors that have to be monitored. GIS is the preferred tool to accomplish this. The use of GIS has resulted in improving the quality of environmental pollution (noise) reduction of costs of studies, and the linking of geographic and engineering data of surrounding area, to the noise prediction models. This integration made possible the design of noise models based on geographical data supplied by GIS to calculate impact of noise on the environment. Elbers (2000) studied methods of noise level prediction techniques and applied them to Holland using the Gerano 98 model which was based on noise data for railroads. GIS was used to predict future noise impact levels. Li, *et al.* (2002) study was concerned with developing a prediction model for noise level in Chinese roads. This model was built using local environmental measurements for types of vehicles and traffic conditions. Model results for noise level near highway and inside residential neighborhoods were compared to actual data. GIS was used in this study as an additional tool for improving the precision of noise level prediction. Pamanikabud and Tansatcha (2003) pointed out that calculation of traffic noise could be done using one of two models. US FHWA and LIK CORTN. These models were applied to calculate noise level in highways and entering this data in GIS programs. Bhaskar, *et. al*. (2004) showed that it was possible to know the dynamic increase in traffic flow by using noise level production model used in this study (ASJ Model 1999). Results were graphically presented in the form of contour maps for large traffic areas, using GIS. Fabjan, *et. al*. (2004) noted that traffic noise has become one of the major environmental problems. Also, traffic needs and the number of cars increase

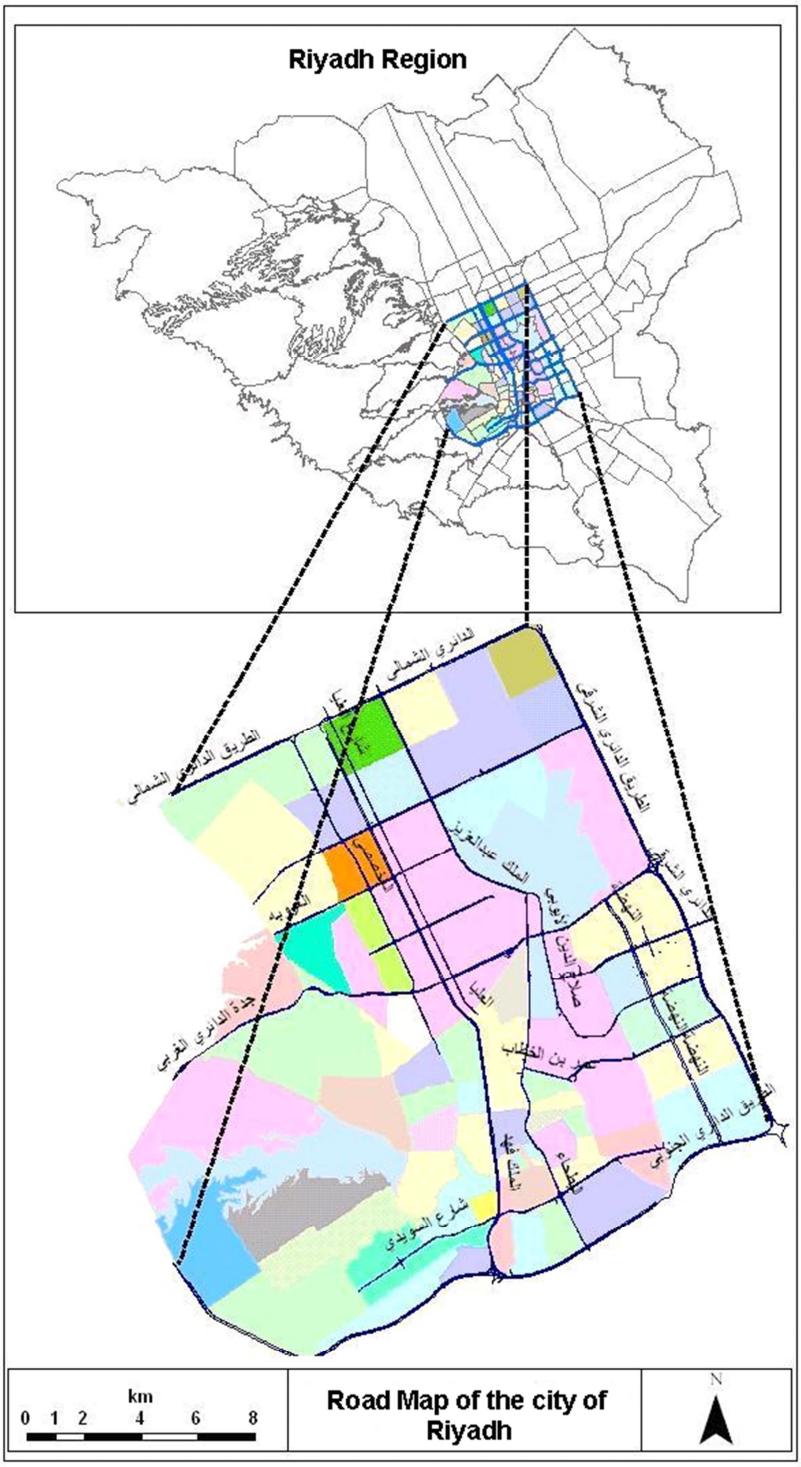

Fig. 1. Riyadh Road Map.

steadily with economic growth. Traffic noise level in Slovakian roads were analyzed after finding average speed of vehicles and using GPS for rating the streets and analysis of results.

6.1 Mathematical model for traffic noise

GIS was chosen to be the tool for measurement and analysis of traffic noise pollution and its impact on areas adjacent to roads. By applying GIS and mathematical modeling it is possible to simulate and analyze traffic noise level in highways and arteries.

Integration between mathematical models and GIS is important in studying the noise impact on infrastructure and producing visual representation of these impacts. By using mathematical model we will be able to produce a number of acoustical maps for evening and morning peak hours and day long.

We have used the model developed by the English Department of the Environment. This mode was also adopted by EPA and MRD and other consultative agencies concerned with traffic noise.

Where;

L_{10} (1h) = 10 log (q) + 33 log (V+40+ (500/V) +1o log (1+5P/V) – 27.6

L_{10} (18h) = 10 log (q) + 33 log (V+40 + (500/V) +1o log (1+5P/V) – 40.7

L_{10} (1hr) = traffic noise level in disciples (dBA), (monitoring time 1 hour)

L_{10} (18 hr) = traffic noise level in disciples (dBA), (monitoring time 18 hours).

q = No. of vehicles (1000 vehicles/18 hours/day)
V = average speed of vehicles (km/hr)
P = Percentage of trucks.

It is also possible to obtain noise level in areas adjacent to roads from the following equation:

$$L_{1z} = 10\,\mathrm{Log}\left(\frac{10(^{L_1}_{10}/-12)}{d_z^2}\right) + 120$$

Where;

L_{1z} = traffic noise intensity level in the measuring point which is located in the area adjacent to the road, in dB

L_1 = traffic noise level in the road in dB

d_z = distance between road and measuring point (meters).

