Effect Of Traffic Characteristics And Road Geometric Parameters On Developed Traffic Noise Levels

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ABSTRACT

The main objective of this study was to evaluate the major factors affecting traffic noise levels at signalized intersections. To achieve this objective, traffic noise levels and the factors expected to affect it were measured at 40 signalized intersections. Equivalent, maximum, and minimum noise levels were measured during one minute interval including the green time interval. The traffic volume and composition was taped using a video camera, while the traffic speed was measured using speed radar. The geometric parameters of the intersections approaches, including number and width of driving lanes, approaches width and slope, were collected. Also, pavement surface texture was evaluated using the British pedulum. The collected data was analyzed to evaluate the effect of the main factors controlling traffic noise levels. Results of the analysis indicated that equivalent noise levels are mainly dependent on traffic volume, while the maximum noise levels were found to be dependent on the number of heavy vehicles passing through the intersection and horn effect. On the other hand, the minimum noise levels were mainly dependent on pavement surface texture. When noise levels at different distances from the signal stop line were considered, traffic speed was found to have a significant effect on equivalent noise levels.

SOMMAIRE

L'objectif principal de cette étude était d'évaluer les facteurs importants qui peuvent influencer les niveaux de bruit du trafic aux intersections routières comportant des feux de signalisation. Pour atteindre cet objectif, les niveaux de bruit du trafic et les facteurs susceptibles de les affecter ont été mesurés à 40 intersections. Les niveaux équivalents, maxima et minima ont été mesurés pendant des périodes de 1 minute, incluant l'intervalle de temps où le feu était vert. Le volume de trafic ainsi que sa composition ont été enregistrés à l'aide d'une caméra vidéo, alors que la vitesse a été mesurée à l'aide d'un radar. Les paramètres géométriques d'approche des intersections, incluant le nombre et la largeur des voies, la largeur des approches et la pente ont été répertoriés. De plus, la texture de la surface du pavage a été évaluée selon le « pedulum » britannique. Les données ont été analysées dans le but d'évaluer les facteurs principaux qui contrôlent les niveaux de bruit du trafic. Les résultats indiquent que les niveaux de bruit équivalents dépendent principalement du volume de trafic, alors que les niveaux maxima sont plutôt attribuables aux nombre de poids lourds qui empruntent l'intersection et à l'effet des klaxons. Par ailleurs, les niveaux minima sont surtout reliés à la texture de la surface de pavage. Lorsque les niveaux de bruit à des distances variables de la ligne d'arrêt sont considérés, la vitesse du trafic s'avère avoir un effet significatif sur les niveaux équivalents de bruit.

1. INTRODUCTION

In recent years the, highway traffic noise has been an increasing concern to both the public and governments. Many studies indicated that one of the major sources of noise in our environment is those associated with transportation. Traffic noise tends to be a dominant noise source in urban as well as rural environments.

Vehicle noise is a combination of the noises produced by the engine, exhaust, and tires. The level of highway traffic noise depends mainly on: traffic volume, composition of traffic, traffic speed, and road geometric parameters. Generally, heavier traffic volumes, higher speeds, and greater number of trucks are expected to increase the loudness of traffic noise. The loudness of traffic noise can also be increased by defective mufflers or other faulty equipment on vehicles (Newman and Beattie, 1985).

Simulation of urban traffic noise in the central part of Bangkok, was the main objective of a study performed by Pamanikabud and Tharasawatpipat (1999). The analyzed data consisted of traffic characteristics and its noise levels. The single model approach, applied to build a single stop-and-go traffic flow noise model for one side of the road way, can be applied to both sides of an urban roadway. Another approach of analysis was applied by developing two similar separate models for a deceleration lane and an acceleration lane on both sides of an urban road. The separate acceleration and deceleration lane models found to be effective in forecasting interrupted flow traffic noise on Bangkok's urban road net work.

A new method was proposed Di Nijs (1989) to measure the noise level as a function of the number of motor revolutions and the speed of a vehicle while it is on the road. This method leads to detailed time plots. The measurements of sound level, number of motor revolutions, and the speed of a vehicle were taken for three vehicle classes: passenger car, van, and lorry. Results indicated that the sound levels increase per road segment at intersections compared to those at road segments with free traffic flow. The increases in sound level was in the range of 6 to 8 dB at road segments close to the edges of intersections.

2. PROBLEM STATEMENT

As part of an international plan to minimize the negative environmental impact of road traffic, a better understanding of factors controlling traffic noise and quantification of its impact is needed. In the last two decades, Amman, Jordan's capital, as well as most other cities in the world, has been exposed to continuous growth of urban and suburban residential areas accompanied by the resultant growth of noise levels along highways. This causes one of the most invasive forms of pollution. In Jordan, currently, there is no regulation relating to noise pollution in urban planning, and only a few studies have reported the evaluation of the dramatic increase in noise pollution due to the impact of traffic. Therefore, this research is considered a step forward towards evaluating the effect of different traffic characterisitics and road geometric parameters on developed traffic noise levels at signalized intersections where noise levels are anticipated to be high.

