Assessment of Road Traffic Noise Pollution at Selected Sites in Amman, Jordan: Magnitude, Control and Impact on the Community

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ABSTRACT

The present study provides an evaluation of road traffic noise pollution in the city of Amman and its effects on residents. Statistical noise index L10(18 hr) was measured at nine different sites throughout the city of Amman. The British Calculation of Road Traffic Noise (CRTN) method was used to predict noise levels at the chosen sites. The CRTN method proved to be successful in predicting noise levels under traffic conditions in Amman. The results showed that Amman is environmentally noise polluted at the studied locations with noise levels ranging between 80.41 and 83.71 dB(A); thereby exceeding the maximum allowable limit of 63 dB(A). The CRTN method was also employed to predict future noise levels which were found to be higher than the current predicted noise levels.

The effectiveness of noise barrier walls in reducing noise levels was investigated. Noise barriers 5 meter high were found to be effective in reducing noise levels below the permissible limits at all sites. A social survey was carried out to evaluate the perceived noise impacts of road traffic noise on residents. The results of the survey revealed that road traffic noise is a major concern for the communities living in the vicinity of streets in urban areas. The noise problem affects the ordinary daily activities of residents to the extent that about 65% of them consider moving to quieter areas.

KEYWORDS: Road traffic noise pollution, CRTN method, Noise barriers, Future predicted noise, Social survey, City of Amman.

INTRODUCTION

Noise, associated with the modern society, is a common environmental pollutant in nearly all urban communities. It is an undesirable waste product generated from various anthropogenic activities that can interfere with the individual or group social activities such as communication, reaction, sleep and rest (Davis and Masten, 2004). According to the World Health Organization (WHO), noise is considered as the third hazardous environmental pollutant right after air and water pollution (WHO, 2005). However, urban noise pollution has not received much attention in the developing countries as the other two mentioned pollutants. This lack of recognition can be contributed to three valid reasons: perception of noise is highly subjective and can vary from one person to another; unlike air and water pollution, noise has a short decay time and thus does not last long in the environment; finally, the impact of noise on people is subtle, so that it appears so gradual, and therefore it becomes difficult to associate the cause with the effect (Davis and Masten, 2004).

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In 2006, the total population of Jordan exceeded 5.6 millions representing a six-fold increase since the 901,000 registered in 1961(DOS, 2008). The population of Jordan is highly urban. In 1952, about 39.6 percent of Jordan’s population lived in urban areas while by the year 2006; the figure has reached about 82.6 percent. Such increase is mainly the result of internal rural-to-urban migration combined with the waves of in-migration due to political instability and military conflicts in the region. The three most populated cities in Jordan are: Amman, Irbid and Zarqa and constitute about 71.5% of the total population.

Table 1. Selected sites for measuring road traffic noise in the City of Amman

Site position number	Location
P_1	Al-Istiqlal Street
P_2	7^{th} Circle
P_3	Al-Madina Al-Munawara Street
P_4	Prince Shaker Street
P_5	Prince Ali Ben Al-Hussien Street (Wadi Abdoun)
P_6	Al-Sakhra Al Mosharrafa Street
P_7	King Abdullah II Ben Al-Hussein Street
P_8	Queen Rania Al-Abdullah Street
P_9	Ibn Sina Street (Wadi Saqra)

Table 2. The input data for the CRTN method

Site position number	Traffic speed, km/hr	Traffic volume, Vehicle/day	Percent of heavy vehicles, %	Road gradient, %
P_1	80.7	55041	31.1	5
P_2	83.2	74197	18.52	6
P_3	77.9	58667	18.42	6
P_4	75.7	90595	21.32	5
P_5	74.0	99975	17.02	8
P_6	68.4	99952	18.56	7
P_7	86.5	45341	37.94	4
P_8	86.2	96227	23.48	4
P_9	67.2	83567	23.87	6

As many big cities in the world, Amman, the capital of Jordan, has experienced a rapid growth rate in the socio-economic and infrastructures over the past two decades. As a result, Amman is experiencing increased volumes of traffic, greater trip frequency and increasing trip length. The level of generated noise from road traffic is therefore expected to rise. Moreover, due to inadequate urban planning many homes, schools, hospitals and other community buildings are routinely built on main roads without buffer zones or adequate soundproofing. Thus, more and more people are adversely affected by the road traffic noise pollution calling for the need to provide an insight into this ever growing issue.