6.2 Stage of building a mathematical model for traffic noise level using GIS

6.2.1 First stage

Collection, classification and preparing of the database. This stage involves the collection of descriptive data related to counting of traffic movement, its processing, preparation of the descriptive database, preparing it for use within the GIS environment. This data can be classified into two types:

- **Descriptive data**
  This is related to vehicle traffic count. It includes the calculation of daily average of count of vehicles, their speed and the percentage of trucks. It also includes the calculation of the average number of vehicles during peak time, average speed and average percentage of trucks. This information was obtained from Riyadh Development Authority which contracted a specialized firm to measure traffic density in the streets of Riyadh. This company installed measuring instruments to count the number of vehicles in the streets that has been specified by RDA. This company presented the data in the form of a report that includes traffic count for Riyadh for the 10 years period 1995 – 2004.

  The city of Riyadh was divided into 15 zones, each zone having its own map. Readings covered most of the city.

- **Spatial Data**
  Traffic pollution is invisible. As such, the presentation of its levels and effect range can be done using GIS in the form of maps based on cartographic modeling. We have used a number of maps from different sources, such as:
  - Digital base-maps for the streets of Riyadh from Military Surveying Department. We have delineated main roads and highways within the study area, 17 of them.
  - Digital map for the location of measuring stations along the roads that were included in the traffic counts. We used RDA printed maps showing the locations of traffic noise measuring stations along the roads that are included in traffic counting. A digitizing method has been used to specify the location of these stations on roads.

6.2.2. Second stage

The construction of a digital map showing the location of the noise measuring stations along the roads included in the study. RDA printed maps were used to specify the location of these stations.

6.2.3. Third stage

The construction of personal geodatabase within the GIS environment containing the main research layers. They are two layers: station layer, which is a digital map showing the location of measuring stations; and roads layer which is a map of Riyadh showing only the roads within the study area.

6.2.4. Fourth stage

This includes dividing the roads being studied into segments, each of which shows the level of traffic noise originating from it. Roads have been divided according to the number of measuring stations in each road. Each segment represents one measuring station.

6.2.5. Fifth stage

The use of the mathematical model which consists of two equations, the first one calculates the average noise level for the whole day, while the other calculates it only during the peak hours.

6.2.6. Sixth stage

The use of the equation related to the buffer zone that shows the measured distance between the center of road segment and the end of the buffer zone, and the traffic noise level in this zone. This is particular importance for vacant areas adjacent to roads (Fig. 2).

6.2.7. Seventh stage

This involves 'overlay analysis' which is one of the spatial analysis in GIS, used for explaining traffic noise, its spread, distribution, and its relationship to land use.

7. Results and Analysis

Results indicate a high level of traffic noise level in most of the roads in Riyadh. It ranges from 85 dB to 67dB during most of the day (during peak hours and day long). This exceeds the allowable levels. Noise levels should not exceed 70 dB in roads in residential areas that contains schools, hotels and mosques. In places requiring quietness such as hospitals, noise level should not exceed 60 dB.

By examining tables of road classification, according noise level (Tables 1, 2, 3, 4, 5 and 6) derived from maps of peak-hours noise-level, we find that roads with the highest level of traffic noise in the study area are:

Eastern Ring Road, Southern Ring Road,
Khurais – Mekhah Road, King Fahad Road
(where noise level can reach 85 dB).

Traffic noise levels in the rest of the roads range from 67dB to 70dB. An Example of these is King Abdul Aziz Road, in which traffic noise level range from 67dB to 77dB (Figs. 3-6).

By studying land use of land adjacent to these roads, we can state the main factors that contributed to the increase of noise level

- Many commercial activities of various types are located on highways, as highway are the only link between other roads. This has slowed down traffic and caused crowdedness in the highways.
- Too many exits in some main roads, because of the spread of different land uses (residential, offices, commercial, government, services) on road sides, which led to slowing down of traffic and disruption to its flow.
- Drivers not abiding by traffic laws is another factor contributing to increase in noise level. Some of violations include over-speeding, turning from the other extreme side of the road, red-light crossing and sudden changes of lanes.

8. Traffic noise analysis for some important roads in Riyadh

8.1. King Abdula Aziz Road (Al-Batha Road)

In this road noise level varies from 65 dB to 80 dB, as shown in Fig. 7 below. Traffic noise in this street is concentrated between the points 6E – 7D, the area between crossing with Prince Mohammed bin Abdul Rahman and Manama Square. This segment includes a large number of shops, especially clothing retain and whole sale. In the northern part of this segment there are Al-Rajhi Buildings which contain shops and offices. To the south of Al-Rajhi Buildings there are some of the oldest shops in Riyadh.

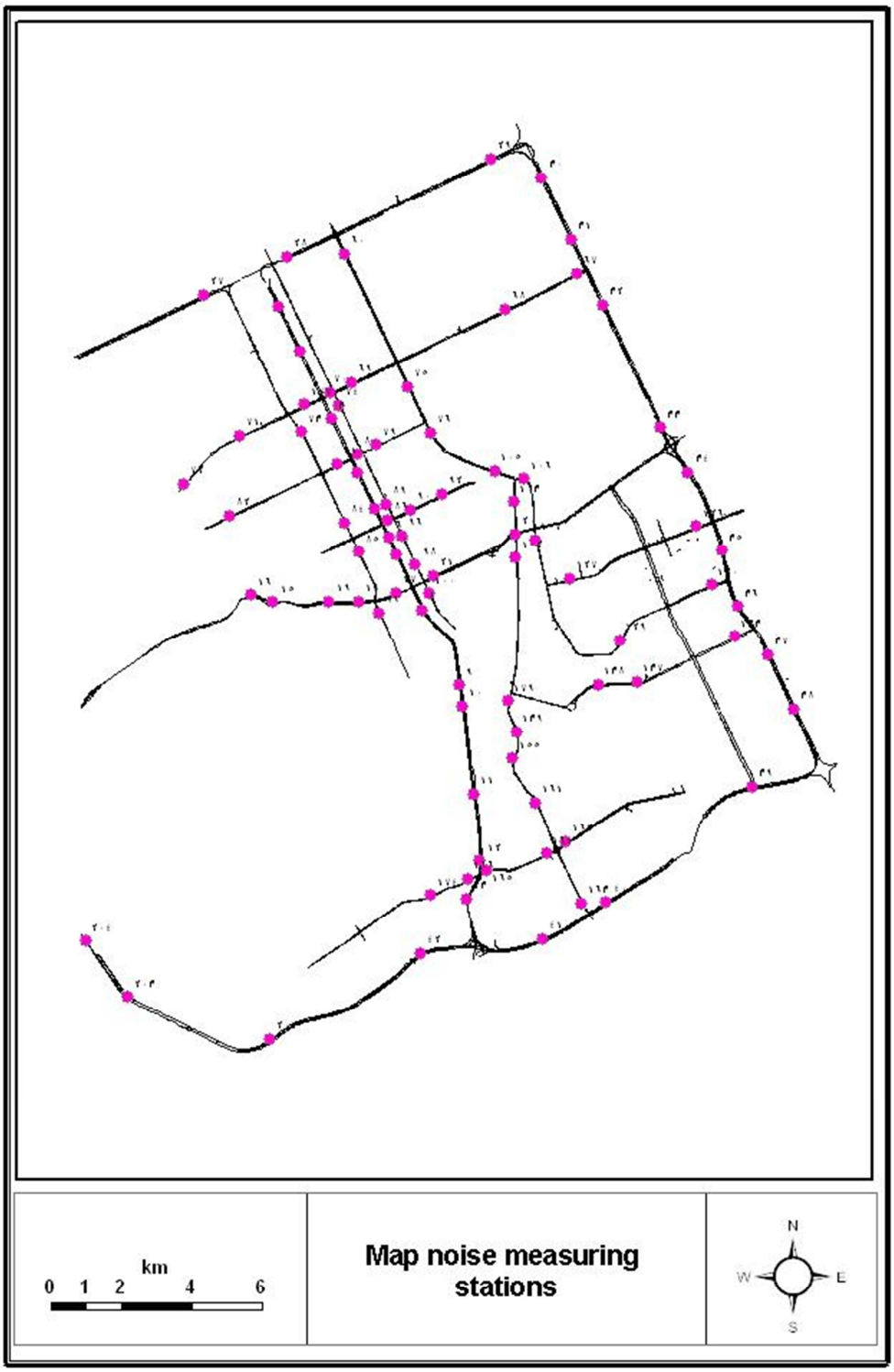

Fig. 2. Map of the Location of Stations for Noise Measurements.