3. RESEARCH OBJECTIVE

The aim of this study was to evaluate highway traffic noise pollution at signalized intersections in Amman. In order to achieve the objective of this study, three major tasks were undertaken: data collection, evaluation of the effect of the opposite direction traffic on developed noise levels, and data analysis including statistical analysis and evaluation of significant variables.

4. DATA COLLECTION

The data collection included: selection of evaluated intersections, noise measurements, traffic volume and composition, traffic speed, road geometric parameters, surface texture, and the effect of opposite direction traffic on measured noise levels. The following paragraphs explains in detail the methodology used for the collection of various types of data in this study.

4.1 Selection of Signalized Intersections

The main signalized intersections in Amman were selected for evaluation and traffic noise levels were measured at these intersections. Signalized intersections that are located in areas where bridges and tunnels were under construction were not included in this study, due to the fact that noise levels would be affected by the constructions activities. Signalized intersections that are in vicinity of bridge or tunnel or followed by another intersection or rotary within a distance of less than 400 m were not considered. so as to avoid the influences of these features. To provide enough database that could be used in statistical analysis, a total of forty intersections representing the signalized intersections in Amman were studied. The selected intersections are three leg and four leg signalized intersections distributed all over Amman and have different traffic volumes that ranged between 5 and 130 vehicle/minute/approach and different geometric design parameters (number of lanes, lane width, approach width, and roadway slope).

4.2 Noise Measurements

Noise measurements in this study were performed from June, 3, 2001 to October, 2001. All measurements were during daylight hours under favorable weather conditions for traffic noise data collection (dry weather and low wind speed). A total of 4745 noise measurements were performed at all approaches to these forty intersections. One thousand five hundred and twenty eight (1528) measurements were performed at a distance of 0 m from the signal stop line, while the rest were performed at distances of 50, 100, 150, 200, 250, and 300 m from the signal stop lines. Noise levels were measured using an integrating sound level meter (ISLM) Type 1. The Precision Integrating Sound Level Meter Type 2230 (Bruel and Kjaer) was used to measure simultaneously, the maximum noise level (L_{max}), minimum noise level (L_{min}), and equivalent noise level (L_{eq}). This type of ISLM has an accuracy of 0.1 dB which is sufficient to yield valid data for the purpose of this study.

After calibrating the microphone, the ISLM was set on a specially designed stand at 1 m away from the driving lane and at 1.5 m above the road surface as shown in Figure 1. For each measurement the device was switched on at the beginning of each green time interval, measurements were performed for a duration of 1 minute, after which the device was switched to the pause mode and the noise levels were recorded. The device was reset before performing another trial.

For each measurement in the study, two trials were performed during the morning peak hours between 7:30-9:30 a.m, another two trials during the afternoon peak hours between 1:00-3:00 p.m, and one trial during the evening peak between 5:30-7:30 p.m. All of these trials were taken during representative working days of the week. If a horn was used during noise measurements, horn effect was notified.

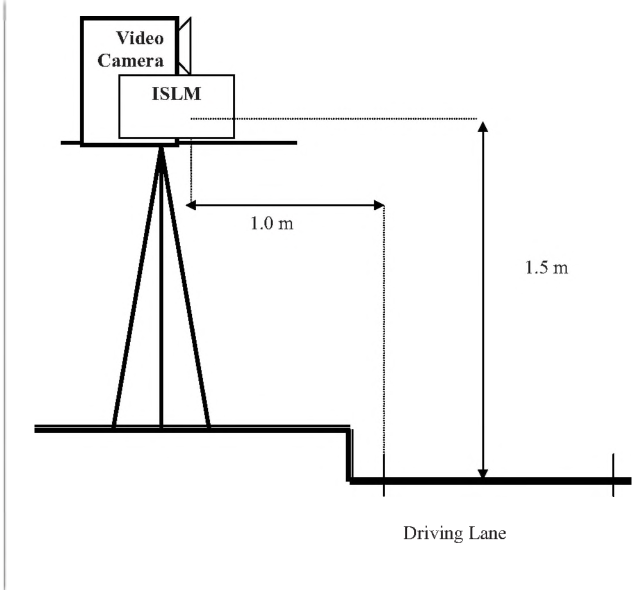

Figure 1. Noise levels and traffic volume measurement setup

4.3 Traffic volume and composition

A Video Camera was used to video tape the traffic movement through each intersection. The video camera which is a charged coupled device (CCD) has a flying erase head, power zoom, and high speed shutter (8X-auto focus). The video tape used was an 8mm video cassette.

