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Evaluation of Traffic Noise Level: A Residential Area Case Study

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Abstract - The World Health Organization (WHO) has recognized environmental noise as harmful pollution that causes adverse psychosocial and physiologic effects on human health. Motorized vehicles are a major source of noise pollution. It is a universal phenomenon, and it has grown to the point that it has become a major concern for the public and policymakers. The aim of this paper, therefore, is to investigate the traffic noise levels during peak and off-peak hours and contributing factors such as traffic volume, heavy-vehicle speed, and metrological factors, such as temperature, humidity, and wind speed, in a selected residential area in Kuwait. An expressway, a major arterial road, and a collector street were the three types of roads that were chosen for this study. Other sources of noise were also considered. All the measurements were conducted simultaneously. The results showed that the traffic noise levels were over the allowable limit on all the chosen types of roads. The average equivalent noise levels (LAeq) for the expressway, the major arterial road, and the collector street were 74.2 dB(A), 70.47 dB(A), and 60.84 dB(A), respectively. In addition, a positive correlation coefficient between traffic noise versus traffic volume and between traffic noise versus 85th percentile speed was obtained. However, there was no significant relation in metrological factors. Abnormal vehicle noise due to poor maintenance or user-enhanced exhaust noise was found to be one of the highest factors that affected the overall traffic noise readings.

Keywords**:** Traffic Noise, Kuwait, Noise pollution, Environmental noise

1. Introduction

Traffic noise pollution is becoming a universal problem in most world cities, and it has been a great concern to both the public and the cities in developed and developing countries alike. The World Health Organization (WHO) has recognized environmental noise as harmful pollution that causes adverse psychosocial and physiologic effects on human health [1]. Traffic noise pollution, in particular, is universal, and in the past few decades, it has grown to the point that it has become a major concern for the public and policymakers. There have been many studies and investigations that assess the impact of traffic on noise levels. Airports are also known to be a major source of noise pollution, and the effect of airport noise on health and the environment has become a concern.

Road and air traffic noise have been examined in the developed world in the last few decades, and possible measures and policies have been investigated that can be utilized to reduce noise levels in urban areas. Less research, however, has been conducted in this research area in developing countries. The State of Kuwait is one developing country that has experienced a rapid increase, not only in its socio-economic characteristics but also in the number of cars and road networks that have contributed to the increase in noise levels in Kuwait. Although required, the increase in roads has contributed to the apparent noise levels in the country, and traffic noise is still one of the major concerns in Kuwait.

The issue of traffic noise is an ever-increasing problem as the urban environment continues to expand and develop and as traffic volumes increase. While there is currently no limit on the level of noise that can emanate from an existing roadway, often it is seen that when new routes are constructed, designers need to mitigate the impact of the increase in noise taking place. Within the UK, where this increase in noise is seen to exceed certain constraints, compensation and insulation may be provided to the premises owner issued by the Department of Transport [2]. The level of change in noise is based on site-specific criteria, with each development being analyzed individually to determine if the described criteria have been met to justify remediation of the issue.

To reduce the impact of traffic noise, a multitude of measures can be taken to achieve the goals of the relevant stakeholders. Currently, within the UK, aircraft noise is not deemed to be a statutory nuisance, and local authorities do not have any legal power to act in this regard [3]. However, to control the level of noise generated by aviation, the

International Civil Aviation Organization (ICAO) has in place regulations and standards to limit the noise from civil air transport craft. These standards are in operation in over 180 countries, including the entire EU, and require all aircraft to pass inspections, ensuring that they adhere to these standards. The implementation of these standards has led to a maximum 75% reduction in noise levels. In 2001, all ICAO member states agreed to a four-step program to reduce the impact of air traffic noise [4]. These steps included reducing noise at the source, land use planning around airports to ensure that inappropriate developments are not allowed around airports, and noise abatement operational procedures to help reduce the nuisance caused by aircraft. Also included were operating restrictions to limit the access of aircraft to airports, such as restrictions on flights at night and the phased removal of noisier aircraft. Within the UK, some airports operate schemes to provide residents who live in the areas with the highest noise levels a grant to install additional noise-mitigating insulation within their homes. This initiative is dependent on the relevant airport, if such a scheme exists, and the parameters to which individuals must adhere to receive the grant aid.

