A PERSPECTIVE OF ROAD TRAFFIC NOISE ON JORDANIAN URBAN ROADS

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Abstract **- Road traffic noise constitutes a growing environmental problem in Amman, the capital of Jordan. The present and future magnitudes of this problem are evaluated using British Calculation of Road Traffic Noise (CRTN) method. The impact of the problem on the exposed residents is also evaluated through a social attitudinal survey. The results confirm that the present and predicted noise level are high and exceed the maximum allowable limits. The problem has negative impact on daily activities of the exposed residents as about 80% of them report it to affect their sleeping, reading, and rest.**

Keyword: Traffic noise, CRTN, Social Survey, Amman.

I. INTRODUCTION

Road traffic noise is a main environmental problem facing populations of many cities in the world including Amman, the capital of Jordan. Numerous researchers in developed countries have investigated the problem of traffic noise, its characteristics and impact and highly ranked it on the list of environmental pollution. In developing countries, however, limited work has been done although the problem of noise pollution assumes a more complex dimension exhibited by the continuous migration from rural to urban areas leading to major cities being overcrowded .The problem is aggravated by the lack of city planning and the very high noncompliance with traffic rules and regulations.

This paper presents the results of a research carried out to determine the present and future magnitude of traffic noise along urban arterials of Amman the capital city of Jordan, and to examine the effect of traffic noise on residents through investigating the attitudes of exposed individuals.

II. AN OVERVIEW OF PREVIOUS WORK

Extensive studies were carried out on traffic noise mainly in developed countries. However, limited work, has taken place in developing countries. In Jordan, an early study [1] was carried out along the main streets in Greater Amman area. The study was limited and used fixed percentages of heavy vehicles and speeds along all streets.

A more detailed study [2] was carried in where future noise levels were predicted using the British Calculation of Road Traffic Noise (CRTN) method [3]. The study concluded that CRTN can be used satisfactorily in Amman and the predicted levels would exceed the maximum allowable noise limits.

Another study [4] was carried out to evaluate the effect of distance from signalized intersection on traffic noise levels. The equivalent noise level (L_{eq}) was measured at 40 signalized intersections in Amman. L_{eq} is the average acoustic energy over the measurement period.

The collected data was utilized to develop the following noise prediction model in terms of distance from signal stop line.

$$L_{eq}=75.387-1.357*10^{-6}*Distance^3+0.0006863*Distance^2-0.0713524*Distance \quad (1)$$

More variables were considered and the nonlinear regression model which was found to have the highest prediction capability is of the form

$$L_{eq} = -5.23\ BNP^{-0.60} * S^{0.02} * D^{-0.44} + 0.035V^{1.28} + 80.00 \quad (2)$$

Where BNP = British Pedulum Number,

S = Traffic speed (km/h)

D = Distance from the signal stop line

(m)

V = Traffic volume (veh/min)

Another study into the management of traffic noise along Amman urban arterials [5] reported that a 3-m high timber barrier is the most favourite amelioration measure to lower the noise levels at the studied sites below the maximum allowable limit. In another study carried out to measure the road traffic noise levels adjacent to residential areas in Amman, researchers reported that noise levels were ranging between 72.7 and 78.5 dBA [6]. The effect of these high levels on people was to the extent that over half of the residents consider changing their place of residence.

Abo-Qudais et al. [7] studied the impact of road traffic noise on owners and employees of businesses around major streets in Amman. The study revealed that 81% of interviewed people were annoyed by noise and it interferes with their daily activities.

Jamra et al. [8] found that the minimum and maximum noise levels at 28 locations in Amman are 46 and 81 dBA during the day and 58 and 71 dBA during the night.

More recent studies[9], [10] concluded that the growth in urbanization in Jordan coupled with lack of proper planning brought adverse environmental impacts with an average increase of noise levels of about 4.5 dBA over 15 years. Another recent study of the magnitude, control and impact of traffic noise on Amman community [11] found that 5-m high barrier are effective in reducing noise levels below permissible limit at all studied sites. The same study revealed that road traffic noise is a major concern for the communities living in the vicinity of urban roads and affects their daily activities to the extent that 65% of the residents consider moving to quieter areas.

Using the experience and research results from developed countries estimation of external cost of road traffic noise [12], and on estimated vehicle travel in Jordan, Jadaan et al. [10] estimated the external cost of noise in Jordan for the year 2008 to be about $ 80 million.