Table 1. Classification of Streets According to Noise Level in Peak Hours (6-9 am), Based on noise level map for peak hours (6-9 am)

67 _ 69 dB	70 _ 73 dB	74 _ 77 dB	78 _ 81 dB	82 _ 85 dB	Road Name
-	-	✓	-	-	1e-3h : Northern Ring Road
-	✓	-	-	-	3h-3j :Northern Ring Road
-	-	-	✓	-	(1e-3d)and(6b-7a):Eastern Ring Road
-	-	-	-	✓	3d-6b :Eastern Ring Road
-	-	-	✓	-	(7a-8d)and(9e10g):Southern Ring Road
-	-	-	-	✓	8d-9e:Southern Ring Road
-	-	✓	-	-	9g-9j :Ring Road, the south-western
-	-	-	✓	-	(3h)and(4g-9e):King Fahad Road
-	-	✓	-	-	3g-4g:King Fahad Road
-	-	-	✓	-	(2d-4g)and(4h):King Abdullah Road
-	-	✓	-	-	(4g-4h)and(4h-4i) :King Abdullah Road
-	-	-	-	✓	4c-5f : Makkah
-	-	-	✓	-	6g : Makkah
-	-	✓	-	-	(5f-6g)and(6g-6i): Makkah
✓	-	-	-	-	(2g-4f)and(4e-5e):King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	(4f-4e)and(8d) :King Abdul Aziz/Al Bat'ha
-	-	✓	-	-	5e-8e :King Abdul Aziz/Al Bat'ha
-	-	-	✓	-	5e:King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	3g and 5f : Al Olaya
✓	-	-	-	-	(4g-5f)and (5f-6e) : Al Olaya
-	-	✓	-	-	3h-3g : Al Olaya
-	✓	-	-	-	(3h-4h)and(5g-6f) : Al Takhassosi
✓	-	-	-	-	4g-5g : Al Takhassosi
✓	-	-	-	-	(4g-5h)and(4g-4f) : Al Uroubah
-	✓	-	-	-	4g: Al Uroubah
✓	-	-	-	-	4e-5g : Mohamed Bin A-Aziz
-	✓	-	-	-	5b-5d : Omar Bin A-Aziz
✓	-	-	-	-	(6c-6d) : Salah al Din
-	✓	-	-	-	(4e-6d)and(5b-6c) :Salah al Din
✓	-	-	-	-	: Mohamed Bin A-Rahman/Al Siwaidi (7c-8d) and (8f) and (8f-9g)
-	✓	-	-	-	8d-8e :Mohamed Bin A-Rahman/Al Siwaidi

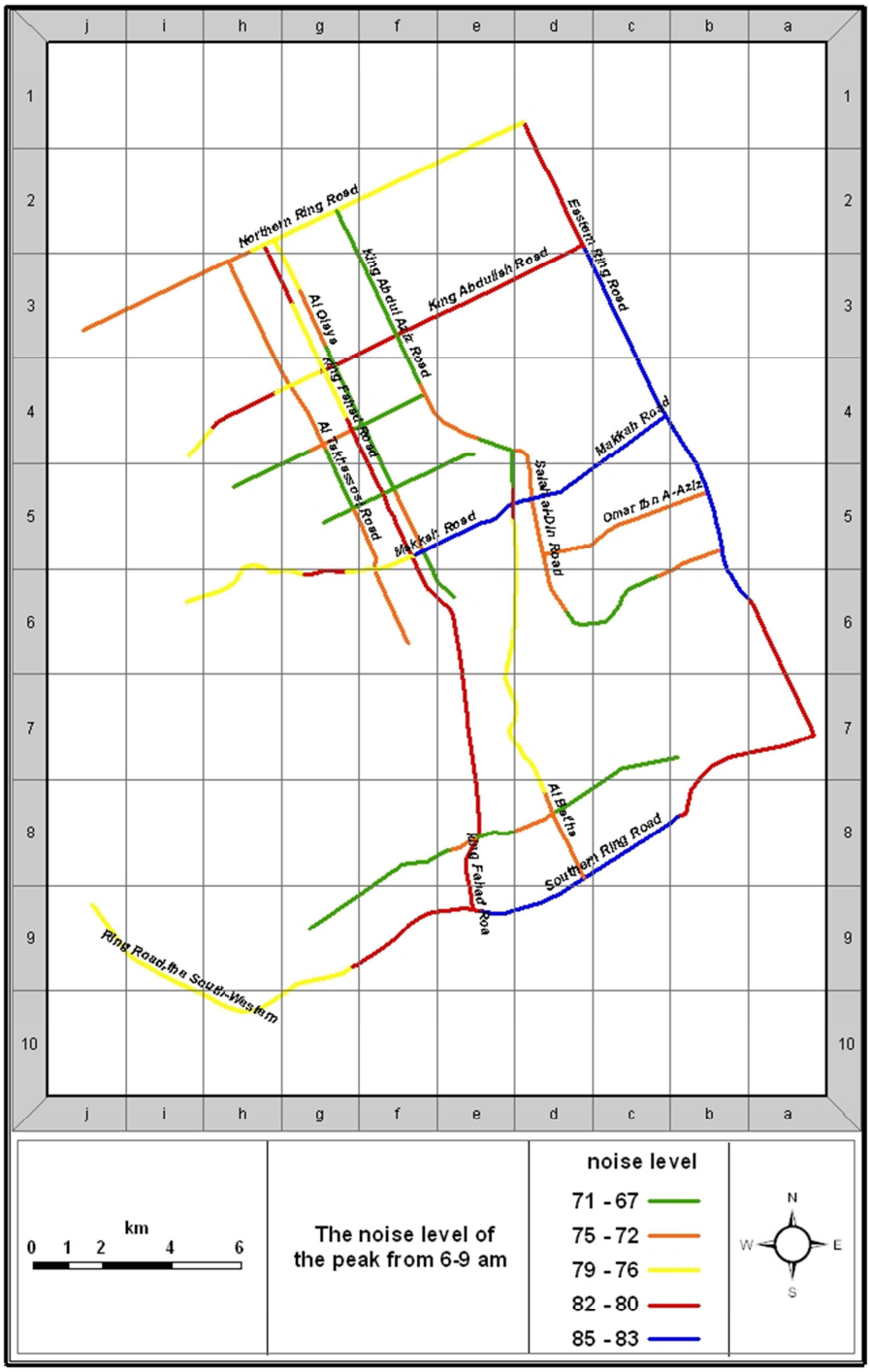

Fig. 3. Noise Levels in Peak Hours 6-9 AM.