The camera was set on the stand besides the ISLM as shown in Figure 1, and switched on at the same time with the ISLM. The number of vehicles and the number of heavy vehicles were determined by replaying the recorded tapes.

4.4 Traffic Speed

Speeds measurements were performed at distances of 50, 100, 150, 200, 250, and 300 m from the signal stop line at each approach of the intersections. The Laser Speed Detection Radar was used to measure the traffic speeds. The device has speed accuracy of (± 1 km/hr), with laser power output of 52 Micro-Watt. In order to detect speed, the radar was set up on a stand placed at a proper location to view vehicles passing the approach of the intersection under evaluation. The speed measurements were performed during the whole minute in which the noise levels were measured. The reported speed represents the weighted average speed for the minute during which the noise levels were measured.

4.5 Road Geometric Parameters

Approach and lane widths were measured using a plastic tape of 30 meter long. The number of lanes also was determined according to the existed stopped rows of vehicles at each approach for the signalized intersection. However, at distances 50, 100, 150, 200, 250, and 300 m the lane widths and number of lanes were not well defined at more than half of the evaluated intersections. Due to this limitation, the effect of road geometric parameters on noise levels was considered only at the signal stop line.

The slope of intersections approaches were determined using a level device. The level was set at a suitable intermediate point between two points on the approach, 50 to100 m apart. The level readings at the two points were taken. The slope was determined by dividing the difference in level readings by the horizontal distance between the two points.

4.6 Evaluation of Pavement Surface Texture

The pavement surface's micro-texture was evaluated indirectly by measuring the surface frictional properties using the British Pendulum Skid Resistance Tester according to ASTM E303-83. The device is a dynamic pendulum impact-type tester used to measure the energy loss when a rubber slider edge is propelled over a test surface. The tester is suited for field tests on flat surfaces. The values measured are British Pendulum Number (BPN) and represents the frictional properties of the surface. Measurement were taken at the outer wheel path and at distances of 0, 50, 100, 150, 200, 250, and 300 m from the signal stop line at each approach of the evaluated intersections.

5. EFFECT OF OPPOSITE DIRECTION TRAFFIC ON MEASURED NOISE LEVELS

At intersection approaches where the movement of traffic is allowed in two directions at the same time, noise levels were expected to be affected by opposite direction traffic. Four intersections were selected for the purpose of evaluating the effect of opposite direction traffic on measured noise levels. A test was performed in the early morning at 6:00 a.m when the intersection was almost free of traffic flow. Two vehicles were driven in opposite directions to pass each other in front of the noise measurement setup. The equivalent noise level (L_{eq}) was measured for three trials and the results at the first evaluated intersection were 71.4 dB, 71.6 dB, and 71.3 dB. The same test was repeated using only one vehicle passing in front of noise measurement setup at the same speed as that for the two vehicles in the first stage of the test. The measured equivalent noise levels (L_{eq}) for three trials were 71.5 dB, 71.3 dB, and 71. 2 dB. The test results indicated that the differences between the measured (L_{eq}) in the two stages of the tests are negligible. This means the effect of opposite traffic on measured L_{eq} is insignificant.

Another test was performed at the same intersection at 6:30 a.m. when few vehicles pass through the intersection. The measured L_{eq} were 74.4 dB, 74.8 dB, and 74.1 dB when the traffic was traveling only in one direction and were 74.6 dB, 74.8 dB, and 74.5 dB when similar traffic volumes existed in the same direction accompanied by traffic in the opposite direction. Similar tests were repeated at the other three signalized intersections and similar results were obtained.

Based on the above results, it can be concluded that the effect of opposite direction traffic on the measured noise levels is negligible. This may be explained by the fact that the distance between the opposite direction traffic and the noise measurement device is relatively large in comparison to distance between the near lane and the noise measurement device. Also, at high noise levels, the addition of other sources of lower or similar noise levels will not significantly affect the measured noise level. The above results agrees with those obtained by Bjorkman (1988).

6. RESULTS AND DISCUSSION

The collected data was statistically analyzed to evaluate the effect of each variable believed to have an effect on the measured noise levels. The evaluated variables included traffic volume, composition of traffic, traffic speed, and pavement surface texture in addition to road geometric parameters (number of lanes, lane width, approach width and slope). Statistical characteristics of collected data are summarized in Table 1. Table 2 presents the correlation coefficients for measured noise levels and evaluated variables. The following sections discuss the effect of different evaluated variables on measured noise levels.