In addition, traffic management schemes are implemented where large vehicles are restricted from entering certain areas during certain times of the day, as well as pedestrian areas, to eliminate road traffic noise. Care should be taken to ensure that such a measure would not harm the economy of the local area, however. Along with each of these measures, there has been an increase in the prevalence of alternate fuel vehicles throughout the world. In many instances, these vehicles result in smaller engine sizes, which in turn reduce their overall traveling noise. As these vehicles continue to develop and become more popular, there is the likelihood that there will be a knock-on effect of reducing overall traffic noise levels.

2. Research Objectives

1- Investigate the traffic noise levels and the factors affecting their level, such as traffic volume, heavy-vehicle speed, and other metrological factors.

2- Measure the traffic noise to make sure it is within the allowable level.

3- Reduce the knowledge gaps and limitations of previous studies to reach a better understanding of the exposure to the urban population in Kuwait.

3. Location

The site selected to be monitored for road traffic noise pollution in an urban area in this study was a residential area named Ishbiliya (Figure 1). The area is located near Kuwait International Airport and comprises several types of roads. Three road types were selected and monitored simultaneously, namely an expressway, a major arterial road, and a collector street, and are shown in Table 1. The 12-lane Expressway has a speed limit of 120 kph. The major arterial road has three lanes in each direction with a speed limit of 80 kph. The 4-lane collector street is located near a roundabout with a speed hump in both directions and has a road speed limit of 45 kph. Also, it is in a shallow street canyon, approximately parallel to the prevailing wind. The monitoring operation was carried out on the 10th of October 2021.

4. Material and methods

The monitoring was carried out by taking the measurements at a fixed location near the collector street, the major road, and the expressway, simultaneously. The monitoring operations took place to reflect the effects of road traffic noise pollution.

The methodology consists of several stages performed at the selected sites, as shown in Figure 2. It focuses on outdoor noise levels and the events influencing them. The first stage involved selecting the study area and formulating the procedure for the data collection. Statistical software (SPSS-27) was used for the analysis to find the main factors influencing noise levels. A descriptive statistical analysis, in addition to other analyses, was also conducted.

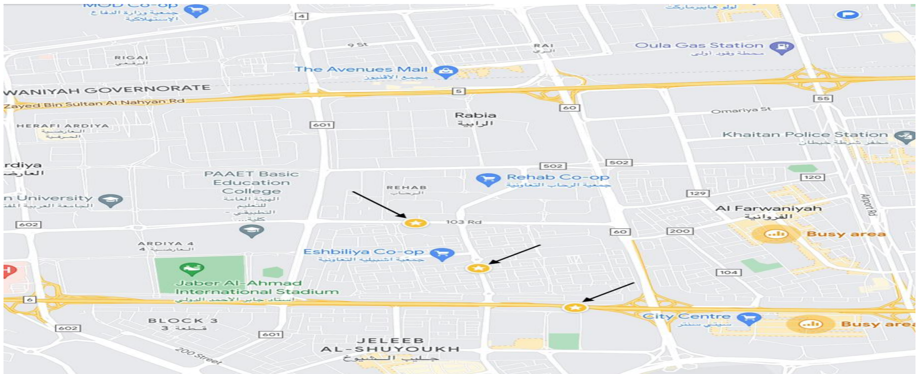

Fig. 1: Location of the 3 sites where the monitoring operations were carried out [Source: Google Maps]

Table 1: Summary of three sites chosen for the monitoring operation

ID	Name		Location	Moring		Noon		Campaign Date	No. Lane	Canyon	Speed hump	Near **intersection**
	Neighbourhood	Road Type		start	end	start	end					
E1	Ishbiliya	expressway	29.266522, 47.946348	4:30	9:30	12:30	15:30	10/10/2021	12	No	No	No
M1		Major	29.280158, 47.934822						6	No	No	No
C1		Collector	29.272871, 47.939346						4	yes	yes	yes