The importance of studying traffic noise stems from the fact that its prediction and measurement are essential for roadway planning, residential entitlement for sound insulation and control of noise. The response of the society to this growing problem also needs to be addressed. In addition, analysis of road traffic noise constitutes an integral part of any environmental impact assessment which is necessary for highway development and improvement. Therefore, the aim of this study was to evaluate road traffic noise pollution in the city of Amman and its effects on residents. The study also aims at evaluating the appropriateness of noise barriers to attenuate the noise levels at locations where levels exceed the acceptable limits.

LITERATURE REVIEW

Noise can be emitted from various sources such as aircraft, construction, factories, railway and road traffic. Among those sources, research reported that road traffic is by far the major source of noise in the urban areas contributing to 55% of the total noise (Banerjee et al., 2008; Nirjar et al., 2003). Social surveys conducted in various cities throughout the world have revealed that road traffic noise is the major source of nuisance and annoyance (USDOT, 1995; Dora, 1999). In an urban noise study conducted by Calixto et al. (2003), about 73% of the respondents believed that road traffic noise was the main source of annoyance. In the European Union, about 40% of the people are exposed to road traffic noise exceeding 55 dB(A) during daytime and more than 30% during nighttime (The national Board of Health and Welfare, 2001).

Table 3. Measured and predicted noise levels at the selected sites

Site position number	Measured noise level L_{10}(18 hr), dB(A)	Predicted* noise level L_{10}(18 hr), dB(A)	Relative error
P_1	79.64	81.96	2.91
P_2	80.68	82.12	1.78
P_3	78.80	80.41	2.04
P_4	81.33	82.79	1.80
P_5	88.85	83.71	5.79
P_6	81.96	82.59	0.71
P_7	80.4	81.78	1.72
P_8	79.37	82.88	4.42
P_9	79.27	82.35	3.89

* Predicted noise level: noise level obtained using CRTN prediction method.

Table 4. Comparison between current and future predicted noise levels using the CRTN method

Site position number	Current noise level, L_{10}(18hr), dB(A)	Future noise level, L_{10}(18hr), dB(A)
P_1	81.96	84.49
P_2	82.12	84.66
P_3	80.41	82.94
P_4	82.79	85.33
P_5	83.71	86.25
P_6	82.59	85.13
P_7	81.78	84.32
P_8	82.88	85.41
P_9	82.35	84.88

Noise effects depend on various factors such as time duration, noise source level, distance from the source and age subgroups. Vulnerable people such as elderly and young children are severely more affected by noise pollution. For instance, several studies have shown that noise intrusion can result in decreasing children's learning skills, productivity and performance (Mato and Mufuruki, 1999).

The health impact associated with the noise pollution on human well being is well documented in literature (Briggs et al., 2008; Belojevic et al., 2008;Clark et al., 2006; Hyder et al., 2006; Lam et al., 2008; Piccolo et al., 2005). The most obvious impact of noise is damage to hearing ability ranging from slight impairment to nearly total deafness depending on intensity and duration of noise (Davis and Masten, 2004; Morillas et al., 2002). Noise exposure can also cause non-auditory effects that can be categorized into short- and long-term effects. Short term, but serious, impacts include interference with speech communication, disturbance of rest and sleep, annoyance, interference with intended activities as well as general diminution of quality of life (Ouis, 2001; Morrell et al., 1997). Long-term effects include psychosocial health problems (Ohrstrom, 1998; Com and Taylor, 1978). It has been concluded in a study conducted by Griefahn et al., (2000) that unlike people living in quite areas, people living near streets with busy traffic or near airports tend to close their windows, spend less time in their gardens and have less visitors.

