

## **Analysis and Evaluation of Road Traffic Noise in Al-Dammam: A Business City of the Eastern Province of KSA**

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**Abstract:** The main objective of this study is to analyze and evaluate road traffic noise in the City of Al-Dammam. Digital sound level meters with frequency weighting networks were used in this study. All measurements were taken on an A weighting frequency network, at a height of about 1.5 m from ground and on a fast range time weighting. The A weighting characteristics and Fast range simulated the human ear listening response. Noise measurements were taken at locations in selected districts. Day-night and day time noise maps were then drawn with the districts being classified into moderate, high and extremely-high risk zones in accordance with noise risk levels. Mean day-night ( $L_{dn}$ ) values obtained ranged from 68.1 to 90.6 dB (A) and exceeded the permissible environmental standards used in Kingdom of Saudi Arabia while mean day time ( $L_d$ ) values ranged from 75.3 and 85.4 dB (A). They too exceeded permissible limits. This indicates that residents of all locations investigated are exposed to high noise levels mainly caused by road traffic.

**Key words:** Noise pollution, noise annoyance, road traffic noise

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### **INTRODUCTION**

Nowadays, noise pollution is considered a major factor affecting the quality of life in urban centers. Road traffic noise is a particularly important factor in noise pollution (Skånberg and Öhrström, 2002; Björk *et al.*, 2006). Research conducted in 2002 in Spain reached the conclusion that noise pollution resulting from traffic was one of the main problems affecting small and non-industrial cities (Morillas *et al.*, 2002). In another research carried out in Beijing, vehicle speed, the nature of traffic load, the number of trucks and road-surface conditions were found to have a significant effect on the level of traffic noise (Li *et al.*, 2002).

Adverse effects of noise pollution include interference with communication networks, noise-induced hearing-loss, personal annoyance, sleep disorder, poor cardiovascular and psycho-physiological performance, low productivity and erratic social behavior (Jakovljevic *et al.*, 2006; Muzet, 2007; Enmarker, 2004; Ouis, 2001; Kryter, 1982). Many are the past studies that have indicated that noise pollution affects the physical and mental health of people (Guite *et al.*, 2006; Vera *et al.*, 1992). Numerous other studies have shown that people living in crowded areas are highly prone to suffering from sleep disorder (Muzet, 2007). This same fact is actually emphasized in a report published by the FHWA (2006) in USA. Noise is a hazardous agent that has many negative implications for the urban environment; its costs on local communities (Elshorbagy, 1999) and society at large (Martín *et al.*, 2006) can be overwhelming.

The City of Al-Dammam is located in the Eastern Province of the Kingdom of Saudi Arabia (KSA), bordering the Arabian Gulf. It is one of the nation's chief ports and

serves as a major export outlet for petroleum and natural gas. The rapid growth of the oil industry in Saudi Arabia brought about rapid development to the region, causing Dammam City to undergo significant development with the following consequences:

- Within three decades, the sleepy little fishing village grew exponentially and became the capital of the Eastern Province. No area of the Middle East, or perhaps the world, has undergone such dramatic transformation in such a short period of time
- Al-Dammam is now a modern urban and industrial city; it is a major residential and commercial center that serves as the headquarters of the Saudi Arabian oil industry
- An excellent network of roads, railways and air routes link the port city to the rest of Saudi Arabia and to the kingdom's neighboring countries
- As oil production increased, the number of people required to run the industry also increased. This naturally led to a population explosion requiring more housing, more hospitals and more schools
- To promote the proliferation of non-oil industries, an industrial city was established nearby (Jubail Industrial City)
- Al-Dammam City is also famous for its wide variety of recreational facilities
- The primary goal of the present study was to evaluate the environmental noise pollution of Al-Dammam City and suggest control measures

## MATERIALS AND METHODS

### Survey Area

With a population growth rate of 4% per annum, Al-Dammam City is currently home to one million people. For comprehensive coverage, sampling locations were selected in twenty-seven districts of this bustling business city of Kingdom of Saudi Arabia. And for the proper assessment of road traffic noise due to vehicular movement, sampling, analysis and interpretation tools capable of producing the most realistic results were used. The sampling locations were situated in zones of the city covered by the permissible-noise legislation currently in use in Kingdom of Saudi Arabia, Table 1. This study was carried out from November 2007 to May 2009. Residential, commercial and mixed areas were investigated to make sure the samples were statistically representative.