Table 2. Classification of streets according to peak hours (12-2 pm) noise level, based on noise level map for peak hours (12-2 pm

67 _ 69 dB	70 _ 73 dB	74 _ 77 dB	78 _ 81 dB	82 _ 85 dB	Road Name
-	-	✓	-	-	1e to 3h :Northern Ring Road
-	✓	-	-	-	3h to 3j :Northern Ring Road
-	-	-	✓	-	(1e to 3c) and (6a-6f) :Eastern Ring Road
-	-	-	-	✓	(3d to 6b) and (6a to 7a) :Eastern Ring Road
-	-	-	-	✓	7a to 9e :Southern Ring Road
-	-	-	✓	-	9e to 10i:Southern Ring Road
-	-	✓	-	-	9i to 9j:Ring Road, the south-western
-	-	-	-	✓	(2h)and (6e to 9e):King Fahad Road
-	-	-	✓	-	3g to 6e :King Fahad Road
-	-	-	-	✓	3f to 4g:King Abdullah Road
-	-	-	✓	-	(3d to 3f)and(4g-4h):King Abdullah Road
-	-	✓	-	-	(4h to 4i)and (4g):King Abdullah Road
-	-	-	✓	-	(4c to 5f) and (6f to 6g): Makkah
-	-	✓	-	-	(5f) and (6g to 6i) : Makkah
✓	-	-	-	-	2g to 3f :King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	(3f to 6e) and (8d):King Abdul Aziz/Al Bat'ha
-	-	✓	-	-	6e to 8d :King Abdul Aziz/Al Bat'ha
✓	-	-	-	-	(3h to 5f) and (5f to 6e): Al Olaya
-	✓	-	-	-	(5f) : Al Olaya
-	✓	-	-	-	3h to 6f : Al Takhassosi
-	✓	-	-	-	4f to 4g : Al Uroubah
✓	-	-	-	-	5g to 5h : Al Uroubah
-	✓	-	-	-	4e to 5g :Mohamed Bin A-Aziz
-	✓	-	-	-	5b to 5d :Omar Bin A-Aziz
-	✓	-	-	-	(5b to 6d) and (4e-5d):Salah al Din
✓	-	-	-	-	6c to 6d:Salah al Din
-	-	✓	-	-	5d-6d :Salah al Din
✓	-	-	-	-	:Mohamed Bin A-Rahman/Al Siwaidi (7c to 8d)and (8e) and (8f to 9g)
-	✓	-	-	-	8d-8e :Mohamed Bin A-Rahman/Al Siwaidi

Fig. 4. Noise Levels in Peak Hours, 12 Noon to 2 pm

Table 3. Classification of streets according to noise level, all day, Saturday to Wednesday, based on noise level maps for all day

67 _ 69 dB	70 _ 73 dB	74 _ 77 dB	78 _ 81 dB	82 _ 85 dB	Road Name
-	-	✓	-	-	3h-2j :Northern Ring Road
-	-	-	✓	-	1e-2f :Northern Ring Road
-	-	-	-	✓	2f-3h :Northern Ring Road
-	-	-	-	✓	1e to 2d :Eastern Ring Road
-	-	-	✓	-	(2d-3d) and (3c-6a) :Eastern Ring Road
-	-	✓	-	-	(3d-3c) and (6a-7a) :Eastern Ring Road
-	-	-	✓	-	(8c-8d) and (9e-9g) :Southern Ring Road
-	-	-	-	✓	7a to 8c :Southern Ring Road
-	-	-	✓	-	9i to 9h :Ring Road, the south-western
-	-	-	-	✓	9g to 9i :Ring Road, the south-western
-	-	-	-	✓	5g to 6e :King Fahad Road
-	-	-	✓	-	(4g to 5f) and (6e to 9e) :King Fahad Road
-	-	✓	-	-	3g-4g :King Fahad Road
-	✓	-	-	-	3h :King Fahad Road
-	-	-	✓	-	(3e to 4g) and (4h) :King Abdullah Road
-	-	✓	-	-	:King Abdullah Road (3d-3e) and (4g-4h) and (4h-4i)
-	-	-	✓	-	(6f to 6g) : Makkah
-	-	✓	-	-	(4c to 5f) and (6h to 6i) : Makkah
✓	-	-	-	-	2g to 3f :King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	3f to 4e :King Abdul Aziz/Al Bat'ha
-	-	✓	-	-	8d :King Abdul Aziz/Al Bat'ha
-	-	-	-	✓	7e to 8d :King Abdul Aziz/Al Bat'ha
-	-	-	✓	-	(5e to 7e) and (8d) :King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	(2h to 4g) and (5f to 6e) : Al Olaya
✓	-	-	-	-	4g to 5f : Al Olaya
✓	-	-	-	-	3h to 6f : Al Takhassosi
✓	-	-	-	-	4f to 5h : Al Uroubah
-	✓	-	-	-	5e to 5f :Mohamed Bin A-Aziz
✓	-	-	-	-	5f to 5g :Mohamed Bin A-Aziz
-	✓	-	-	-	5c to 5d :Omar Bin A-Aziz
✓	-	-	-	-	5b-5c :Omar Bin A-Aziz
-	✓	-	-	-	(5b to 6c) and (5d-6c) :Salah al Din
✓	-	-	-	-	(6c to 6d) and (4d-5d) :Salah al Din
✓	-	-	-	-	:Mohamed Bin A-Rahman/Al Siwaidi (8d-8e) and (8e)
-	✓	-	-	-	:Mohamed Bin A-Rahman/Al Siwaidi (8e) and (8f to 9g) and (7c to 8d)