Various studies have been conducted to investigate and evaluate the road traffic noise pollution in the city of Amman. Hammad and Abdelazeez (1987) investigated the traffic noise pollution and related annoyance to people living in the vicinity of urban roads. The authors concluded that the traffic noise is a major environmental problem in the city of Amman and the noise levels were higher than those measured in cities in well planned and developed countries. Additionally, the results of the indirect questionnaire showed that most people suffer from annoyance and that people prefer to move away from the vicinity of roads. Traffic noise levels and their effects on residents along urban arterials were also studied by Abu-Hadba (1995). The noise levels ranging from 72.7 to 77.8 dB(A) were found to exceed the internationally maximum allowable limits at all sites. The author reported that a timber barrier of 3 meters height was the most favorite amelioration measure to reduce noise levels to acceptable limits below the maximum allowable level. The results of the social survey indicated that a substantial proportion of respondents considers relocating their residence due to severe effects of traffic noise. Alhiary (2002) studied traffic noise pollution at signalized intersections in Amman. The study concluded that the maximum noise level at signalized intersections exceeded the maximum levels recommended by Australia, Canada, Singapore, Thailand and United Kingdom. Moreover, Abo-Qudais and Alhiary (2004) reported that traffic noise levels were significantly affected by the distance from the road intersection. The impact of road traffic noise on owners and employees of businesses around major streets in Amman was studied by Abo-Qudais and Abu-Qdais (2005). The authors reported that about 81% of the interviewed people were annoyed by noise and their daily activities were interfered by such noise. In another study carried out to measure the road traffic noise levels adjacent to residential areas in Amman, researchers reported noise levels ranging from 72.7 to 78.5 dB(A) (Al-Dakhlallah and Jadaan, 2005). Jamrah et al. (2006) showed that the minimum and maximum noise levels in the city of Amman were 46 and 81 dB(A) during the day and 58 and 71 dB(A) during the night. Their study concluded that the measured noise levels exceeded the acceptable limit of 63 dB(A) at most of the locations studied.

METHODOLOGY

Equipment

Road traffic noise levels were recorded using Bruel and Kjaer (B & K) sound level meter (Precision Integrating Sound Level Meter Type 2215). The microphone was positioned 1 meter away from the curb and 1.2 meter above the road surface and pointed out towards the source. The instrumentation use and calibration were executed in accordance with the manufacturer's suggested procedure.

Data Collection

Road traffic noise was measured at nine different sites in the city of Amman. The sites were selected since they suffer from a persisting traffic noise problem. The chosen sites are listed in Table 1. At each monitoring site, 10 noise level readings were recorded hourly at a frequency of 125 Hz for full 18-hour period from 6 a.m. to 12 midnight. The statistical noise index L_{10} (18 h) dB(A) was calculated. All the measurements took place during working days and under ideal meteorological conditions: no wind and no rain. The monitoring sites were chosen so that the view of the road was substantially unobstructed.

The British Calculation of Road Traffic Noise (CRTN) prediction method was used to predict current and future noise levels at the selected sites (Her Majesty Stationary Office, 1988). The method allows the prediction of L_{10}(18 hr). The input data for the CRTN method include traffic volume, speed, percentage of heavy vehicles, type of road surface, road gradient, road obstructions meaning that whether the source line of the road is obstructed or unobstructed, distance between reception point and the edge of the nearside carriageway, noise path, intervening ground and effects of shielding. The traffic volume, percent of heavy vehicles and road gradient data for each selected site were collected from the Traffic Department of the Ministry of Interior. The traffic speed for each site was determined using radar speed meter provided by the Traffic Department of the Ministry of Interior. Table 2 shows the average traffic speed, traffic volume, percent of heavy vehicles and road gradient for each of the selected sites.

Social Survey

In order to measure the subjective reaction of residents to noise, a social survey was carried out using a predesigned questionnaire which was distributed randomly to 100 respondents. The survey was conducted over a period of three weeks and distributed to residents along the nine selected sites where noise levels were measured. The social survey included questions that evaluate the respondent's annoyance level to noise and its effect on his/her life, daily activities (such as talking and watching TV) and productivities (such as studying and working).

RESULTS AND DISCUSSION

Validation of CRTN Method

The CRTN method was used to predict the statistical noise level L_{10}(18 hrs) for the nine studied sites. Relative errors between the predicted and measured noise levels were calculated as shown in Table 3. The relative error is defined as the difference between the measured and predicted values divided by the measured value and the result is multiplied by 100. The average relative error was 2.78 which is considered within the practically acceptable relative error limits of 10% (Sen et al., 2006). The results from relative errors suggest that the CRTN method can be applied to predict the road traffic noise level under Amman driving conditions. Several successful attempts were made using the CRTN method in the city of Amman (Abu-Hadba, 1995). Jamrah et al. (2006) came to the same conclusion.