Three Bruel and Kjaer (B and K) type 2260 Digital Sound Level Meters with frequency weighting networks were used in this study. A linear frequency range of 31.5 to 8 KHz and a dynamic range of 0-150 dB were applied. Type 4230 Acoustics calibrators were used to set (calibrate) the Sound Level Meters at a referenced level of 94 dB before and after taking field measurements. All measurements were taken on an A weighting frequency network, at a height of about 1.5 m from ground and on a Fast range time weighting. The A weighting characteristics and fast range simulated the human ear listening response. All measurements were carried out during working days and under suitable climatic conditions. For the proper assessment and analysis of the results, the following noise indices were computed:

Table 1: Maximum permissible noise limits used\* in KSA (Hassall and Zaveri, 1988)

Type of area	Permissible limit for equivalent continuous sound level- $L_{eq}$ dB(A)	
	Day (07:00-22:00)	Night (22:00-07:00)
Residential	55	45
Commercial-residential (Mixed)	60	50
Commercial	65	55
Industrial-residential	70	60
Industrial	75	65

\*ISO R-1996, Assessment of noise with respect to community response

Table 2: Noise risk zone criteria adopted to be used in this study

Intensity of noise in dB(A)	Zones
Less than 66	Safe
66-71	Tolerable
71-76	Low risk
76-81	Moderate risk
81-86	High risk
Greater than 86	Extremely high risk

- $L_{aeq}$  : A- weighted equivalent sound level
- $L_r$  : Statistical levels  $L_1, L_{10}, L_{50}, L_{90}$
- $L_d$  : Day average sound level
- $L_n$  : Night average sound level
- $L_{dn}$  : Day-Night average sound level and
- $L_{max}$  : Maximum noise level during sampling
- $L_{min}$  : Maximum noise level during sampling

### **TNI: Traffic Noise Index**

For the purpose of assessing Noise-Risk Zones (NRZs), a coherent evaluation criteria was adopted which resulted in six zones being established based on noise intensity levels (Banerjee *et al.*, 2008). Not only were these NRZs useful for assessing noise areas, but they also provided a platform for identifying noise-sensitive spots. Six categories of noise levels measured in dB (A) were established on the basis of human health factor. Levels below 66 dB (A) were classified as least harmful while those above 86 dB (A) as most harmful (Table 2). For the purpose of this investigation, the study area was divided into three zones based on their noise levels.

Horns, sirens from emergency vehicles and other noises are very rarely used in Kingdom of Saudia Arabia due to restrictions imposed by the country's internal regulations. Nevertheless, measurements in this case were taken under controlled conditions to minimize the influence of these types of noise.

Lima environmental noise calculation and mapping software was partly used to determine noise contours. The data obtained was then superimposed on the Al-Dammam area map.

## **RESULTS AND DISCUSSION**

Obtained noise index results for the major zones of Al-Dammam City are hereby specified and discussed:

### **Time-Based Noise-Level Variation**

An example of measured acoustics data is presented in Fig. 1 where, time-based variations of A-weighted sound levels  $L_{Aeq}$  and statistical levels  $L_1, L_{10}, L_{50}, L_{90}$  are plotted for Al-Nozha district. The day profile of results measured shows very high noise levels with a slight average drop of 3 dB during the period between 10 am to 12 noon and from 1 to 4 am. Table 3-5, list the diurnal average noise index values for commercial, residential and mixed (residential-and-commercial), respectively.

### **Mean Noise**

For all locations measured, the day-night average sound level  $L_{dn}$ , exceeded the maximum permissible limit of 55.0 dB (A) set by the European Union (EU). The overall mean value was 82.7 dB (A) with a standard deviation of 2.6 dB (A) while the overall over-the-limit mean value