6.1 Effect of Traffic Volume

Noise levels found to be significantly affected by traffic volume. Figure 2 presents the scatter gram of the relationship between L_{eq} and traffic volume. This figure indicates that the equivalent noise level (L_{eq}) is highly correlated to the traffic volume. The correlation coefficient, shown in Table 2, was found to be 0.892. As it can be seen from Figure 2, higher traffic volume causes higher equivalent noise levels. The highest measured L_{eq} was about 92 dB at a traffic volume of 120 vehicles per minute. While it ranged between 68 and 76 at 10 vehicles per minute. Also, based on the same figure, the relationship between L_{eq} and traffic volume seems to be linear. The variation in L_{eq} at the same traffic volume can be explained by the fact that other parameters affecting noise levels including number of lanes, lane width, traffic speed, road slope and surface texture, and distance from signal stop line. When the effect of traffic volume on L_{eq} was considered at only 0 m from the signal stop line, the variation in L_{eq} for similar traffic volumes was considerably reduced as shown in Figure 3.

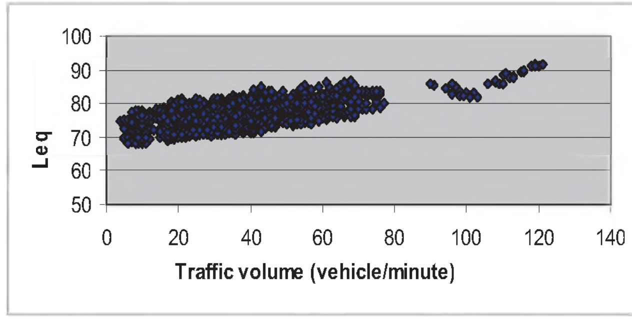

Figure 2. Effect of traffic volume on measured equivalent noise level

The correlation between maximum noise level and traffic volume and minimum noise level are not as strong as that between equivalent noise levels and traffic volume. The correlation coefficient between L_{max} and traffic volume was 0.305. While the correlation between L_{min} and traffic volume was -0.114, which indicates that L_{min} is inversely proportional to traffic volume.

Table 1 Statistical characteristic of evaluated variables

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
L_{eq} (dB)	4745	68	91.6	76.092	3.142
L_{max} (dB)	4745	75.7	115.4	88.519	7.327
L_{min} (dB)	4745	53.9	69.5	63.685	2.619
Traffic Volume(veh/min)	4745	6	121	33.926	14.609
Speed (km/hr)	4745	4.6	110	48.912	27.725
BPN	4745	33	72	48.844	7.73
Heavy vehicle no.	4745	0	6	1.156	1.502
Slope%	4745	- 6	8	0.181	2.688
No .of lanes	1528	2	5	3.46	0.908
Lane width (m)	1528	2	3.6	2.818	0.298
Approach width (m)	1528	5	18	9.852	2.531
Green time interval (sec)	1528	15	90	32.375	12.387
Distance from C.L. to noise level meter (m)	1528	3.5	10	5.926	1.265