III. METHODOLOGY

The magnitude of traffic noise along urban arterials in Amman was researched to provide a further insight into the problem in Jordan. The methodology adopted involved the collection of data on traffic noise and affecting factors at nine sites in Amman Urban area. The sites were selected where traffic noise levels were expected to be high and cause annoyance to nearby activities, and where the view of the road is substantially unobstructed. The sites shown in Fig.1 are described as follows:

S1:- Queen Rania Al-Abdullah St. in front of agriculture municipalities.

S2:- Ibin-Sinna Street, (Wadi Saqra), approximately 150 meters away from tunnel toward city center.

S3:- The Seventh Circle in front of the Modern Education School.

S4:- King Abdullah Al Thani St. beside fastlink company.

S5:- Al-Istiqlal Street, in front of Al Amanna building "Health Sector".

S6:- Abu-Nsair Street, beside Flona Nursery.

S7:- Al-Madina Al Munawarra St. Approximately 500 meters away from Suhayb mosque toward Kilo Bridge.

S8:- Al-Ameer Ali Bin Hussein Approximately 100 meters away from USA Embassy toward Al-Muhajereen

S9:- Al-Sakhrra Almosharraha Street, approximately 600 meters away from Crown Hotel.

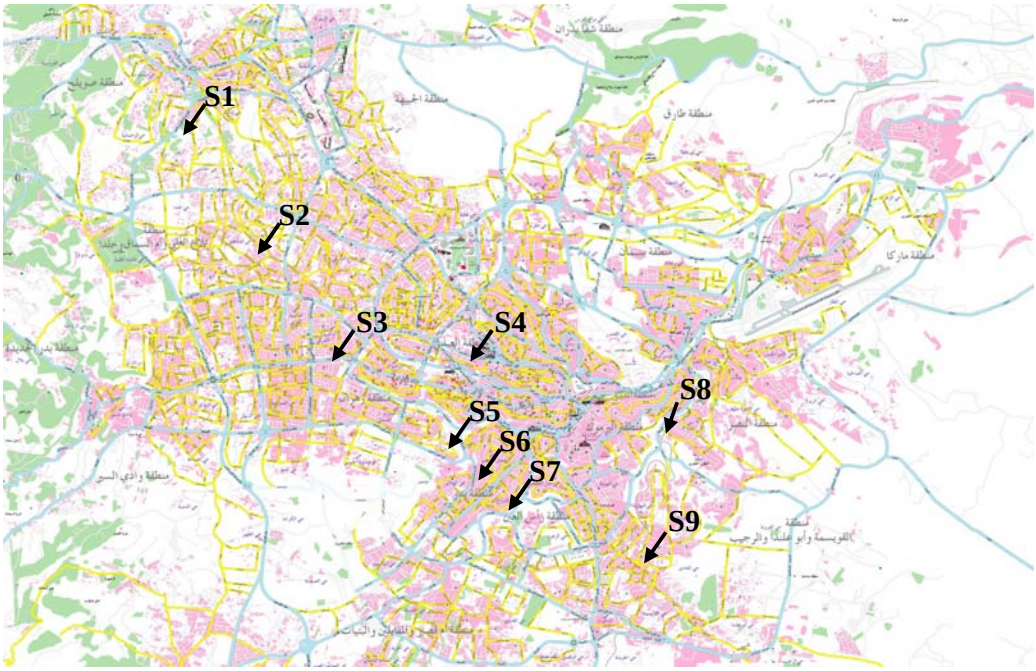

Fig. 1: Locations of the Studied Sites

At each of the nine roadway monitoring sites, the L_{10} (18hr) traffic noise level was measured during full 18-hr period (from 6.00 a.m. to midnight) required by the CRTN procedure. This period covers all daily peak and off-peak traffic flow periods. L_{10} noise level is the one that is exceeded 10 percent of the time for the period under consideration.

Noise levels were measured near the edge of the roadway but within CRTN limits and at distances where the exposed residents live using a microphone height of 1.2m above the road surface The effect of wind was minimized by the use of windshield at all times.

All the measurements of traffic noise level were recorded using an Extech data logging sound level meter along with a microphone unit. The measuring equipment was calibrated at hourly intervals. The instrumentation and calibration of equipment were done according to the manufacturer's recommended procedure. A theodolite was used to survey the site and determine the gradient of the studied roadways.

Traffic speeds were collected using a laser radar speedometer and, a (TRAX-11) instrument was used to measure the number of vehicles from 6.00 a.m. to midnight. This calibrated equipment was provided by Jordanian Traffic Institute (J.T.I.).