4.1 Equipment

The equipment was selected for its durability and accuracy. The instrument primarily used in this study for noise level monitoring was the Bruel & Kjaer outdoor sound level meter 2250-L. This instrument was chosen due to its level of precision and durability given the budget constraints. The Bruel & Kjaer outdoor sound level meter 2250-L is a portable and easy-to-use device and can detect noise levels ranging from 21.5 dBA to 140.8 dBA [5]. Spack Solutions Countcam 2 camera was used to record road traffic [6], which was reviewed later for the road traffic count. Decatur Genesis GHD-KPH by Decatur Electronics was employed to measure vehicle speed at the sites randomly. The chosen instrument has a speed detection range of 20 to 337 kph [7]. The Ambient Weather WM-5 Handheld Weather Meter was used to record windspeed, temperature, and relative humidity [8].

4.2 Data Handling and Analysis

All logged data was downloaded using suitable software. The data were conveyed in Microsoft Excel format and amalgamated into a master spreadsheet using time as a benchmarking variable to merge the data. All data were monitored at one-minute intervals. The noise levels were plotted with respect to time. The distribution of the noise levels in all the sites was calculated using a 1 dB(A) bin at a 1-minute interval. The distribution of the noise levels for each trial was calculated at 1 dB(A) at a 1-minute interval and was then saved in a separate CSV file. These data were analyzed using Excel and SPSS-27 software packages to produce descriptive analysis. The value of the Pearson correlation coefficient was then computed. The multiple regression method was carried out to find the significant predictors of traffic noise. The significant variables were selected to have a 95% level of significance, and the p-value used was < 0.05.

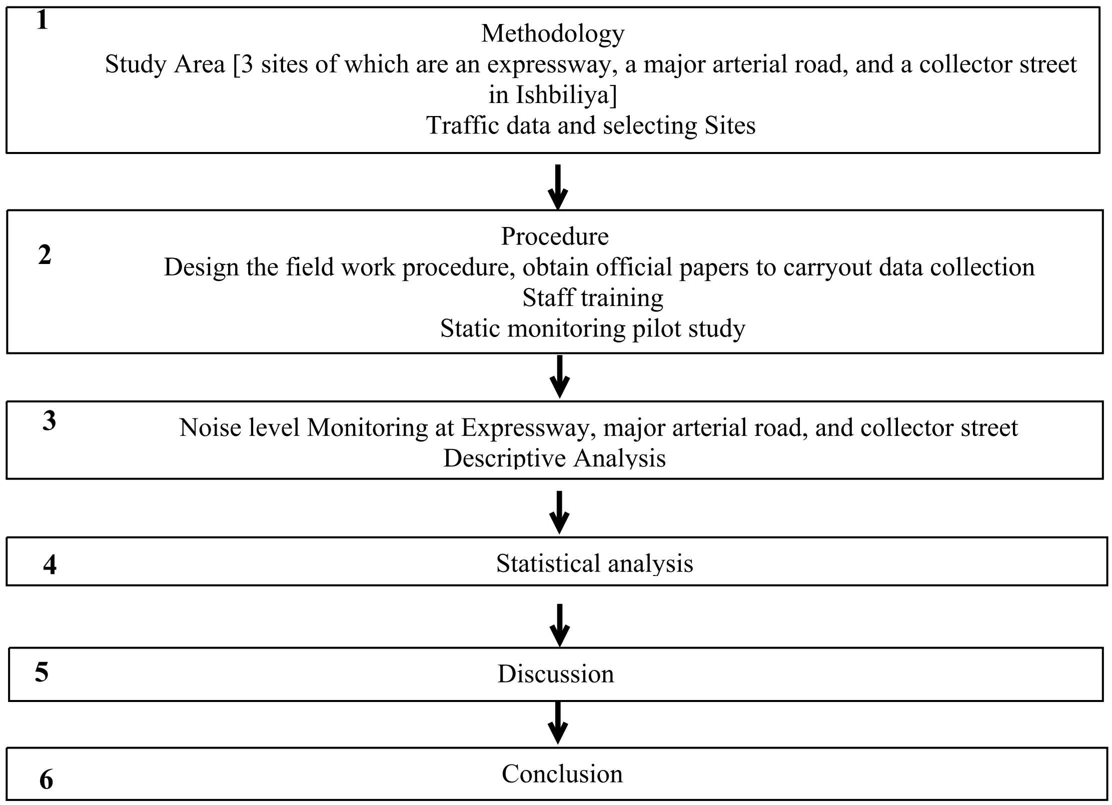

Fig. 2: Conceptual framework showing the methodology.