Table 2 Correlation matrix of evaluated variables

		L_{min}	L_{max}	L_{eq}	Traffic Volume	Traffic Speed	Distance from Signal	BPN	No. of Heavy Vehicles	Road Slope	Use of Horn			
L_{min}	Pearson Correlation	1	0.0938852	0.0722508	-0.1143211	0.1105943	0.1417418	-0.974642	0.0814465	0.049786	0.028370248	-0.129	-0.111	-0.192
	Sig. (2-tailed)		9.185E-11	6.289E-07	2.818E-15	2.179E-14	1.012E-22	2.59E-23	1.929E-08	0.000602	0.406283561	0.0007	0.0034	4E-07
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
L_{max}	Pearson Correlation	0.0938852	1	0.3221974	0.3055429	0.1429921	0.079512	-0.0925175	0.9169178	0.0390859	0.066689908	0.2960	-0.104	0.2362
	Sig. (2-tailed)	9.185E-11		2.59E-23	2.59E-23	4.239E-23	4.15E-08	1.714E-10	2.59E-23	0.0070874	0.00507102	1E-5	0.0062	3E-10
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
L_{eq}	Pearson Correlation	0.0722508	0.3221974	1	0.5899675	0.5699654	0.6048446	-0.0628985	0.2219457	0.0060096	-0.003771491	0.43244	-0.0416	0.44031
	Sig. (2-tailed)	6.289E-07	2.59E-23		2.59E-23	2.59E-23	2.59E-23	1.452E-05	2.59E-23	0.0067898	0.912110438	4.1E-22	0.02738	4.1E-22
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	-0.0416	4745
Traffic Volume	Pearson Correlation	-0.1143211	0.3055429	0.5899675	1	0.0692866	0.0248924	0.1246131	0.2732668	-0.091471	-0.00838802	0.45746	-0.0223	0.4779
	Sig. (2-tailed)	2.818E-15	2.59E-23	2.59E-23		1.777E-06	0.0864365	6.983E-18	2.59E-23	2.746E-10	0..806078388	4.1E-22	0.55645	4.1E-22
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
Traffic Speed	Pearson Correlation	0.1105943	0.1429921	0.5699654	0.0692866	1	0.9153735	-0.106196	0.0690311	-0.048363	-0.01066890	0.3986	0.28349	0.415
	Sig. (2-tailed)	2.179E-14	4.239E-23	2.59E-23	1.777E-06		2.59E-23	2.234E-13	1.94E-60	0.0008608	0.754854177	4.1E-22	0.9733	4.1E-22
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
Distance from Signal	Pearson Correlation	0.1417418	0.079512	0.6048446	0.0248924	0.9153735	1	-0.1415062	-0.0051165	0.0059894	-0.022740813	0.91	0.18	1
	Sig. (2-tailed)	1.012E-22	4.15E-08	2.59E-23	0.0864365	2.59E-23		1.192E-22	0.7245749	0.6799941	0.50565449	0	0	0
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
BPN	Pearson Correlation	-0.9746419	-0.0925175	-0.0628985	0.1246131	-0.106196	-0.1415062	1	-0.0819836	-0.0600078	-0.028688601	0.16	0.06	0.2
	Sig. (2-tailed)	2.59E-23	1.714E-10	1.452E-05	6.983E-18	2.234E-13	1.192E-22		1.555E-08	3.531E-05	0.41035049	0	0.11	0
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
No. of Heavy Vehicles	Pearson Correlation	0.0814465	0.9169178	0.2219457	0.2732668	0.0690311	-0.0051165	-0.0819836	1	0.0055019	0.055124855	0.212	-0.124	0.151
	Sig. (2-tailed)	1.929E-08	2.95E-23	2.59 E-23	2.59E-23	1.94E-06	0.7245749	1.555E-08		0.7049631	0.106416187	2E-8	0.001	6E-05
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
Road Slope	Pearson Correlation	0.04975	0.0390859	0.0060096	-0.0914714	-0.048363	0.0059894	-0.060007	0.0055019	1	-0.039004282	-0.12	-0.08	-0.147
	Sig. (2-tailed)	0.00060	0.0070874	0.0067898	2.746E-10	0.0008608	0.6799941	3.531E-05	0.7047361		0.253481125	0.0015	0.0349	0.0001
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
Use of Horn	Pearson Correlation	0.02837	0.0666699	-0.0037715	-0.008388	-0.010668	-0.0227408	-0.028683	0.0551249	-0.039004	1	0.062	0.0042	0.0526
	Sig. (2-tailed)	0.40628	0.005071	0.0091211	0.8060784	0.7548542	0.5056545	0.401035	0.1064162	0.253481		0.1025	0.9123	0.166
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	859	4745	4745	4745
Number of Lanes	Pearson Correlation	-0.129	0.2960	0.43244	0.45746	0.3986	0.91	0.16	0.212	-0.12	0.062	1	-0.20415	0.9136334
	Sig. (2-tailed)	0.0007	1E-5	4.1E-22	4.1E-22	4.1E-22	0	0	2E-8	0.0015	0.1025		5.6E-08	4.075E-22
	N	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528
Lane Width	Pearson Correlation	-0.111	-0.104	-0.0416	-0.0223	0.28349	0.18	0.06	-0.124	-0.08	0.0042	-0.29415	1	0.1760842
	Sig. (2-tailed)	0.0034	0.0062	0.02738	0.55645	0.9733	0	0.11	0.001	0.0349	0.9123	5.85E-08		3.008E-06
	N	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528
Approach Width	Pearson Correlation	-0.192	0.2362	0.44031	0.4779	0.415	1	0.2	0.151	-0.147	0.0526	0.913634	0.17608	1
	Sig. (2-tailed)	4E-07	3E-10	4.1E-22	4.1E-22	4.1E-22	0	0	6E-05	0.0001	0.166	4.08E-22	3E-06	
	N	4745	4745	4745	4745	4745	4745	4745	4745	4745	4745	4745	4745	4745

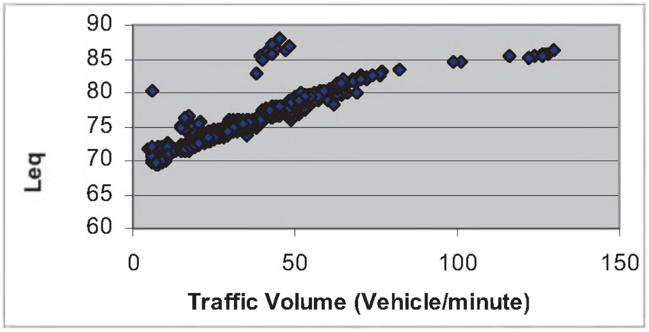

Figure 3. Effect of traffic volume on measured equivalent noise level at 0 m from Signal Stop line