IV. MAGNITUDE OF CURRENT NOISE LEVELS

In addition to L_{10} (18-hr) another indicator that is commonly used to represent the traffic and the community noise levels is the equivalent sound level (L_{eq}) which is computed according to the following equation.

$$L_{eq} = L_{10}(18hr) - 3dBA \quad (3)$$

The measured values of L10 (18 hr) and Leq at the studied locations are as shown in Table 1. The results show high noise levels at all studied sites with site 3 having the highest L10 (18hour) level of 80 dBA. , There is a little variation between the sites despite the different characteristics of their area and no significant change was found in noise levels during the 18-hours even during the late night hours. The Environmental Protection Law of Jordan [13] specifies the day and night maximum allowable noise limits as 60 and 50 dBA respectively indicating the seriousness of the problem and its anticipated effects on the exposed residents.

TABLE 1. $L_{10\ and}$ L_{eq} TRAFFIC NOISE LEVELS AT THE STUDIED SITES

Site Position No.	L10(18 hr) (dBA)	Leq (dBA)
S1	78.9	75.9
S2	77.0	74.0
S3	80.0	77.0
S4	78.0	75.4
S5	78.5	75.5
S6	77.2	74.2
S7	77.8	74.8
S8	76.2	73.2
S9	77.3	74.3

The CRTN method was used to predict noise levels along the nine urban arterials, where the noise levels were measured. The validity of CRTN method for Jordanian condition was evaluated by comparing measured data with values predicted by the method at the selected sites. These values together with the prediction differences, which are the predicted minus the measured values, associated with all locations are presented in Table 2. The high difference between the two levels was at locations where significant unplanned development took place resulting in an unexpected increase of traffic volumes, traffic composition and speeds. However, noise level was well predicted at the more stable site such as site (S3) where normal development took place and as planned. The performance of the CRTN method was demonstrated via the plot shown in Fig. [2], which shows the predicted L10 (18 hr) values plotted against measured values for the nine urban arterials. The Fig. illustrates that CRTN method appeared at all locations to overpredict the L10 (18 hr).

TABLE 2. MEASURED AND PREDICTED NOISE LEVELS AT THE STUDIED SITES

SITE POSITION NO.	MEASURED LEVELS(X)	PREDICTED LEVELS(Y)	PREDICTION DIFFERENCE (Y-X)
S1	78.9	81.3	2.4
S2	77.0	77.5	0.5
S3	80.0	75.7	0.2
S4	78.0	78.8	0.4
S5	78.5	80.4	1.9
S6	77.2	77.7	0.5
S7	77.8	78.7	0.9
S8	76.2	76.6	0.4
S9	77.3	78.3	1.0

A = -12.409 Number of pts= 9 R-Square =0.7729

A regression model that relates the predicted values and the measured data was developed and was found to have the following form:

P= -12.409+1.1709M

(R^2=0.7729)

Where: M= measured noise level

P=predicted noise level

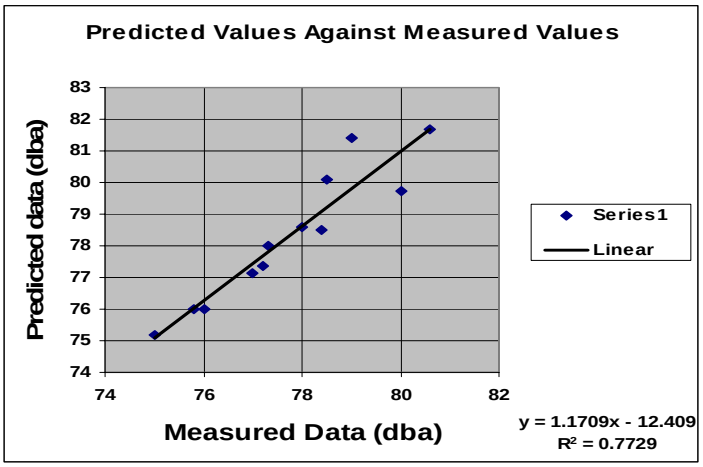

Fig. 2: Relationship Between Measured and Predicted Noise Levels.

The performance of the CRTN method was evaluated by statistically examining its accuracy in predicting noise level over the complete range of situations covered by the method. Using this set of measured and predicted data, the accuracy of the prediction method can be defined by the mean of the prediction difference which is equal to 0.91 dB (A) and the standard deviation of the prediction difference, equals 0.76 leading to the conclusion that CRTN method can be used satisfactorily in Amman.

After calibration, the CRTN prediction method was applied to estimate future traffic noise levels at year 2020 for the same sites where road traffic noise was measured. This exercise is carried out in order to decide whether amelioration measures will be required.

The future traffic flow in 2020 was obtained using an average annual growth rate of 2.3%. The results, which are shown in Table 3, demonstrate that all the levels of noise at all sites at 2020 exceeded the maximum acceptable limit (L_{10}, 18h) of 60 dBA adopted in Jordan. These levels creates a lot of concern in view of the fact

that they are produced solely by traffic as there are no other consistent sources of noise at the studied sites. Therefore, attenuation measures are needed to lower these levels below the maximum acceptable limit.