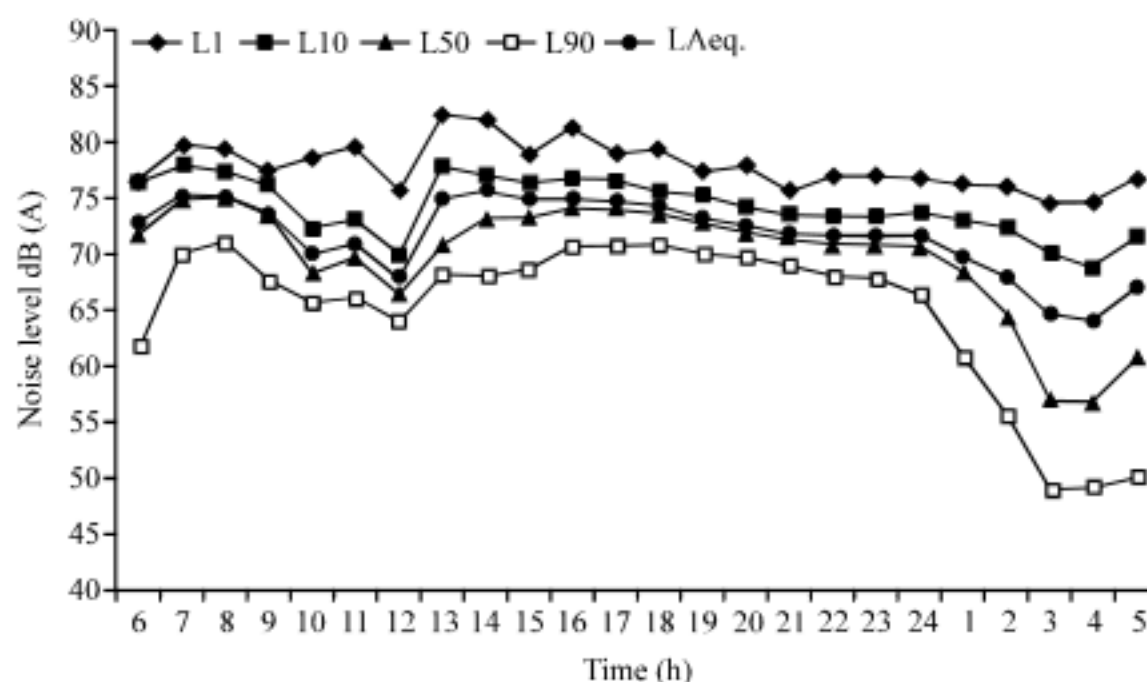


Fig. 1: Hourly noise levels at locations in Al-Nozha district

Table 3: Diurnal average noise index values in commercial areas

District	Mean $L_{\text{eq}}$		$L_{\text{max}}$		$L_{\text{min}}$		$L_{10}$		$L_{90}$		TNI		$L_{\text{dn}}$	SD
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night		
Fruit and vegetable market	80.4	73.9	88.6	87.3	63.5	60.7	78.1	77.9	67.6	65.3	79.6	85.7	82.1	2.7
Down town	81.7	74.3	88.4	87.2	63.6	61.4	78.6	78.2	67.7	66.7	81.3	82.7	82.9	2.6
Saptco	78.6	73.1	85.9	83.9	55.1	53.3	79.5	77.6	63.2	61.2	98.4	96.8	80.8	2.1