6.2 Effect of Traffic Speed

Results of the study revealed that traffic speed is significantly correlated with equivalent noise levels. The correlation coefficient was 0.569, as shown in Table 2. Figure 4 shows the scatter plot for equivalent noise levels versus traffic speed. A drop in measured L_{eq} was monitored as speed increased up to about 10 km/hr, while a significant increase in measured L_{eq} was monitored as traffic speeds increased more than 35 km/hr. The L_{eq} ranged between 68 to 79 dB at a speed of 20 Km/hr, while it ranged between 77 to 83 dB at speed of 100 km/hr.

The traffic speed effect on equivalent noise levels varies as distances from the intersections' signal stop line increased. At 0, 100, and 150 m from the signal stop line, speed was found to have a significant effect on L_{eq}. While at 150 and 200 m from the signal stop line, the traffic speed effect on L_{eq} was not significant. This may attributed to the fact that, at 150 and 200 m from the signal stop line, vehicle speeds tend to be similar at different gears, This lead to different engine labor at similar speeds, resulting in different noise levels being emitted at similar speeds. At 250 m and 300 m distances from the intersections, equivalent noise levels were significantly increased as traffic speed increased. This is because the fourth gear was most probably used at distances between 250 and 300 m while the speed continued to increase, so the engine labor was higher for the same gear leading to higher equivalent noise levels as the distance increased. Figure 4 shows the variation of equivalent noise levels as

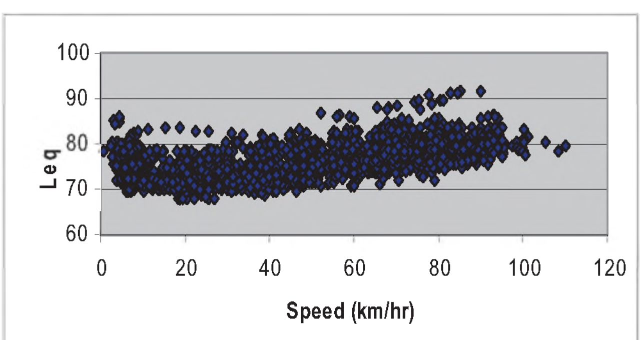

Figure 4. Effect of traffic speed on measured equivalent noise level

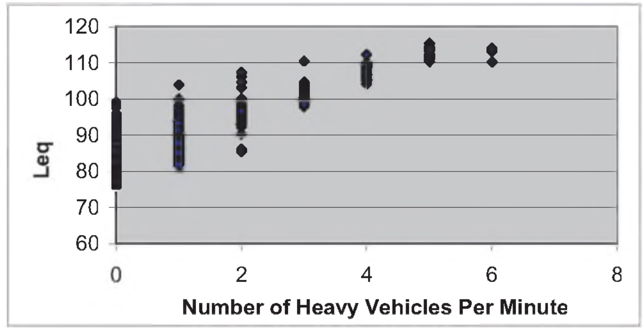

Figure 5. Effect of number of heavy vehicles on measured maximum noise level

the speed increase. This agrees with results obtained at road segments with free traffic flow. Makarewicz and Sato (1996) reported that the sound pressure level of free traffic flow without heavy vehicles showed an increase as the equivalent traffic speed increased.

It was found that traffic speed has less effect on maximum and minimum noise levels than that on equivalent noise level. The correlation coefficient between L_{max} and traffic speed was 0.143. The correlation coefficient between L_{min} and traffic speed was 0.110.

6.3 Effect of Heavy Vehicles

The maximum noise level (L_{max}) was found to be highly affected by the existence of heavy vehicles in the traffic passing the intersection. Figure 5 shows the scatter plot of the maximum noise levels versus the number of heavy vehicles. The correlation coefficient for this relationship was 0.916 as shown in Table 2. The scatter plot and correlation coefficient indicated a strong relationship between the two parameters. Greater numbers of trucks increased L_{max}. This is due to the fact that heavy vehicles have larger engines and exhaust systems, which result in high noise emissions levels. In addition it was found that the equivalent noise levels and minimum noise levels were less affected by the number of heavy vehicles, the correlation coefficient between L_{eq} and heavy vehicles was 0.221, while it was 0.081 between L_{min} and heavy vehicles. The small effect of heavy vehicles on L_{eq} is due to the small number of heavy vehicles in the traffic composition causing little effect on measured L_{eq}. In the case of significant numbers of heavy vehicles in the traffic stream, the heavy vehicle is expected to have a significant effect on the measured L_{eq} as concluded in a study performed by Ramalingeswave and Seshagri Rao (1991). This study reported that L_{eq} is directly proportional to the percentage of heavy vehicles in the traffic stream.