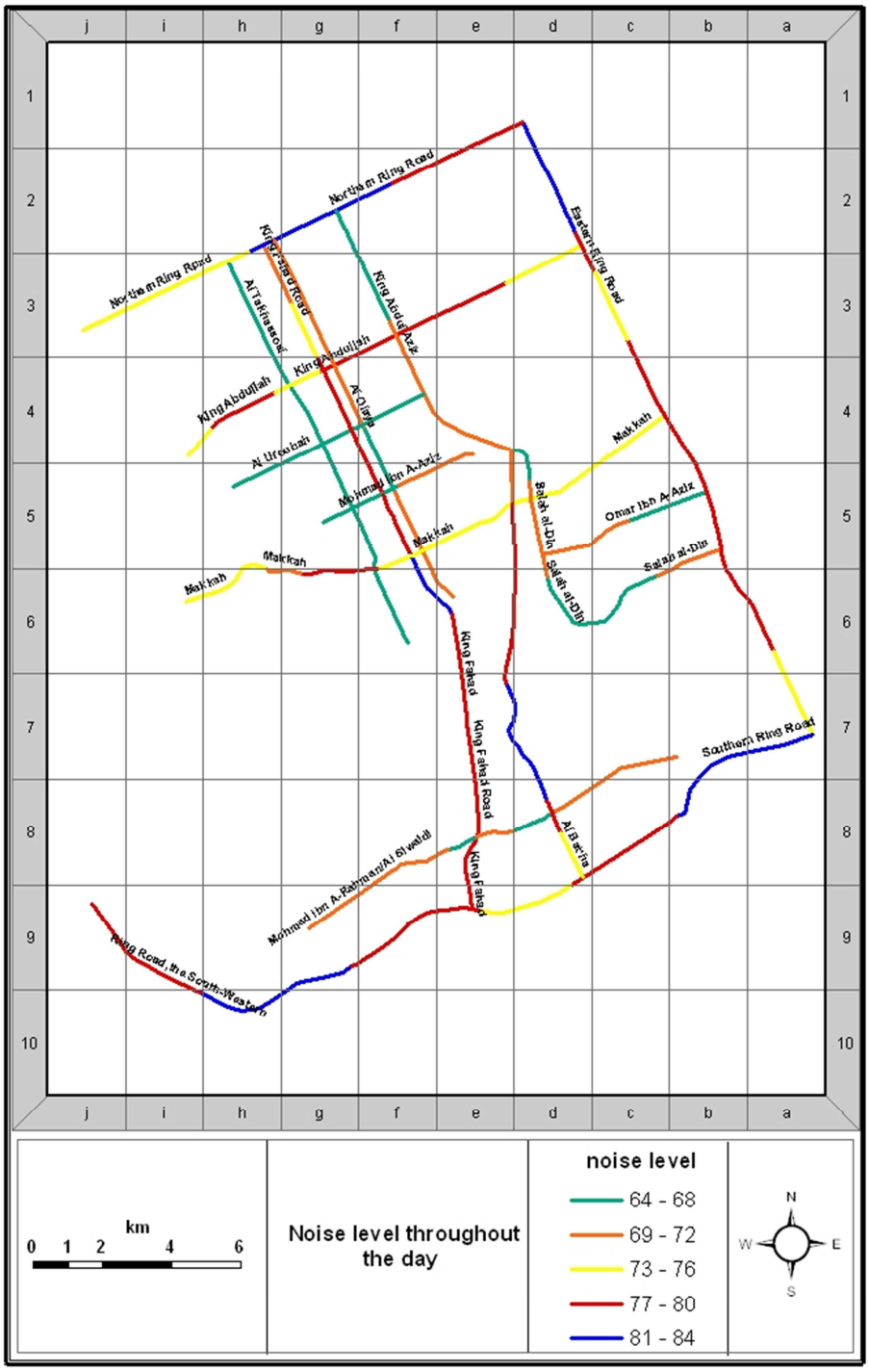

Fig. 5. Noise Levels All Day Long.

Table 4. Classification of streets according to noise level during Friday, based on noise levels map for Friday

67 _ 69 dB	70 _ 73 dB	74 _ 77 dB	78 _ 81 dB	82 _ 85 dB	Road Name
-	-	-	✓	-	3h-3j :Northern Ring Road
-	-	-	-	✓	1e-2h :Northern Ring Road
-	-	-	-	✓	:Eastern Ring Road (1e-2d) and (3d-3c) and (5b-7a)
-	-	-	✓	-	(2d) and (3c) :Eastern Ring Road
-	-	✓	-	-	(2d) and (3c to 4b) :Eastern Ring Road
-	-	-	✓	-	(7b-8c) and (9e-9f) :Southern Ring Road
-	-	-	-	✓	:Southern Ring Road (7a-7b) and (9f to10h)
-	-	✓	-	-	8c to 9e :Southern Ring Road
-	-	-	✓	-	9i to 9j :Ring Road, the south-western
-	-	-	-	✓	9j :Ring Road, the south-western
-	-	-	✓	-	5f-7e :King Fahad Road
-	-	✓	-	-	4g-5f :King Fahad Road
-	✓	-	-	-	3h to 4g :King Fahad Road
-	-	-	✓	-	3d to 4g :King Abdullah Road
-	-	✓	-	-	4g to 4i :King Abdullah Road
-	-	-	✓	-	5e and 6g : Makkah
-	-	✓	-	-	(4c to 5e) and (6f-6g) : Makkah
-	-	-	-	✓	5e to 5f : Makkah
-	✓	-	-	-	(5f) and (6g to 6i) : Makkah
✓	-	-	-	-	2g to 3f :King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	3f to 4e) :King Abdul Aziz/Al Bat'ha
-	-	✓	-	-	:King Abdul Aziz/Al Bat'ha (5e to 7e) and (8d)
-	-	-	-	✓	:King Abdul Aziz/Al Bat'ha (7e) and (7d-8d)
-	-	-	✓	-	(7e) and (8d) :King Abdul Aziz/Al Bat'ha
-	✓	-	-	-	(3h to 4g) and (5f to 6e) : Al Olaya
✓	-	-	-	-	4g to 5f : Al Olaya
-	✓	-	-	-	3h to 4g : Al Takhassos
✓	-	-	-	-	4g to 6f : Al Takhassos
✓	-	-	-	-	4f to 5h : Al Uroubah
-	✓	-	-	-	4e to 5f :Mohamed Bin A-Aziz
✓	-	-	-	-	5f-5g :Mohamed Bin A-Aziz
-	✓	-	-	-	5c to 5d :Omar Bin A-Aziz
✓	-	-	-	-	5b-5c :Omar Bin A-Aziz
-	✓	-	-	-	4e to 6b :Salah al Din
-	✓	-	-	-	:Mohamed Bin A-Rahman/Al Siwaidi (7c to 9g)