Table 4: Diurnal average noise index values in residential areas

District	Mean $L_{\text{eq}}$		$L_{\text{max}}$		$L_{\text{min}}$		$L_{10}$		$L_{90}$		TNI		$L_{\text{dn}}$	SD
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night		
Ibn Khaldoon	77.1	72.8	99.7	83.8	60.1	59.4	78.3	76.8	65.7	63.3	86.1	87.3	80.2	2.9
Al Adamah	79.2	74.6	96.9	90.7	62.9	58.4	79.9	77.5	69.03	62.7	82.7	92.0	82.0	2.5
Al Badeyah	84.7	74.3	109.7	82.2	51.4	60.4	80.9	77.9	63.7	65.6	102.5	84.8	84.5	2.6
Al Qazzaz	75.3	72.8	90.8	84.1	64.6	62.2	77.8	76.4	68.6	65.7	75.4	78.5	79.6	2.3
Al Muhamadyat	77.9	74.1	86.4	84.3	73.9	63.1	82.1	76.9	74.3	68.5	75.5	72.1	81.3	2.6
Madinat Al Ummal	81.6	77.1	93.4	88.2	68.6	64.8	84.1	80.6	75.0	70.1	81.2	82.2	84.5	1.2
Sub division no. 75	81.1	77.5	90.6	82.2	71.3	62.8	84.2	79.2	74.6	74.5	83.7	63.3	84.6	2.7
Al Mazroeyah	76.3	72.9	97.3	88.5	65.7	54.2	83.7	76.9	67.1	60.2	103.5	97.2	79.9	2.4
Amir Talal	77.8	72.7	95.4	87.8	61.9	50.9	85.6	77.5	66.3	53.5	113.5	117.5	80.3	2.3
Ad Dawaser	79.1	73.3	99.6	90.8	67.3	52.2	81.7	74.7	69.2	57.2	89.2	97.2	81.2	2.6
Al Jalawyah	79.9	76.7	94.1	87.4	64.1	65.9	84.3	79.5	74.7	68.5	83.2	82.3	83.7	1.5
Al Anood	78.1	73.1	95.3	83.6	68.3	59.6	85.8	76.7	76.0	64.1	85.1	84.3	82.5	1.8
Al Mubarakyah	76.7	76.4	90.8	89.9	59.8	53.5	80.1	79.7	63.8	59.5	99.2	110.2	82.8	3.1
Al Hamra	79.2	75.3	96.2	82.9	72.8	62.9	80.3	78.9	70.2	67.2	80.45	84.3	82.5	2.1
Al Azizyah	79.4	74.2	89.5	83.9	67.5	60.1	82.7	78.0	71.9	65.2	85.4	86.2	81.8	2.3
Al Khalij	78.1	75.2	95.1	89.4	59.4	55.4	82.2	78.9	65.7	62.3	101.6	98.8	82.2	3.1
Al Tobayshi	80.4	76.8	98.3	93.4	56.9	52.1	82.3	78.4	63.5	56.3	108.8	114.7	83.9	2.8
Al Murakebat	68.1	66.2	79.1	74.7	54.3	52.3	71.3	69.9	58.2	54.6	81.2	85.8	72.9	2.1
Abdullah Fouad	80.3	79.1	103.1	96.4	61.5	55.2	87.8	82.3	71.8	64.7	105.8	105.1	85.7	2.4

was 27.8 dB (A). The commercial-zone day average sound level  $L_d$  of 80.2 dB (A) exceeded the maximum permissible limit used in Kingdom of Saudi Arabia (Table 1) by 15.2 dB (A); the value for the residential zone exceeded it by 23.4 dB (A) while that of the mixed residential-and-commercial zone was above limit by 21.1 dB (A). Likewise, the commercial zone night average sound level  $L_n$  exceeded the maximum permissible limit in Table 1 by 18.8 dB (A), with the residential and mixed residential-commercial zones exceeding the limit 29.5 dB (A) and 27.7 dB (A), respectively. In Fig. 2 and 3, average  $L_d$  and  $L_n$  values per acoustic zone are shown depicting the extent to which permissible values are exceeded.

Table 5: Diurnal average noise index values in residential and commercial areas

District	Mean $L_{\text{aeq}}$		$L_{\text{max}}$		$L_{\text{min}}$		$L_{10}$		$L_{90}$		TNI		$L_{\text{dn}}$	SD
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night		
Madinat Al Ummal	77.1	72.4	85.6	84.2	59.1	55.8	75.7	74.7	63.1	62.0	83.5	82.8	79.8	2.9
Al Amir Talal	82.5	80.0	92.7	90.9	67.4	63.1	83.8	81.7	72.2	70.8	88.6	84.4	86.8	4.6
Al Adamah	78.5	71.9	91.85	88.4	56.7	52.6	77.5	76.9	61.5	60.9	95.5	94.9	80.1	3.8
Al Zohor	79.9	74.3	87.3	83.3	56.0	53.1	80.8	78.3	65.6	63.9	96.4	91.5	82.1	4.1
Al Badeyah	85.4	84.7	90.9	87.2	65.9	57.3	81.1	80.7	72.4	69.3	77.2	84.9	90.6	3.3
Sub division no. 75	84.4	82.5	93.3	91.2	62.0	60.6	81.4	80.5	68.5	67.2	90.1	90.4	89.2	2.4
Sub division no. 8	79.8	77.9	83.8	81.1	55.8	54.7	77.6	76.9	66.1	64.2	82.1	85.0	84.6	3.5
Ad Dawaser	80.8	79.4	88.5	87.1	59.4	58.3	76.9	75.3	65.2	64.5	82.0	77.7	86.1	2.5
Al Qazzaz	79.6	76.2	81.3	80.7	54.8	53.4	74.9	72.3	59.6	58.4	90.8	84.0	83.3	3.2
Al Nozha	82.9	78.1	91.0	83.7	60.0	59.7	78.9	77.7	66.4	64.8	86.4	86.4	84.2	2.2
Emirate	80.9	77.7	91.9	90.7	58.6	56.3	80.1	79.3	67.5	66.7	87.9	87.1	84.1	2.4