Present Noise Levels

Predicted noise levels L_{10}(18 hr) at the selected sites are depicted in Figure 1. It can be seen that all the selected sites were severely affected by traffic noise as these noise levels exceeded the maximum allowable limit of 63 dB(A) adopted by the 2003 Environmental Protection Law in Jordan. The average noise level was 82.29 dB(A). The lowest and highest noise levels were 80.41 and 83.71 dB(A) at sites P_3 and P_5, respectively. These findings are similar to those reported for other cities around the world (Zanning et al., 2002; Pandya, 2003; Piccolo et al., 2005; Al-Ghonamy, 2010). Moreover, these noise levels exceeded the bed-noise level of 25-30 dB(A) (Davis and Masten, 2004). This might result in more sleep disturbance due to road traffic noise.

Future Noise Levels

The future noise levels at all sites were predicted using the CRTN method. The year 2021 was selected for the future prediction (n=10 years). The input data needed for predicting future noise levels were assumed to be the same as for the current year 2011. The future traffic flow used in the CRTN method was obtained by applying the following relationship using an annual growth rate of 6%. This rate is based on statistics provided by Jordan Traffic Institute, taking into consideration the limitation of saturation level of car ownership (Public Security Directorate, 2009).

$F = P\,(1+i)^n$ ………………………… (Eq. 1)

where,
F = Future predicted traffic volume.
P = Present traffic volume.
i = Rate of growth.
n = Number of years.

Table 4 shows that there is a slight increase in the future noise levels throughout all the sites. The average future noise level was 84.82 dB(A) corresponding to an average increase of 2.54 dB(A) from the average current noise level. This increase can be explained by the fact that all the selected sites are well developed and a fairly low increase in urban activities is expected meaning low increase in traffic volume and speed. The minimum future predicted noise level was 82.94 dB(A) and the maximum future predicted noise level was 86.25 dB(A).

Table 5. Predicted and actual noise levels for current and future years in presence of noise barriers

Position site number	Current predicted noise level L_{10}(18hr), dB(A)	Future predicted noise level L_{10}(18hr), dB(A)	Actual current noise level L_{10}(18hr), dB(A)	Actual future noise level L_{10}(18hr), dB(A)
P_1	62.96	65.49	56.42	59.58
P_2	63.12	65.66	56.62	59.79
P_3	61.66	64.19	54.79	57.95
P_4	63.79	66.33	57.45	60.62
P_5	64.71	67.25	58.60	61.77
P_6	63.59	66.13	57.20	60.37
P_7	62.78	65.32	56.19	59.36

Noise Attenuation

At all locations where the anticipated noise levels exceeded the desirable limits, necessary steps should be taken to prevent or reduce the road traffic noise problem. There is a range of alternatives to mitigate the impact of road traffic noise. Among these alternatives, noise barriers are the most effective mitigation measure especially in the city of Amman due to limited right of way along many busy streets of urban areas. Noise barriers are therefore selected for further investigation.

Noise barriers of 5 meter height were studied. The height of point source, distance between point source and barrier and height of reception point were taken to be 0.5, 3.5 and 1.2 meters, respectively. Figure 2 illustrates the predicted noise level L_{10}(18 hr) with and without noise barrier at all locations. The results clearly show that the barriers result in consistent noise reduction. The average noise reduction due to the barrier was 18.94 dB(A). According to Jadaan and Marsh (1993), the effective barrier can reduce noise level by 5 to 20 dB(A). The predicted noise levels with presence of barriers ranged from 61.66 to 64.71 corresponding to sites P_3 and P_5, respectively. In addition, a t-test at 95 percent confidence interval was performed to determine the statistically significant difference between the means of noise levels with and without barriers. The 95 percent confidence interval was (18.86, 19.03) dB(A). This indicates that significant noise reductions have been achieved due to the presence of barriers. The future predicted noise levels with and without noise barriers are shown in Figure 3. The future predicted noise levels in presence of noise barriers ranged from 64.19 to 67.25 dB(A) with an average of 65.88 dB(A).