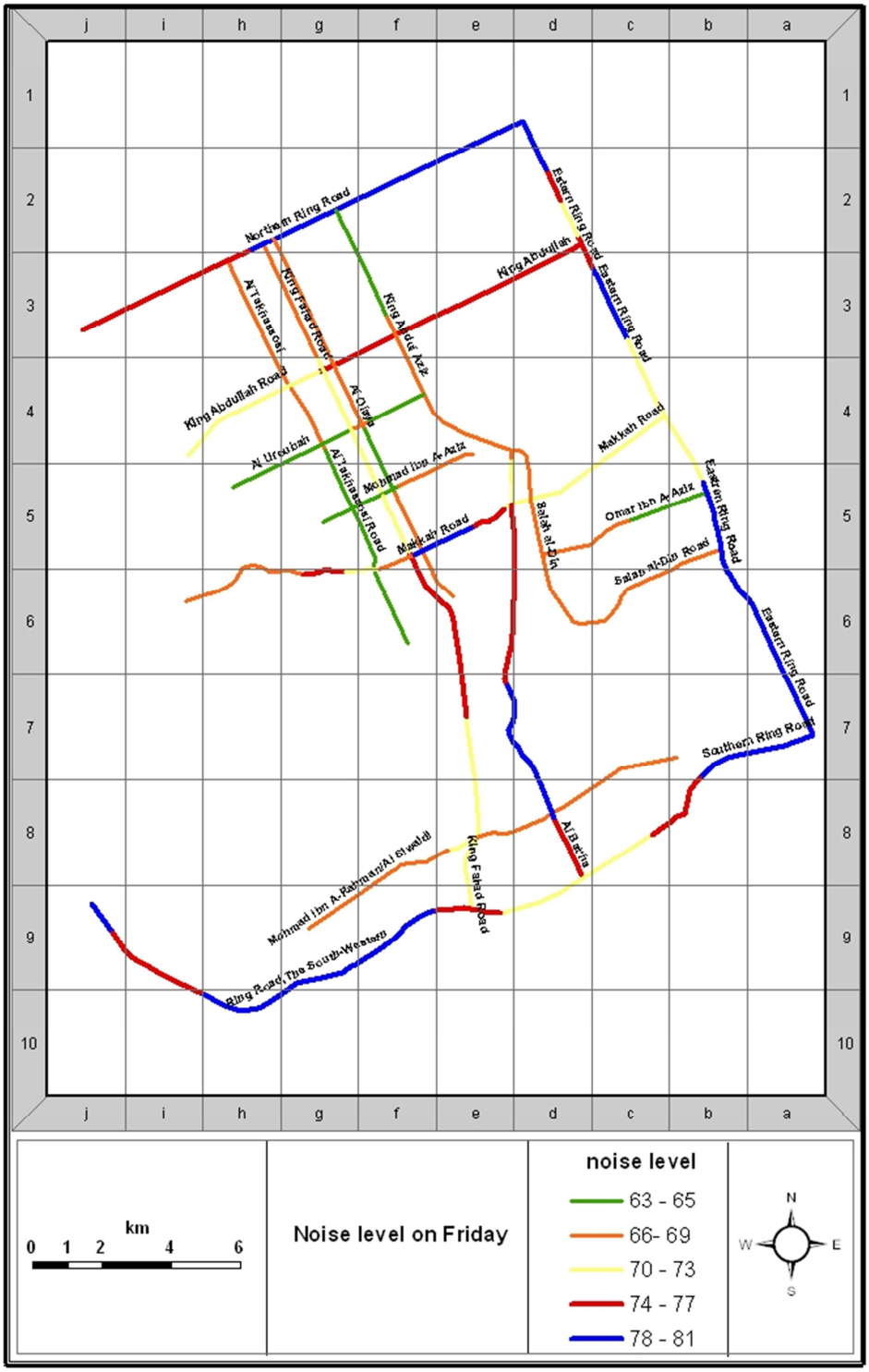

Fig. 6. Noise Levels on Fridays.

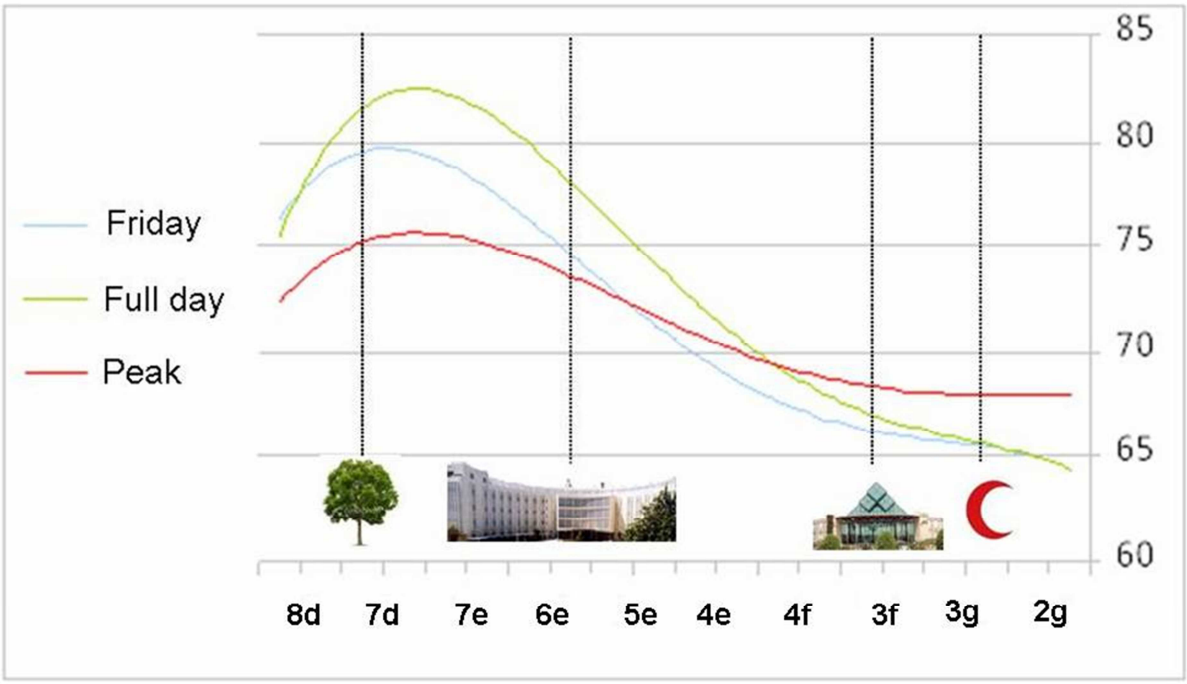

Fig. 7. Noise Level Curves for King Abdul Aziz Road/Al-Batha, in the Three Measurement Periods (All Day, Week Days, Friday, Peak Hours).

Al-Suliman Center is located in the middle of this segment. It is a large multi-storey shopping center. Near this center is the Memorial School, which is the first school in Riyadh. In the southern end of this segment is the Oud Cemetery.

This segment of the street is considered to be the old center of Riyadh after AlDeerah. It is crowded with pedestrians and peddlers. Traffic is much denser here than in nearby streets, especially on Fridays. This explains the high noise level all day and on Fridays in the comparison, to peak hours. On Fridays there is a large gathering of expatriates, especially Indians, Filipinos and Bengalis. There are many grocery stores selling ethnic specialties. In addition, this area has a high residential density.

In this area, there are many cars that take people to other towns and cities. They park in a haphazard manner. The drivers call loudly for passengers. Small commuter buses also stop haphazardly to load and unload passengers.

As to the rest of the street, residential density and traffic go down as we move northward. Beyond Manama crossing, the number of shops goes down and the stores are replaced by government agencies and ministries. Here noise level in different periods varies between 75dB and 70dB.

Noise level is further reduced as we move northward, especially in the segment beyond the airbase (old airport). This area is relatively new and the residential density as well as the number of shops are lower than in the street. This explains why the noise level in this segment is lower than 70dB in all of the three measurement periods.

8.2. Makkah Road

Noise level in this road exceeds 85 dB as shown in Fig. 8, for all three measuring period (peak hours, all day, Friday). Noise is concentrated in the segment 4C-5F which is the area between the National Guard and the Military hospital. During peak hours, noise level in this segment can exceed 85dB, when government offices and schools are open. Number of cars in the road increases, which increases noise level in this segment.

These curves show that noise levels are low, and similar for weekdays and peak hours for area between GF and GI. This is the area adjacent to King Faisal Specialist Hospital (KFSH). It starts from the intersection of Mekkah Road and Takhassusi Street, westwards. This segment passes through areas where there are no shops or government offices. It is also an area of low residential density. In addition, this