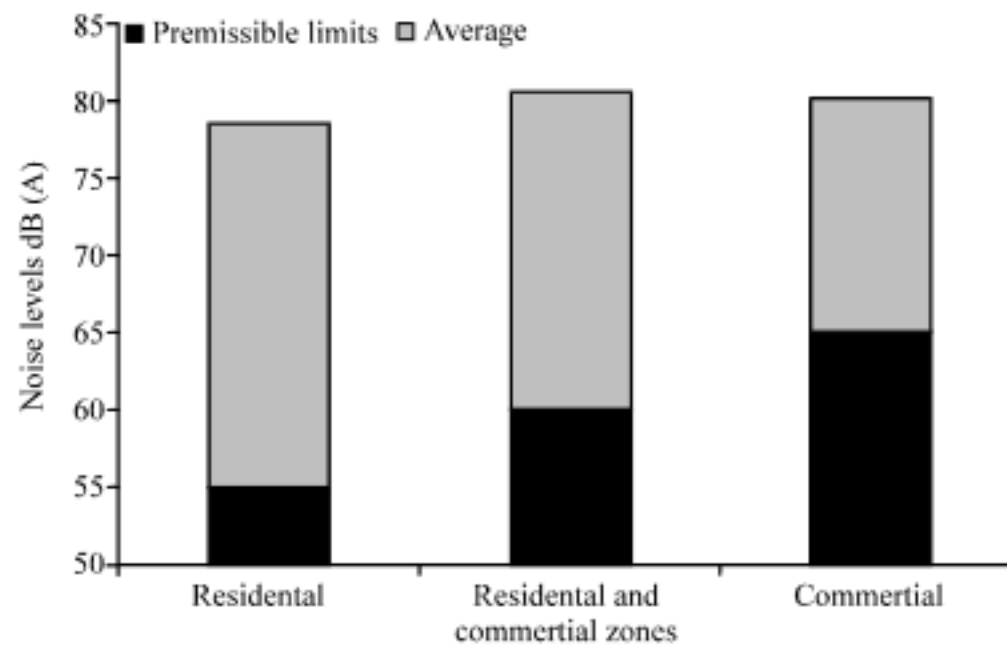


Fig. 2: Average  $L_d$  values per acoustics zone

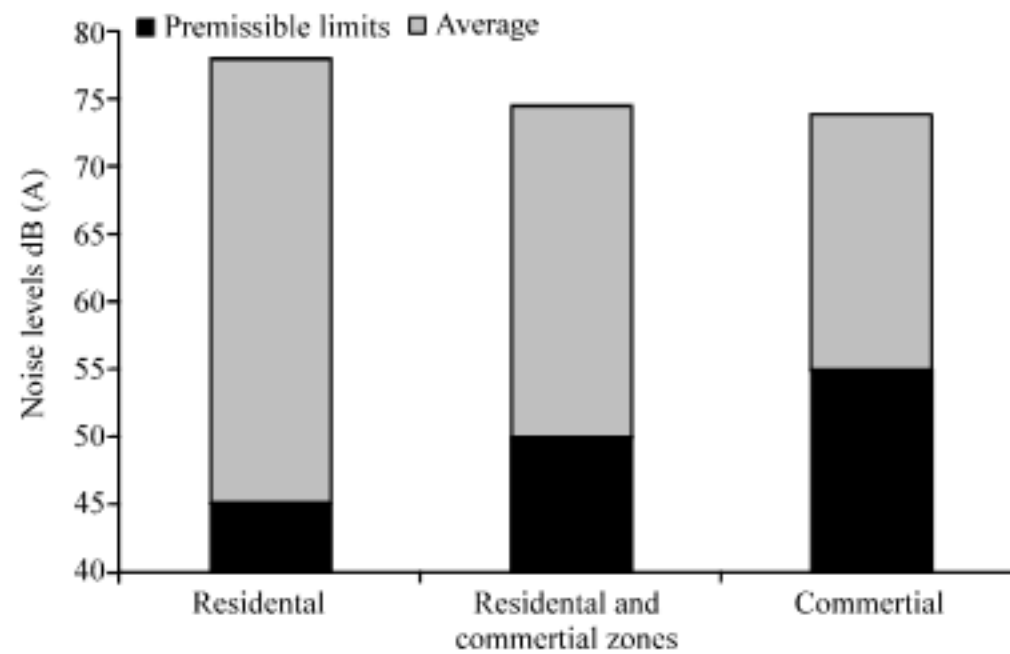


Fig. 3: Average  $L_n$  values per acoustics zone

**Noise Map**

In order to generate the noise contour map for Al-Dammam, given the fact that the city master plan layout follows a grid system design, measurements were taken at 122 locations adjacent to major roads, with the distance between any two contiguous points ranging from 300-500 m. Figure 4 shows the noise contour map based on day noise levels  $L_d$  and Fig. 5 shows one based on day-night noise Levels  $L_{dn}$ .