6.4 Effect of the Number of Lanes and Lane Width

Figure 6 shows a scatter plot of the relationship between the equivalent noise levels and the number of lanes in each direction of the intersection approach under evaluation. The correlation coefficient between the equivalent noise levels and

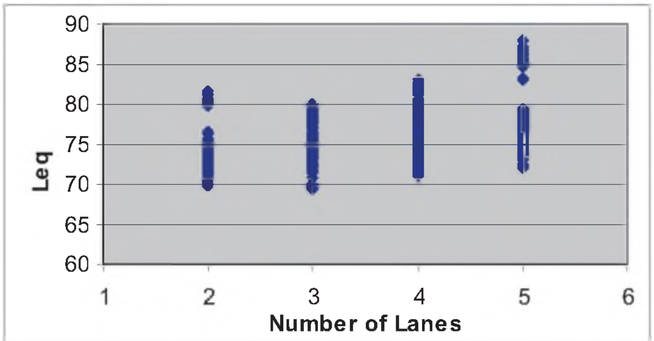

Figure 6. Effect of number of lanes on measured equivalent noise level

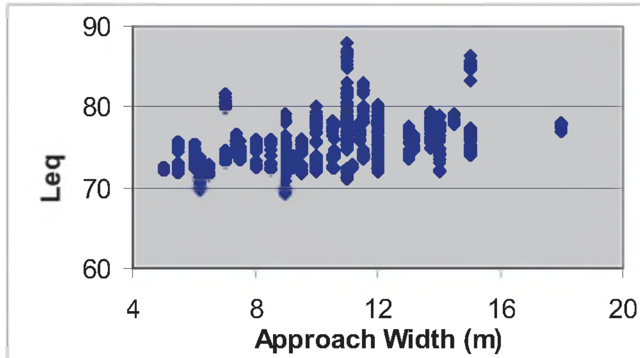

Figure 8. Effect of approach width on measured equivalent noise level

the number of lanes is found to be 0.432 as shown in Table 2. The scatter plot and the correlation coefficient indicate that increasing the number of lanes would cause a slight increase in the average equivalent noise levels.

Figure 7 shows the relation between the equivalent noise level and lane width. The correlation coefficient between the equivalent noise levels and lane width is equal to -0.0416, as shown in Table 2. Based on figure 7 and the correlation coefficient, there is a clear relationship between equivalent noise levels and lane width.

Minimum and maximum noise level were found to be insignificantly affected by the number of lanes. However it was found to be weakly affected by lane width with a correlation coefficient of -0.129 and 0.296 respectively. Lower L_{min} was monitored as the lane width increased. This can be explained by the fact that wider lanes provides enough space for attenuation and absorption of noise emissions, which in turn will cause lower values of measured minimum noise levels. The maximum noise level was found to be insignificantly related to the number of lanes, and lanes width.

6.5 Effect of Approach Width

The equivalent noise level seems to be insignificantly affected by the approach width as shown in Figure 8. Although the correlation coefficient is 0.440, as shown Table 2, indicates a relatively strong relationship between L_{eq} and approach width, figure 8 shows a relatively weak relationship between the same parameters. This figure indicates that a wider approach will cause a slight increase in the equivalent noise level. The maximum and minimum noise levels were found to be insignificantly related to the approach width.

6.6 Effect of Intersection Approach Slope

As shown in the scatter plot, Figure 9, and correlation coefficient indicated a weak relationship between L_{eq} and the approach slope. The correlation coefficient between equivalent noise level and the approach slope, as shown in Table 2, is -0.083. This small magnitude of coefficient indicates weak relationship between the measured slope and monitored L_{eq}. The negative sign of the coefficient means that the increase of road slope will cause a drop in the measured equivalent noise level. In reality, increasing the road slope is expected to cause an increase in the equivalent noise levels, since vehicles exhibits higher engines labor as the gradient of the road increase. The unexpected results in this study can be explained by the fact that most of the approaches slopes were ranged between –3% and 2% which indicated relatively little variation in measured slopes to cause a clear effect on the measured noise levels. Also, the increase of slope causes reduction in speed leading to lower traffic flow, which might cause lower noise emission. The opposite effect of approach slope on measured Leq led to a weak relationship between the two parameters. Maximum and minimum noise levels were found to be insignificantly affected by approach slope.