Abu-Hadba (1995) developed a regression model that can be applied in the city of Amman to relate the predicted noise level obtained by CRTN method to the actual noise level. The predicted noise level L_{10}(18 hr) is related to the actual noise level L_{10}(18 hr) by the following relationship:

Predicted noise level = 17.77 + 0.801 (actual noise level) ……… (Eq. 2)

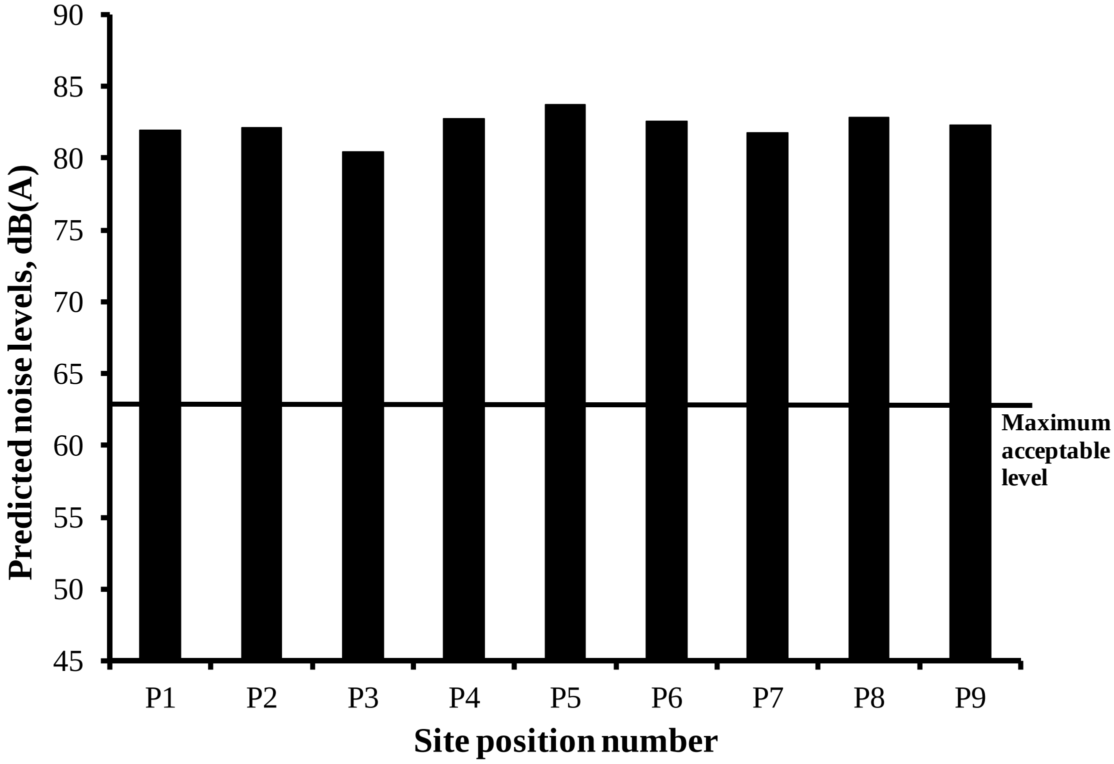

Figure 1: Predicted noise levels, L_{10}(18hr), at the selected sites in the city of Amman

The actual current and future noise levels in presence of noise barriers were calculated based on Equation 2 (Table 5). The results clearly show that the current actual noise levels are below the permissible limit of 63 dB(A) indicating that the noise barrier walls were effective in reducing noise levels below the desirable limit. The average current actual noise level was 56.9 dB(A). Likewise, the actual future noise levels were lower than permissible limit of 63 dB(A). The average actual future noise level was 60.06 dB(A). However, since 5-meter high barriers may not be aesthetically acceptable, it is recommended to use more than one attenuation measure at locations where high noise levels are expected. This may take the form of using a 3-meter barrier, together with an earth berm or vegetation.

Social Survey Results

Awareness of Noise Pollution

The results of the social survey revealed the seriousness of the road traffic noise problem in the city of Amman among general public. This was evident by the fact that about 76% of the respondents consider it a public health problem to the extent that 88% of the respondents consider the road traffic noise an environmental pollutant which reflects the public awareness to this important issue. About 65% of the respondents think of changing their place of residence as a solution to noise problem (Figure 4). These results are higher than those reported in a social survey conducted by Al-Dakhlallah and Jadaan (2005) where 68% of the respondents consider traffic noise as a public health problem, 51% think of moving away and 67% consider it an environmental pollutant which is considered an indication of the growing effect of the problem.