TABLE 3. PREDICTED TRAFFIC NOISE LEVELS FOR YEAR 2020

SITE POSITION NO.	**PREDICTED NOISE LEVELS dBA**	
	2012	**2020**
S1	81.3	87.7
S2	77.5	81.4
S3	80.2	84.1
S4	78.8	82.7
S5	80.4	86.8
S6	77.7	84.1
S7	78.7	85.1
S8	76.6	83.1
S9	78.3	84.7

V. SURVEY OF RESIDENT'S ATTITUDES

The physical measurements of traffic noise consist of calculating the number of people or household being exposed to various noise levels (exposure) and for some studies number of people experiencing health effects and sleep disturbance (exposure-response).

A preliminary social attitudinal survey was conducted as a part of this research not with the aim mentioned above but only to examine the social and environmental effects on the standard of living of residents exposed to excessive road traffic noise. An earlier attempt to evaluate the impact of road traffic noise on residents [6] showed the significance of this impact. Traffic noise was perceived by 70% of neighbouring residents as a problem that is disruptive to their lifestyles to the extent that over half of the interviewed people consider moving their residence to a quieter environment.

This study further evaluates the annoyance reaction and investigates any changes in attitudes that may have happened over time. Therefore, the two studies have some common sites where the investigation was carried out.

A total of 818 households located adjacent to and on both sides of the noise monitoring sites throughout the developed areas of the capital city were interviewed and requested to fill a predesigned questionnaire. The sample size was determined based on a comprehensive review of related literature indicating that such a sample size would be highly ranked among the social survey studies worldwide and on a decision to interview a minimum of 70 households per monitoring site.

Every individual occupant of a property located within the affected areas was eligible to be included in the sample population. The sample population of each site was chosen using the systematic random sampling, technique due to its simplicity, ease and successful implementation. If a selected individual refused to participate in the survey, another eligible individual replaced him. Approximately 5% decline to take part in the interview.

The questionnaire was simple, yet structured, and aimed at assessing the perceived annoyance impacts of traffic noise on exposed individuals.

The questionnaire consists of three parts. The first part includes 13 questions to evaluate the level of annoyance. A simple five–point semantic scale was used to measure all the

effects reported by the respondents. The scale points are, Not at all, Little, Sometime (a fair amount), Most of the time (a lot), and Always (a great deal).

The second part of the questionnaire specifically evaluates the level of annoyance due to traffic noise while doing different daily activities at work and schools. The evaluation was based on the following scale: Strongly Disagree, Disagree, No effect, Agree, Strongly Agree.

The third part consists of one question that asks the respondents to describe the level of traffic noise to which he/she is exposed. The respondents are given the following options: None, Low, Medium, High, and Very High.

A pilot survey was first carried out on a sample of 100 individual heads of households. Based on the outcome of the survey, the questionnaire was modified to incorporate suggested improvements.

The questionnaire data were compiled in a computer file and the Statistical Analysis Software (SPSS) was utilized to process and analyze the annoyance data. The questionnaire survey were sorted out by location, and the data for each site were examined and analyzed, then the data for all sites were compiled together and analyzed. In order to analyze the questionnaire results, numerical values were given to each of the answers. A weighted average was calculated for each of the questions in the three parts of the questionnaire. The results of the analysis are presented in Tables 4 and 5.

The results of the analysis confirmed the seriousness of the problem. More than two-thirds of the respondents reported that traffic noise affect the environment and describe it of high level and affect their daily activates. The respondents reported that they are annoyed by it always or most of the time, and are especially annoyed when they sleep (85%), rest (80%), and read (77%).

A recent study on the community response to road traffic noise[14] confirmed the above findings. 92% of respondents from Amman consider RTN an environmental pollutant, 64% consider it a public health problem,78% are annoyed by it,51% classify it as intense or very intense,61% report increase in its level,84% are annoyed while reading and 61%consider moving to a quieter residence.