6.7 Effect of Pavement Surface Texture

The pavement surface texture was evaluated by

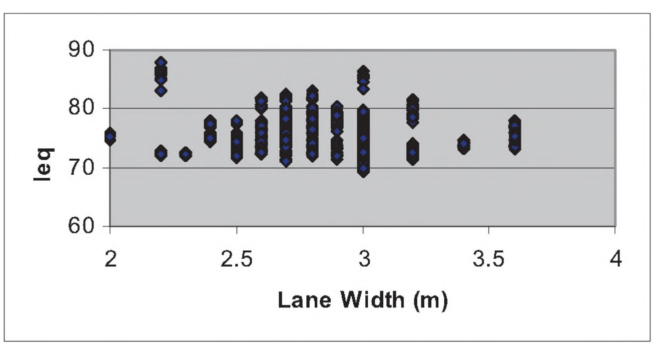

Figure 7. Effect of lane width on measured equivalent noise level

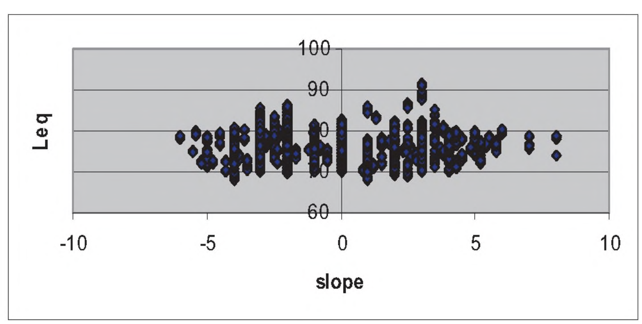

Figure 9. Effect of approach slope on measured equivalent noise level

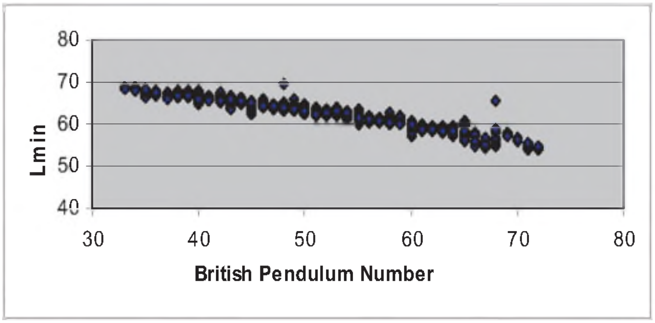

Figure 10. Effect of pavement surface texture on measured minimum noise level

measuring the surface frictional properties using the British Pendulum Tester, and expressed by the British Pendulum Number (BPN). The pavement surface texture was found to be related to the minimum noise levels at intersections. Figure 10 presents a scatter plot between minimum noise levels and BPN. The figure indicates that, increasing the value of BPN cause a decrease in the minimum noise levels, which mean that the rough surface texture properties will reduce the minimum noise levels at intersections. This based on the fact that pavements with a higher BPN have a rougher surface micro texture properties that provides which provide a higher percent of air voids, The voids absorb the noise emissions; especially those resulted from the interaction between vehicles and pavements surfaces. Pavements with smoother surface usually have less percent of air voids, resulting in less noise being absorbed, thus the minimum noise levels would be higher. L_{min} was about 67 dB at a BPN of 35, while it drop to 58 db at a BPN of 65 dB.

The correlation coefficient between minimum noise levels and BPN is -0.974 as shown in Table 2, which indicates a very strong relationship. However, the relationship between BPN and equivalent or maximum noise levels found to be weak as indicated by correlation coefficients in Table 2.

6.8 Horn Effect

The effect of horn use on equivalent, minimum, and maximum noise level was found to be insignificant at all evaluated distances from the signal stop line. However when the data collected at 0 m from the signal stop line was analyzed, it was found that the horn use is weakly related to L_{max} with a correlation coefficient of 0.129.

7. CONCLUSIONS

Based on this study, the following conclusion can be drawn:

1. Traffic volume is directly proportional to the equivalent and maximum noise levels and is inversely proportional to the minimum noise level.
2. As expected, noise levels increased with increasing vehicles speeds.
3. The number of heavy vehicles is directly proportional to noise levels. It is strongly correlated to L_{max}, while its correlation with L_{eq} and L_{min} is relatively weak.
4. The number of lanes were found to have a significant effect on $L_{eq,}$ while it has an insignificant effect on both L_{max} and L_{min}.
5. Lane width has a significant effect on L_{min}. However its effect on L_{eq} and L_{max} is insignificant.
6. In general, approach width has an insignificant effect on noise levels.
7. Approach slope has an insignificant effect on monitored noise levels.
8. As pavement surface skid resistance increased, lower L_{min} was monitored.
9. Use of horn was found to have a significant effect only on L_{max} at 0 m from the signal stop line.
10. Traffic on the far side of the road has a negligible effect on measured equivalent noise level.

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