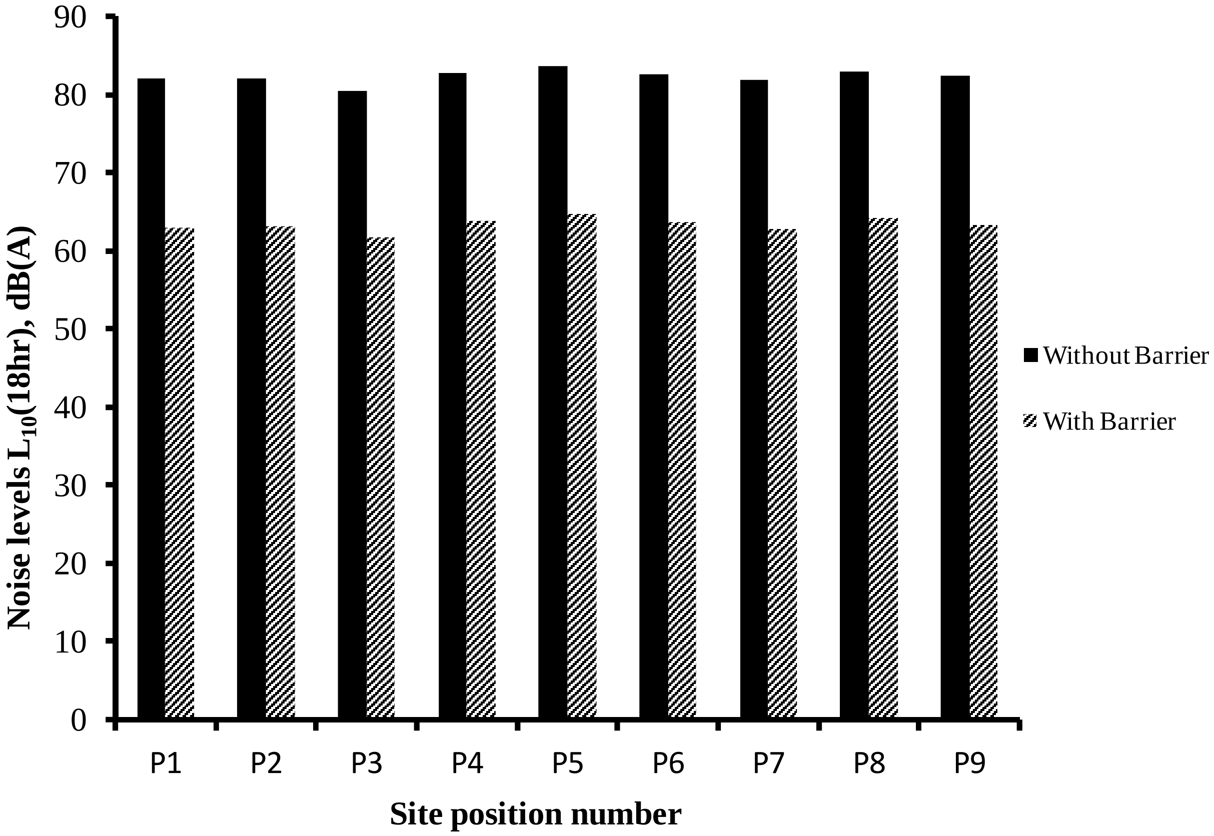

Figure 2: Current predicted noise levels, L_{10}(18hr), with and without noise barrier wall at the selected sites in the city of Amman

Perceived Annoyance of Noise

Community responses to perceived noise impacts are illustrated in Figure 5. The results show that a significant portion of community seems to be negatively affected by road traffic noise while performing their daily activities. The impacts resulting from exposure to noise ranged from sleep interference, to interference when listening to TV, to disturbance and loss of concentration. The lowest and highest negative impacts reported by general public were disturbance of sleep (30%) and loss of concentration as a student (59%). Further impact of road traffic noise on community is that on the real state values. Morda and Bennett (1985) reported that the property value in Melbourne, Australia, for example, falls at 0.5 percent for each one dB increase in traffic noise. However, this aspect of the problem needs to be evaluated for the city of Amman.