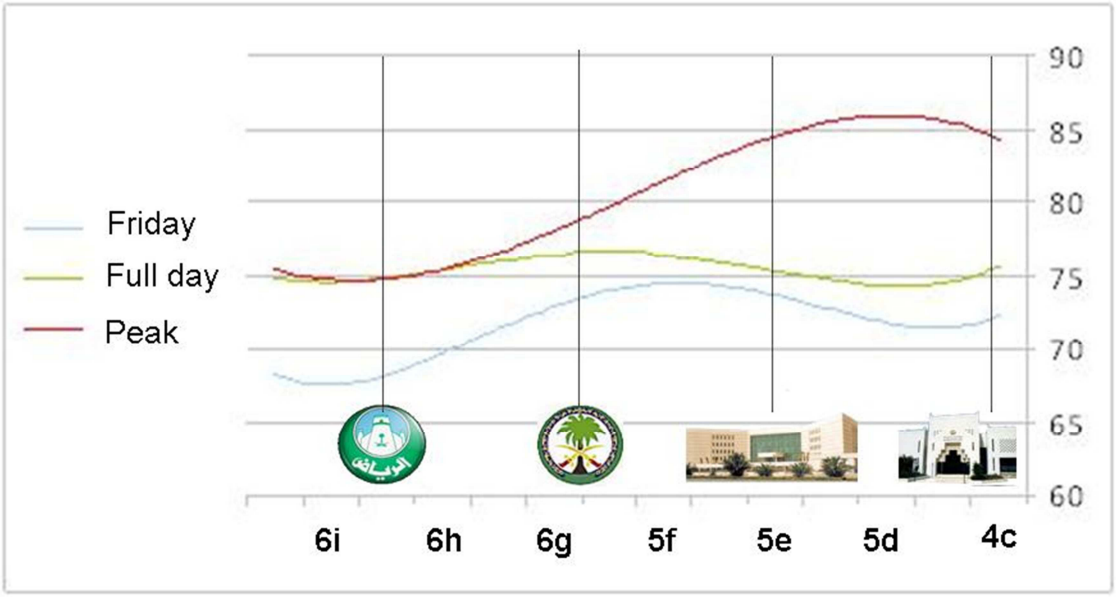

Fig. 8. Noise Level Curses from Makkah Road.

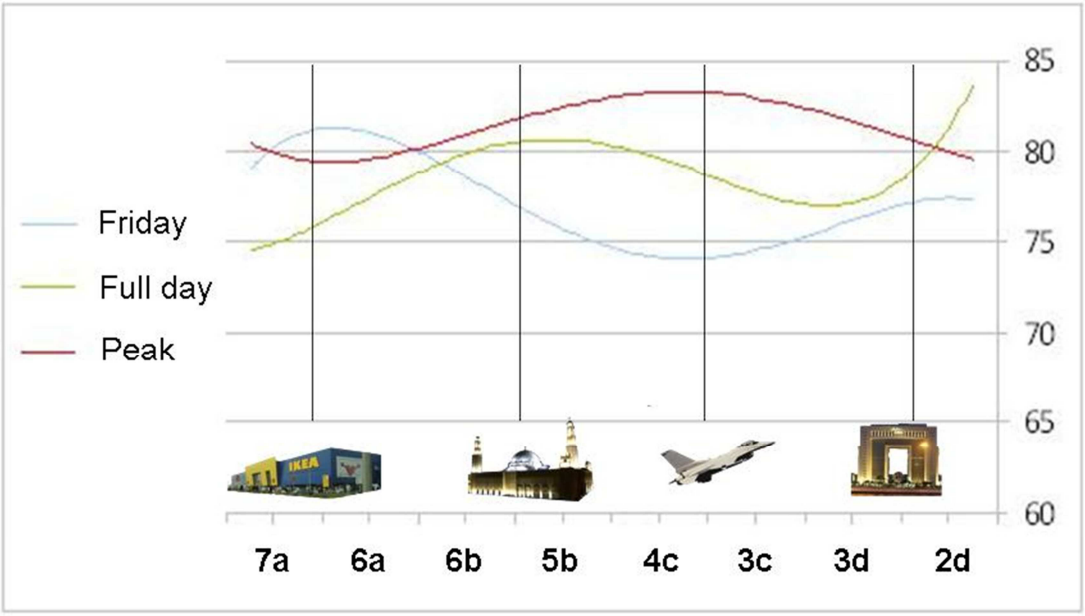

Fig. 9. Noise Level Curves for the Eastern Ring Road for All Measurement Periods.

segment of the street contains a number of underpasses, making this street functions as a highway. For these reasons traffic flow is low on Fridays and so is traffic noise.

8.3. Eastern Ring Road

Traffic noise level in this road exceeds 80dB in peak hours (Fig. 9). Traffic level is high in all parts of this road because it serves King Khaled Airport,

Imam Mohammed bin Saud University, National Guard Administration and King Abdul Aziz Library. Also, a number of activities are spread on both sides of the road. In the northern part of the road there is SABIC headquarters, Gernada Shopping Mall, Al-Hukair and Al-Musa Playgrounds, Air Force Museum and Officers Club. In the middle part of the road there is Al-Rajhi Mosque, Muwasah Hospital, Rabwa Green Market. In the southern part there is a number of shopping centers, such as Remal Mall, Ithraa Mal, IKEA and some workshops, car show rooms, shops selling electric products, houseware and food.

This mix of activities make traffic in this road continuous and dense. In addition, truck traffic is high here compared to that in King Abdul Aziz, Mekkah road or King Fahad Road where trucks are not permitted during day time. As such noise level is high in all segments of this road during peak hours.

Curves also show that noise level is high on Fridays in segment 6A (82 dB). This is the segment that contains IKEA, Remal Mall where families prefer to shop on Fridays. Noise level is lower on other segments of this road.

All day long noise level increases near Al-Rajhi mosque, Al-Muwasah hospital and Rabwah Green Market. These are in close proximity; they are services frequented by people all day long. Noise level increases in the northern end of the Eastern Ring Road that leads to Thamama recreational area, King Khalid Airport, Dammam Road or King Fahad Stadium.

9. Conclusion

This study has shown the importance of using GIS and mathematical modeling in representing noise pollution on digital maps that show the relation to the physical ground features. Users can store data digitally, making it easy to modify and update as the need arises.

Digital data were analyzed using a mathematical model to measure noise level. Results were then plotted on digital maps or graphical curves. This shows the effective role played by GIS and mathematical modeling in the study of noise pollution and its likely side effects through the use of modeling and graphic representation of these effects. This is useful for supporting the decision making process and the planning of urban infrastructure.

10. Findings

The study has resulted in the following findings:

1. Noise levels in Riyadh's highways and main roads are higher than the internationally accepted levels.
2. Ineffective land use planning, such as the concentration of activities in downtown and the overlapping of residential, commercial and governmental activities in some areas greatly contributed to the increase of traffic noise levels.
3. The lack of spaces allocated especially for taxis and small vans for loading and unloading of passengers resulted in chaotic movement and disruption of traffic movements.
4. Taxi drivers do not obey traffic regulations, which contribute to increase in traffic noise level as some drivers move from extreme left to extreme right abruptly in order to pick up additional passengers, which disrupts traffic flow.
5. Drivers in general do not obey traffic laws. They overspeed, change lanes abruptly and cross red traffic lights. This leads to interruption of traffic movement.
6. Noise from traffic is the main source of noise pollution in urban areas.
7. The effectiveness of the use of modern technology i.e. GIS and mathematical modeling to model spatial relations of traffic noise and its intensity level in Riyadh's roads and highways.
8. Mathematical modeling is the key to solve a wide range of problems, instead of experiments which could be costly and time consuming.
9. Mathematical modeling of noise level and GIS enable us to estimate traffic noise level how and in the future, which can be obtained by the use of laboratory instruments.
10. The integration of mathematical models and GIS is very important in studying likely side effects of urban infrastructure, as it is easy to make visual or graphic representation of these effects, by using simulation and analysis of noise traffic level in main roads and highways.

11. Recommendations

1, Allocation of special places for taxis and small vans to load and unload passengers.
2. Reducing highway exits to maintain smooth traffic flow.
3. Developing public transportation for both sexes, in order to reduce dependence on private cars.