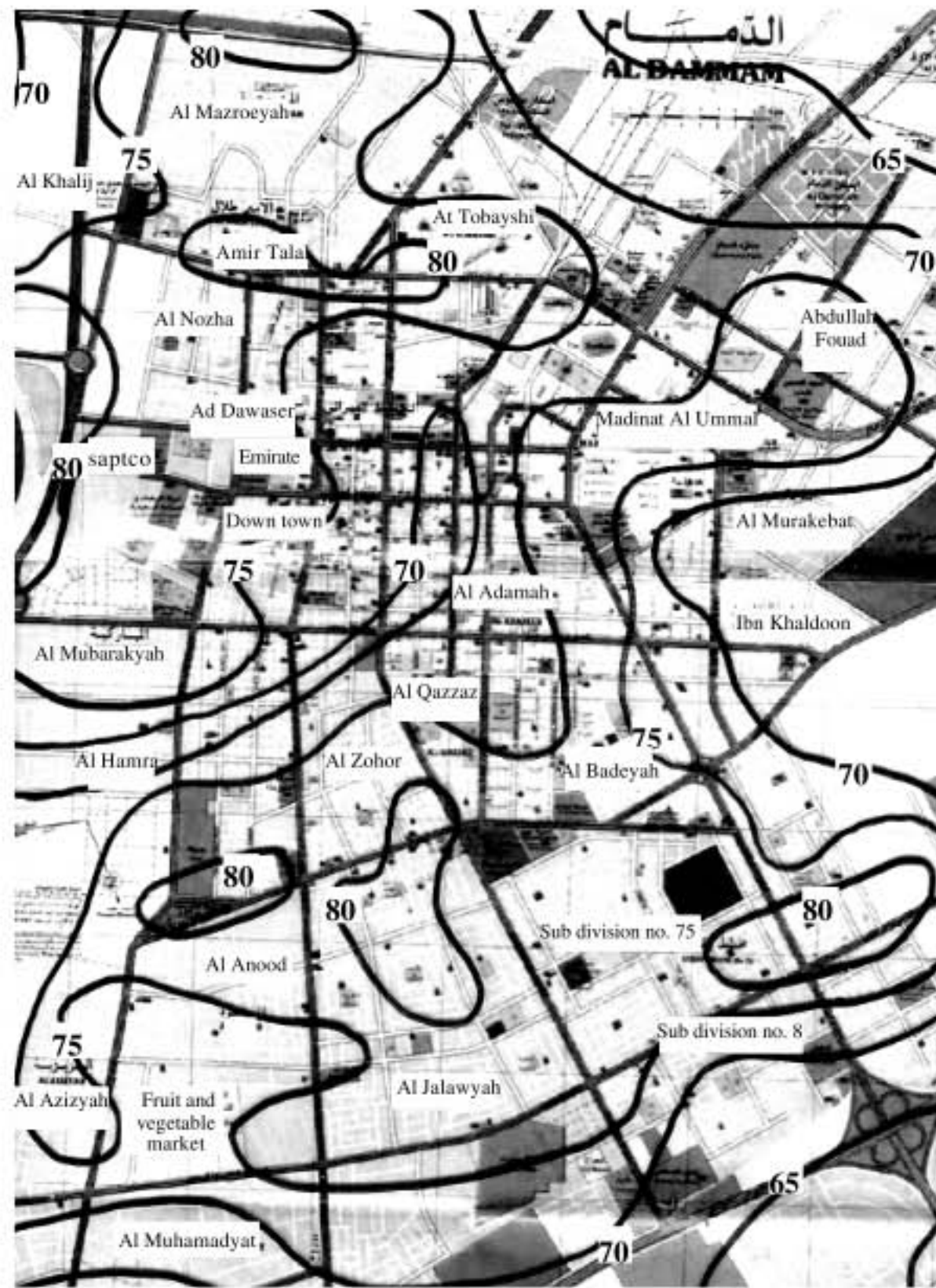


Fig. 4: Noise contour map based on Day noise Level  $L_{d}$

The current study is in a good agreement with the previous one (Skånberg and Öhrström, 2002) where noise pollution from road traffic in residential areas is a growing environmental problem. New approaches to turn the negative trend are needed. Like any other large cities in the world the streets of Al-Dammam are also loaded with traffic flow, shopping centers and other activities. This leads to the exposure of many people to noise pollution caused by the traffic. The previous study (Björk *et al.*, 2006; Jakovljevic *et al.*, 2009) also has indicated that exposure to road traffic noise at high levels was common in the study population and it produced frequent annoyance and disturbances of daily activities.

It was indicated (Lam *et al.*, 2009) that personal noise sensitivity, attitudes towards different means of transport and perceived quality of the living environment are secondary contributing factors. Associations between road traffic noise and negative health effects were observed among the annoyed participants and in other important subgroups. Therefore, the current research study becomes necessary for that business city.



Fig. 5: Noise contour map based on Day-Night noise Level  $L_{dn}$

In general, for current study the noise levels recorded in all zones were very high and exceeded the permissible limits by far. Levels at the following locations were particularly critical:

- The intersection of First street intersections with King Abdul-Aziz, King Saud and King Khalid Streets (affected districts were Al Amir Talal, Al Tobaysh and Al Dawaser)
- The intersection of forty-second street with Ibn Khaldoun Street and King Khaled street (affected districts were subdivision numbers 75 and 8, as well as Al Jalawyah)
- The intersection of Al-Mazari street with King Khaled street (affected districts were Al Anood and subdivision number 75)

Table 6: Count of traffic volumes

Intersections	Vehicular/hour
First street and King Abdulaziz	4014
First street and King Suad	4669
First street and King Khaled	4693