5. Results

5.1 Traffic noise and traffic volume (per minute)

Results of traffic noise levels dB(A), recorded from the three study locations during the peak and off-peak periods, are presented in Table 2. The results show that the traffic noise level was over the allowable limit at the expressway (min 66.4 dB(A), max 78.3 dB(A). The average noise level (average LAeq) at off-peak hours was 73.7 dB(A), 75.1 dB(A) for the morning peak, and 74.1 dB(A) for the afternoon peak. The maximum allowable limit for external noise is 55 dB(A) for daytime and 60-62 dB(A) for evenings (Table 3). There is no significant difference in peak and off-peak hours, although the traffic volume is less in the off-peak hours. This is due to the abundance of vehicles at off-peak hours, or in our case, at 5:00 to 6:30 AM. The quantity of vehicles at off-peak hours is due to local laws not allowing heavy trucks to use the expressway during peak hours.

The results show that the traffic noise levels are over the allowable limit at the major road (min 56.8 dB(A), max 84.5 dB(A)) with the average noise level at off-peak hours at 65.8 dB(A) and 72 dB(A) for the morning peak, 73.6, dB(A) during the afternoon peak hours. It appeared from the results that there is a significant difference between the peak and off-peak hours, although they are all over the allowable limit.

The results show that the traffic noise level is also over the allowable limit in the collector street (min 51.4 dB(A) max 78.1 dB(A)). The average noise level at off-peak hours was 56.7 dba (only 1.7 dB(A) more), 61.6 dB(A) for the morning peak, and 64.3 dB(A) for the afternoon peak hours.

Table 2: Traffic noise (LAEQ) in each location

Trial	Expressway				Major Arterial				Collector Street			
	Period	Descriptive Analysis	LAEQ	LAF90	Period	Descriptive Analysis	LAEQ	LAF90	Period	Descriptive Analysis	LAEQ	LAF90
Trial 1	Morning Off-Peak	Mean	73.7	71	Morning Off-Peak	Mean	65.8	52.5	Morning Off-Peak	Mean	56.6	52.5
		Maximum	76	73.5		Maximum	71.2	62.5		Maximum	62.4	55
		Minimum	66.4	64.5		Minimum	56.8	47.5		Minimum	51.4	50.5
		Std. Deviation	2.4	2.3		Std. Deviation	2.9	3.1		Std. Deviation	2.1	1
		Range	9.6	9		Range	14.4	15		Range	11	4.5
		Median	74.5	72		Median	66.2	51.8		Median	56.7	52.5
	Morning Peak	Mean	75.1	72.9	Morning Peak	Mean	72	62.9	Morning Peak	Mean	61.6	57.8
		Maximum	78.3	74.5		Maximum	77.1	73		Maximum	72.3	62
		Minimum	73.3	70.5		Minimum	63.2	50.5		Minimum	55	51.5
		Std. Deviation	0.6	0.8		Std. Deviation	2.7	5		Std. Deviation	2.3	2.5
		Range	5	4		Range	13.9	22.5		Range	17.3	10.5
		Median	75.1	73		Median	72.4	63		Median	61.8	58
	Afternoon Peak	Mean	74.1	71.8	Afternoon Peak	Mean	73.6	64.9	Afternoon Peak	Mean	64.3	59.2
		Maximum	77.5	75		Maximum	84.5	72		Maximum	78.1	68.5
		Minimum	71.3	67		Minimum	68.5	51.5		Minimum	59.6	54
		Std. Deviation	1	1.1		Std. Deviation	1.7	3.9		Std. Deviation	2.4	1.8
		Range	6.2	8		Range	16	20.5		Range	18.5	14.5
		Median	74	72		Median	73.7	65		Median	63.9	59.5

Table 3: Type of the maximum allowable limit for external noise [9].