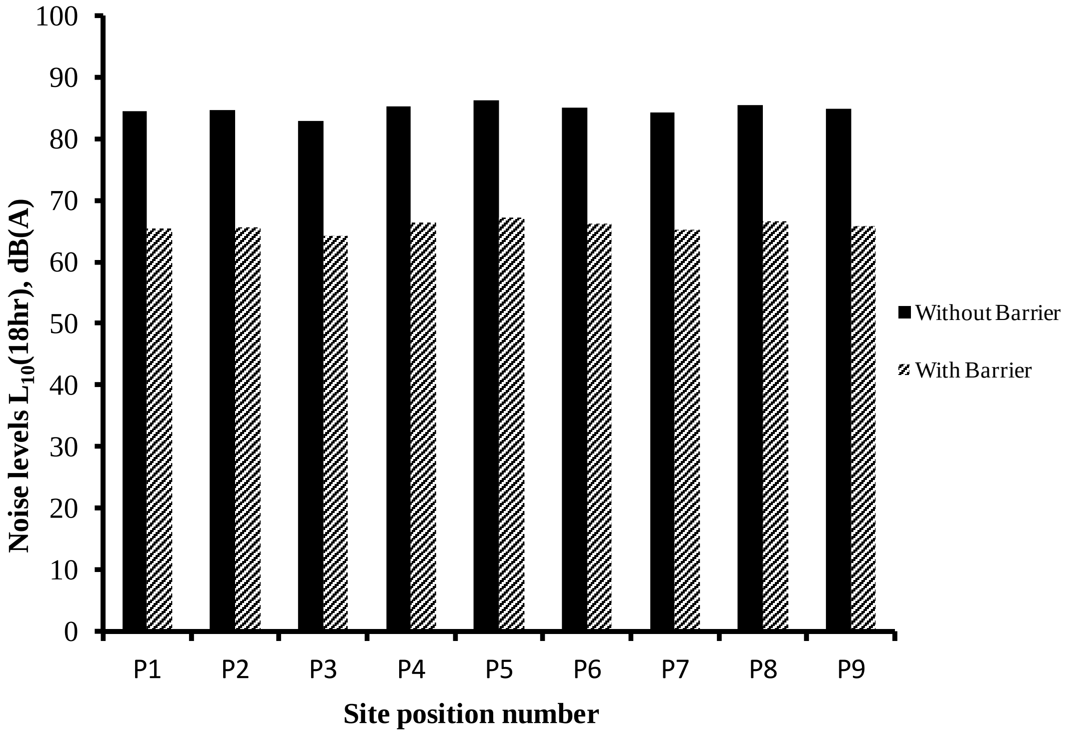

Figure 3: Future predicted noise levels, L_{10}(18hr), with and without noise barriers at the selected sites

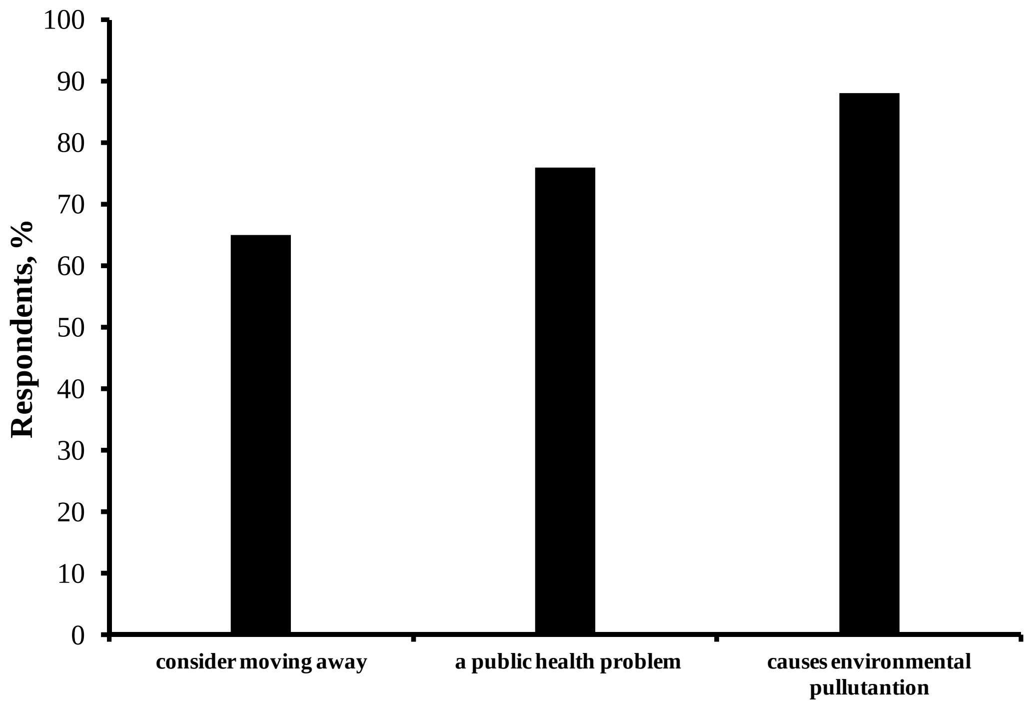

Figure 4: Seriousness of road traffic noise problem as perceived by the general public