Forty-second street and Ibn Khaldoun	7877
Forty-second street and King Khaled	5231
Al-Mazari street and King Khaled	7613

Table 7: Classification of districts of Al-Dammam city

Noise exposure class	District name
Moderate risk	Madina, Al Ummal, Al Mazroeyah, Al Adamah, Ibn Khaldoun, Saptco
High risk	Ad Dawaser, Al Muhamadyat, Al Azizyah, Al Adamah, fruit and vegetable market, Al Zohor, Al khalij, Al Anood, Al Hamra, Al Mubarakyah, downtown, Al qazzaz, Al Jalawyah, Al Tobayshi, Emirate, Al nozha, Al badeyah, Sub division No. 8, Abdullah Fouad
Extremely high risk	Al Amir Talal, sub division No. 75

Recorded traffic volumes at those intersections are presented in Table 6, they explain the reason behind the high level obtained. Using the Noise Risk Zone Criteria shown in Table 2 to assess the situation of Al-Dammam residents led to the classification shown in Table 7.

## CONCLUSIONS

The noise surveys carried out in Al-Dammam city showed that traffic noise produces high noise levels that significantly exceed permissible limits used in the country's codes. Almost the entire population of Al-Dammam city is exposed to high-risk noise levels mainly from road traffic. The situation is of such dire proportions that urgent action needs to be taken to contain and where necessary, reverse the problem. Unfortunately, there were no local environmental departments available to tackle this problem. Nevertheless, the author wishes to make the following recommendations in a bid to help improve the situation:

- Town planning needs to study the city's roads and identify places where new highways and overpasses can be built. This can lower traffic volumes and decongest the streets
- New public transportation systems such as buses and city trains must be established
- Studies need to be carried out to determine social factors, if any, responsible for the high traffic flows way into the late hours of the night all week long
- A public awareness program needs to be established to educate the public in the city about the negative health side effects emanating from prolonged exposure to high noise levels

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