Type of Area exposed to external noise	Maximum Noise Level LAeq dB(A)		
	Day time	Evening Time	Nighttime
Typical Residential Areas	55	55	50
Urban Residential Areas	55	60	62
Residential areas with commercial activities	65	56	55
Industrial and commercial areas	70	70	65

It was noted that the traffic noise level in the expressway is higher than the major road, and the major road is higher than the collector street (see Fig. 3). Also, there was more traffic volume associated with a higher traffic noise level, which shows a positive correlation.

5.2 Correlation analysis

A positive correlation coefficient was found, showing higher traffic volume associated with higher average traffic noise levels. The Pearson correlation coefficients are ($r=0.346$; $p< 0.01$), ($r=0.632$; $p< 0.01$), and ($r=0.685$; $p< 0.01$), for the expressway, major arterial road, and collector street, respectively. It was noted that the correlation coefficient between the traffic noise and traffic volume is much stronger in the major arterial road and collector street than the correlation coefficient for the expressway.

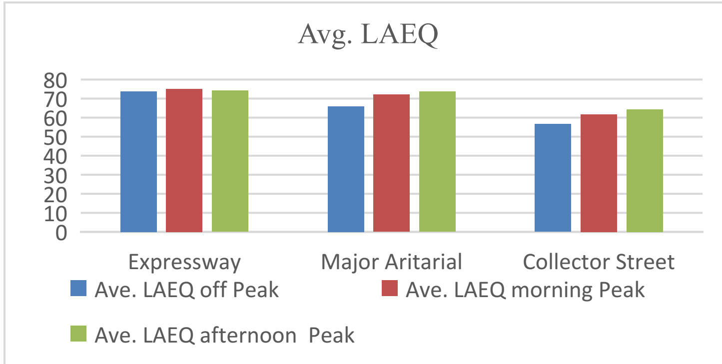

Fig. 3: Average traffic noise (LAEQ) in each location

5.2.1 Traffic noise and spot speed (85th percentile) and the standard deviation of the spot speed

A positive correlation coefficient was found with a higher 85th percentile of speed associated with higher average traffic noise levels. The Pearson correlation coefficient is ($r=0.903$; $p< 0.01$). It should be taken into consideration that the variation in speed could cause more traffic noise because of throttling (or sudden acceleration and deceleration of vehicles). Thus, the results showed that a higher standard deviation in speed was associated with higher average traffic noise levels ($r=0.926$; $p< 0.01$) as shown in Table 4.

5.3 The effect of traffic on the noise level readings

Many other sources of noise were recognized to affect the noise level readings. Some of these sources are part of traffic noise, such as throttle/acceleration, abnormal vehicle noise due to poor maintenance, user-enhanced exhaust noise, police and ambulance and fire truck sirens, and horn noise. These noise levels were measured per minute in addition to traffic volume. The frequency of these noise sources was dependent on the location selected and the type of road.

Other sources of noise not due to traffic, such as airplane noise, construction work, mosque audio, and voices of people, were also monitored. However, the frequency of these other sources was not significant. These factors were discovered during the first trial for the three selected locations in this study.

Table 5 shows that in the Ishbiliya expressway, the average abnormal vehicle noise due to poor maintenance or user-enhanced exhaust noise caused the highest noise level ((Laeq)=75.035) when airplane noise and police sirens were excluded but was not much different than normal traffic ((LAeq)= 74.376 dB(A)). However, on the major road, the difference was almost 5 dB(A), (LAeq)= 75.732 dB(A) for abnormal vehicle noise, and (LAeq)= 70.434 dB(A) for normal traffic. At the Ishbiliya collector road, the highest abnormal noise came from throttle/acceleration noise. Unexpected construction work was identified at the Ishbiliya major road, causing a rise in noise level to almost 74.2 dB(A).

6. Discussion and Conclusions

It appeared from the results that traffic noise is in the upper allowable limit (according to Table 3), especially in the expressway. The overall correlation analysis shows a positive relationship, with more traffic volume causing higher traffic noise readings. However, there is no significant difference in peak and off-peak hours, although the traffic volume is less in the off-peak hours. This is due to the abundance of heavy vehicles on the roads during off-peak hours, which was observed from 5:00 to 6:30 AM (see Table 4). The higher traffic volume during peak afternoon hours caused stop-and-go traffic, which in this case reduced traffic noise (see Table 4). Also, abnormal vehicle noise due to poor maintenance or user-enhanced exhaust noise sometimes appears with low traffic volume. There was also a positive relationship between traffic noise and the 85th percentile speed.