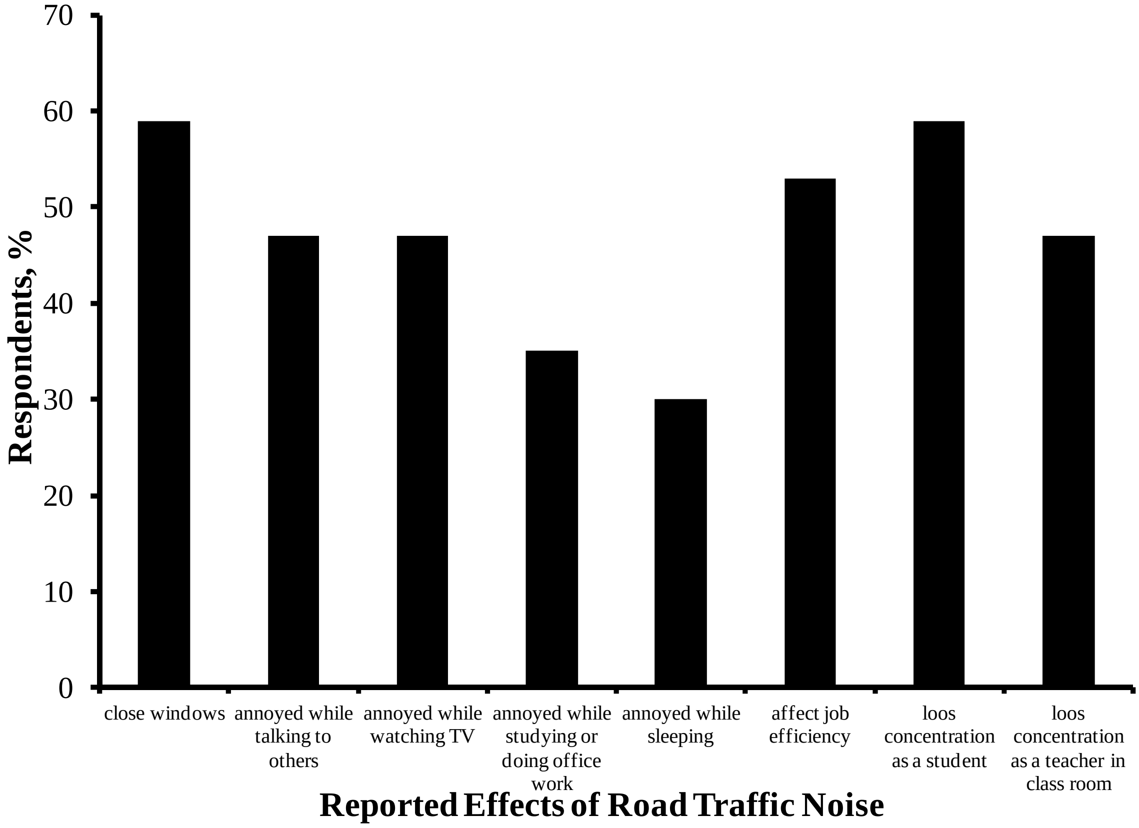

Figure 5: Community responses to perceived noise impact at the selected sites

CONCLUSIONS

This study was conducted to evaluate road traffic noise pollution along selected urban arterials in the city of Amman and assess its effects on residents. On the basis of the results, the following conclusions could be drawn:

1. The British Calculation Road Traffic Noise (CRTN) method can be applied successfully to predict traffic noise level under traffic conditions in the city of Amman.
2. The measured and predicted road traffic noise levels at all studied sites were notably higher than the maximum allowable limit of 63 dB(A) adopted by the 2003 Environmental Protection Law in Jordan, calling for the need to apply noise attenuation measures.
3. Noise barriers of 5 meter height were found effective in reducing noise levels to acceptable limits. However, due to aesthetic considerations, a combination of lower barriers and another attenuation measure such as earth berms may be used to achieve lowering the noise to acceptable levels.
4. The social survey results revealed that road traffic noise is a major concern to people residing in the vicinity of the studied locations. The residents reported that noise affects their daily activities and more than half of them consider moving to quieter areas.

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