4. Enacting strict fines for traffic law violators, such as those who overspeed or change lanes abruptly and frequently.
5. Enacting necessary laws to monitor motors vehicles and the level of noise that they produce, and outlawing cars which produce disrupting noise.
6. The outlawing of mixing residential, commercial and administrative uses along highways.
7. Locating hospitals, schools and public libraries away from noisy highways.
8. Laws must be enacted for organizing land subdivision, areas, building heights, user's intensity, in order to be in line with the roads that pass through them.
9. Intensifying the cultivation of trees and plants alongside roads, to absorb traffic noise and reduce its effects.
10. Paying closer attention to acoustical treatment of buildings near noisy roads in order to insulate them from outside noise.
11. Erection of sound barriers in road segments with high noise level, in order to prevent the transmission of noise to nearby buildings.
12. Preparation of noise maps for different Saudi cities that have high noise level, using the integration of GIS and mathematical models, in order to support decision makers and help them take appropriate measures to combat traffic noise.
13. Publishing noise maps on the internet. Each city site should contain a page of noise maps which should be updated annually. As such, they will important references for engineers, architects, urban planners and environmentalists.
14. Increasing public awareness of the dangers of noise pollution, now and in the future, especially as the effects of noise on human health does not appear clearly except after a period of time.

Bibliography
Arabic Sources

Saleh, Hasan Abdul Kadir. Geographic Orientation of Development in Arab Countries, *Second Symposium of Arab Geographers*, Egyptian Geographic Society, Cairo, Egypt, (2000).

Al-Shareef, Abdul-Rahman Sadiq. *The Geography of the Kingdom of Saudi Arabia*, 6th edition, Dar Al-Marrekh, Riyadh, Saudi Arabia, (1422H.).

Al-Mubayedh, Saad Abdul-Aziz and Mohammed Mustafa Abdul-Fattah. The Contribution of Bus Public Transportation to the reduction of air pollution, *Symposium on Bus Transportation and Social Service*, Ministry of Transportation, Saudi Arabia, (1419).

Al-Mutair, Amir. *A Geographic Evaluation of Multi-storey Parking Structures in Downtown Riyadh, Geographical Research*, Saudi Geographic Society, Geography Dept, King Saud University, Riyadh, Saudi Arabia, (1426H.).

Riyadh Development Authority, Traffic Management Workshop in Riyadh, (1424).

Obaid, Mohammed Abdul-Fattah. *Principles of Architectural Acoustics Design*, King Saud University Press, (1420H.).

Riyadh Development Authority, *Investment Climate in the City of Riyadh*, (1426H.)

English References

Stoter, J. *Noise Prediction Models and Geographic Information Systems, A Sound Combinmation*, The Spatial Information Research Center, University of Otago, Dundin, New Zealand, (2000).

Elbers, F.B.J. "Methods and Tools for Monitoring and Prediction of the Large Scale Environmental Impact of Railway Noise." *Journal of Sound and Vibration*, Vol. 231, No. 3, (2000), 961-973.

Li, B., *et al*., "A GIS Based Road Traffic Noise Prediction Model." *Applied Acoustics*, Vol. 63, No. 6, (2002), 679-692.

Pamanikabud, P. and Tansatcha, M. "Geographic Information System for Traffic Noise Analysis and Forecasting with Appearance of Barriers." *Environmental Modeling and Software*, Vol. 18, (2003), 959-973.

Bhaskar, B., *et al*., (2004), "Integration of a Road Noise Model (ASG) and Traffic Simullation (AVENUE) for a Built-up Area", www.witpress.com, retrieved in July 2006.

Fabian, D., *et al*., "GIS and GPS as Useful Tools to Determine Transportation Noise Levels, " ", www.witpress.com, retrieved in July 2006.

استخدام نظـــم المعلومات الجغرافية في دراسة ونمذجة الضوضاء المرورية وعلاقتها باستعمالات الأراضي في مدينة الرياض

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الكلمات المفتاحية : (الضوضاء، نظم المعلومات الجغرافية، النمذجة الرياضية).

ملخص البحث. تشهد المملكة في هذا الوقت قفزة تنموية كبيرة اشتملت على جميع جوانب الحياة، وواكب هذه الحركة التنموية بعض الآثار السلبية التي انعكس تأثيرها على الفرد والمجتمع على حد سواء. ومن هذه الآثار السلبية ؛ ظاهرة التلوث البيئي والتي بدأت تزداد بشكل ملفت للنظر على مستوى العالم بأجمعه.

ففي نهاية القرن العشرين وبداية القرن الحادي والعشرين برزت مشكلات التلوث البيئي وخاصة التلوث الضوضائي، وأصبح التلوث الضوضائي إحدى الظواهر التي تواجه جميع دول العالم سواء المتقدمة منها أو النامية. ولم تكن المملكة بمعزل عن تلك المشكلة خاصة في ظل الزيادة المضطردة في أعداد السكان والتي واكبتها زيادة في الرقعة العمرانية وتنامٍ في مساحات المدن وتبعاد في أطرافها، ورافق هذا زيادة الحاجة إلى التنقل بين أجزاء المدينة وأحيائها. وترتب على ذلك زيادة في عدد المركبات بصورة كبيرة مما سبب ظهور مشاكل بيئية عديدة، والمشكلة الضوضائية المرورية إحدى هذه الآثار السلبية والتي ظهرت نتيجة الاعتماد المتزايد على السيارات في عملية النقل، والتي تتعاظم أعدادها من عام إلى عام. وقد ترتب على ذلك ازدياد شدة الضوضاء الناتجة من حركة السيارات ومحركاتها، والذي انعكس على صحة الإنسان وراحته بصورة سلبية.

وتهدف هذه الدراسة إلى رصد وتحليل ونمذجة العلاقات المكانية لظاهرة الضوضاء المرورية ومستوى شدتها للطرق الرئيسة في مدينة الرياض والمناطق المحيطة بها وذلك عن طريق استخدام نظم المعلومات الجغرافية، من خلال تبني نموذج رياضي يقوم باستنتاج مستوى شدة الضوضاء من خلال معدل المركبات المارة في الطريق ومعدل سرعتها ونسبة الشاحنات فيها.

وباستخدام طرق الإدراج البيني المكاني في نظم المعلومات الجغرافية تم إعداد خرائط ضوضائية (مساحية مستمرة) تبيِّن طبيعة ونمط توزيع الضوضاء على الطرق والمناطق المحيطة بها وذلك على مدار اليوم وأخرى لأوقات الذروة. وتأتي أهمية هذه الخرائط في تحديد المناطق المناسبة لبناء المباني ذات الطابع الخاص والتي تتطلب مستوًى منخفضًا من الضوضاء مثل المستشفيات والمراكز الصحية والمدارس والمكتبات والمباني المشابهة الأخرى.

ومن خلال تحليل العلاقات المكانية بين الضوضاء واستعمالات الأراضي في مدينة الرياض تم التوصل إلى معرفة العلاقة بين نوع النشاط والاستخدام للمنشآت القريبة من الطرق وبين مستوى الضوضاء المرورية في الطرق القريبة منها، كما ساعد التحليل المكاني في الكشف عن المسببات التي أدت إلى ارتفاع مستوى الضوضاء في بعض الطرق والذي يتناسب تناسباً طردياً مع عدد السيارات وخصوصاً في الطرق المكتظة بها.

وقد ختمت الدراسة ببعض التوصيات والإرشادات وبعض المعايير التخطيطية والتي تساعد المخططين وصناع القرار في تخفيض مستوى الضوضاء المرورية إلى الحد المسموح به حفاظاً على البيئة وعلى صحة الإنسان وراحته.