It should be taken into consideration that the variation in speed could cause more traffic noise due to sudden acceleration and deceleration of vehicles. Also, speed variation indicates that there is unstable flow caused by driver behavior, such as not following the speed limit (upper or lower) or illegal overtaking.

Table 4: Spot speed study

Date	Time	number of minutes	number of speed shots	S.D.	mean speed	85th Speed	mean LAEQ	total traffic	Traffic per minute	Heavy vehicle %
Expressway	Morning									
10/10/2021	5:09 - 6:29	81	567	18.2	89.13	108.64	74.84	17027	210.21	26.19
10/10/2021	6:30 - 7:26	57	410	17.067	91.11	109.86	75.18	18895	331.49	14.41
10/10/2021	7:35- 9:06	67	469	17.029	89.86	107.87	75.02	20064	299.46	14.29
Expressway	Afternoon									
10/10/2021	1:01- 2:00	60	420	17.64	82.76	100.75	74.31	22238	353.70	11.48
10/10/2021	2:01- 3:08	68	477	15.17	82.71	97.30	73.82	23102	334.81	16.06
Major Arterial	Morning									
10/10/2021	5:00-6:29	90	343	10.851	51.63	63.11	66.67	781	8.68	12.38
10/10/2021	6:30-7:59	90	521	16.604	59.72	74.20	73.52	4192	46.58	2.88
10/10/2021	8:00-9:08	69	369	15.974	57.3	73.96	71.05	1850	26.81	3.85
Major Arterial	Afternoon									
10/10/2021	12:50-1:49	60	335	12.781	58.42	70.53	73.87	3088	51.47	3.32
10/10/2021	1:50-3:15	86	525	11.814	60.63	72.30	73.21	3510	40.81	4.26
Collector Street	Morning									
10/10/2021	5:00-6:29	90	329	4.28	27.39	31.54	57.21	360	4.00	3.58
10/10/2021	6:30-7:59	88	630	4.255	28.7	32.66	62.28	1641	18.65	2.62
10/10/2021	8:00-9:09	70	484	4.23	28.84	30.68	62.18	933	13.33	4.61
Collector Street	Afternoon									
10/10/2021	1:01-2:00	60	420	4.824	28.43	32.79	64.35	1343	22.38	4.54
10/10/2021	2:01-3:11	71	490	5.394	28.4	33.65	64	1269	17.87	3.39

Regarding metrological factors, the results show that there is no significant relationship between traffic noise and temperature, humidity, and wind speed. However, several other types of noise cause an increase in overall traffic noise readings, such as police, ambulance, fire truck sirens, horn noise, throttling/acceleration, and construction work. However, the most frequent noise was abnormal vehicle noise due to poor maintenance or user-enhanced exhaust noise.

Throttling/acceleration by trucks was also recognized as a factor that affected the overall traffic noise reading. This could be due to poor vehicle maintenance and could be because of overloading trucks since there is no weight while in motion system in Kuwait. Rutted roads were also considered as a factor that may affect the overall traffic noise reading. Unexpected construction work can also factor in the overall traffic noise readings.

Table 5: Other sources of noise in Ishbiliya

Road type	N	Type of Noise	Ave. LAEQ
Expressway	189	Traffic only	74.376
	67	Abnormal vehicle noise	75.035
	140	Horn	74.672
	10	Airplane	75.180
	5	Police siren	75.080
Total	411		
Major	N	**Type of Noise**	
	244	Traffic only	70.434
	114	Abnormal vehicle noise	75.732
	10	Horn	74.370
	6	Airplane	73.783
	26	Construction work	74.192
	16	Throttle/acceleration	74.975
	0	Police siren	NA
Total	416		
Collector	N	Type of Noise	
	248	Traffic only	60.688
	40	Abnormal vehicle noise	62.590
	36	Horn	62.868
	20	Airplane	65.186
	0	construction work	NA
	0	Police patrol	NA
	3	Mosque audio	75.967
	44	Throttle/acceleration	63.567
Total	391		

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