TABLE 4. RESULTS OF QUESTIONN AIRESIS

SITE NUMBER	1	2	3	4	5	6	7	8	9	10	All
NUMBER OF QUESTIONNAIRE RESPONDENTS	88	87	84	88	76	88	80	70	78	79	818
DO YOU GET ANNOYED BY TRAFFIC NOISE?	3.16	2.16	3.27	1.32	2.37	2.05	2.44	2.36	3.10	1.96	**2.41**
DO YOU CLOSE WINDOWS TO AVOID TRAFFIC NOISE?	2.15	2.33	1.70	1.75	2.03	2.05	2.36	2.73	2.90	2.38	**2.22**
DO YOU THINK TRAFFIC NOISE IMPACTS HUMAN HEALTH?	2.93	3.06	2.85	3.17	2.63	3.00	2.94	2.84	3.09	2.01	**2.86**
DO YOU THINK TRAFFIC NOISE IMPACTS THE ENVIRONMENT?	3.22	3.39	3.04	3.18	3.13	3.13	3.04	3.17	3.23	2.09	**3.07**
DO YOU CONSIDER MOVING TO A QUIETER PLACE BECAUSE OF TRAFFIC NOISE?	0.89	0.82	0.74	0.88	0.64	0.78	1.10	0.50	1.32	1.70	**0.94**
DO YOU THINK TRAFFIC NOISE FORCE YOU TO SPEAK LOUDER?	1.85	2.15	1.69	1.41	1.46	1.90	1.96	1.96	2.56	1.91	**1.88**
TRAFFIC NOISE ANNOYS ME WHEN I:											
WORK	-0.10	0.15	-0.02	0.10	0.28	0.20	0.25	0.49	0.53	0.06	**0.18**
REST	1.01	1.29	1.07	1.01	1.20	1.24	0.88	0.79	1.04	0.52	**1.01**
TALK TO OTHERS	0.69	0.70	0.96	0.65	1.01	0.78	0.48	0.96	0.74	0.08	**0.70**
TALK ON THE PHONE	0.95	0.67	1.07	0.89	0.83	1.26	0.29	1.01	0.86	0.35	**0.82**
EAT	-0.43	-0.39	-0.40	-0.22	0.18	0.19	-0.05	-0.07	0.41	0.01	**-0.09**
READ	1.02	1.28	1.27	0.94	0.88	1.02	1.03	1.09	0.97	0.20	**0.98**
WATCH TV	0.16	0.03	0.11	-0.10	-0.20	0.10	0.03	0.21	0.58	0.06	**0.10**
SLEEP	1.23	1.33	1.32	1.26	1.13	1.44	1.39	1.01	1.27	0.68	**1.22**
HOW DO YOU DESCRIBE THE TRAFFIC NOISE LEVEL YOU HEAR?	3.26	3.23	3.01	2.10	3.03	2.26	2.39	3.04	2.82	2.30	**2.74**

TABLE 5. DISTRIBUTION OF RESPONSES ABOUT INTERFERENCE OF DAILY ACTIVITIES BY TRAFFIC NOISE

Activity	**Distribution of reported interference (%)**					
	Strongly agree	**Agree**	**None**	**Disagree**	**Strongly Disagree**	**Total**
work	6.6	26.04	51.71	10.39	5.26	100
Rest	31.66	47.8	13.08	4.89	2.57	100
Talk to Others	23.84	39	25.43	7.08	4.65.	100
Talk on phone	30.93	35.94	22.01	6.72	4.4	100
East	7.09	14.3	52.32	15.53	10.76	100
Read	31.41	45.48	15.16	5.14	2.81	100
Watch TV	10.15	20.9	46.58	13.08	9.29	100
Sleep	45.35	39	9.9	3.3	2.45	100

VI. CONCLUSION

The existing and the 2020 predicted noise levels were found to be as high as 78.9 and 87.9 dB (A) respectively which exceed by far the 60 dB (A) maximum allowable limit in Jordan. The findings highlight the magnitude of this ever-growing environmental problem, and the need for urgent mitigation measures. The main findings of the study may be summarized as follows:

1. The U.K. Calculated Road Traffic Noise (CRTN) method can be applied satisfactorily to predict noise level under traffic conditions in Amman.
2. Traffic noise is presently a serious problem in Amman and is expected to remain so in the future. The measured levels indicate that all values exceed the Jordanian acceptable limits and those of many developed countries such as the UK limit of 68 dBA.
3. The preliminary attitudinal survey of residents along the studied locations revealed that about 80 % of respondents perceive road traffic noise as an environmental problem seriously affecting their ordinary daily activities such as sleeping and reading and more than half consider moving to quieter places. Compared with the results of an earlier study, these findings show an increasing impact of traffic noise on the daily activities of residents over time.

Jordan has not yet started any practical action to control traffic noise. However, the findings of this and other earlier studies, call for the need to carry out a comprehensive study in order to give a better insight into the problem and identify its magnitude over the whole urban road network, then identify and apply most appropriate mitigation measures as necessary. Such a study is essential to develop a comprehensive national strategy to face the adverse environmental effects of ever-growing road traffic.

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