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Impact of Speed Hump on Noise Pollution

Mohamed Jassim Haroon[1], Mohamed Kharbeche[2], Wael Alhajyaseen[1,2], Alaa Alhawari[1]

[1]Department of Civil and Architectural Engineering, College of Engineering, Qatar University, P.O. Box 2713 Doha, Qatar

[2] Qatar Transportation and Traffic Safety Center, College of Engineering, Qatar University, P.O. Box 2713 Doha, Qatar

Email for correspondence: mh1912362@qu.edu.qa

Abstract

Traffic-related noise pollution has become a major environmental stressor causing various adverse health impacts on humans. Noise levels from road traffic depend on the type of vehicle, friction between the tyre and the pavement, and the driver's behaviour. Traffic calmers like speed humps play a significant role in affecting overall operational factors of vehicles, whereas the major contributors of these pollutants are caused due to the abrupt deceleration, braking, and acceleration of vehicles while passing over them. This research aims to study the impact of speed humps on the effect of noise generated with respect to the traffic flow. For an effective comparison of traffic emissions from the speed hump, this paper aims to perform a simultaneous at and after hump study, where most of the site characteristics and traffic data stay the same. This study will ascertain a statistical regression analysis and paired t-test between the noise levels emitted from vehicles caused by speed humps resulting in annoyance based on the perception and sensitivity reported. Data collection for noise and traffic counts was conducted for 8- hours for 3 locations (residential and school) zone by considering all the peak and off-peak hours. The residential zone noise levels followed a constant trend, whereas the school zone had a significant jump in the noise during peak hours due to a greater number of vehicles approaching the school. The overall mean 8-hours of traffic noise levels exceeded slightly the World Health Organization (WHO) standard for the allowable noise level at the daytime threshold of 53 dB(A) and along with Qatar's standard allowable noise level at the daytime threshold of 55 dB(A) due to the special vehicle fleet mix. Moreover, the analysis revealed that speed humps generated higher noise levels compared to the control point during the study.

1. Introduction

Increased road traffic leads to an elevated amount of both noise and air concentration causing hazards to the environment and public health (Khan et al., 2018). Elevated traffic volumes along with the high speed of vehicles are the key element for the continuous and long-lasting exposure to traffic noise levels among the residents which has become a major and substantial environmental concern for public health (Yang et al., 2020). Constant exposure to noise annoyance causes displeasure and irritation and affects mental and physical human health (Sun et al., 2018). Acoustic noise exposure is one of the main challenges faced by public health, as it causes auditory and non-auditory health complications (Basner et al., 2014).

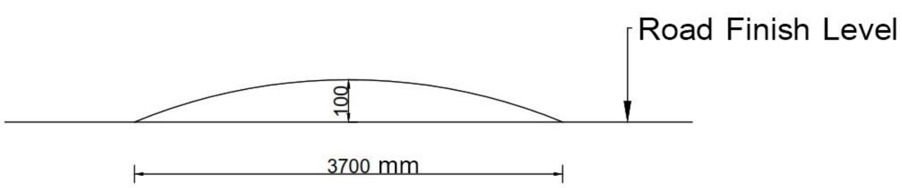
Road traffic noise pollution is usually generated from the vehicle power unit (engine, exhaust, fan), aerodynamic noise (turbulent airflow around the vehicle), and as well as during the tyre pavement interaction (Del Pizzo et al., 2021). The major contributors to the generation of outside noise emissions are the interaction between the tyre and the pavement. They can be due

to Vibro-dynamic noise generated through tyre vibrations due to the contact of the tyre tread against the pavement, and aerodynamic noise generated by the compression and followed by the expansion of the air trapped within the tyre tread and pavement surface (Li, 2018). This compression process is also known as air pumping, and they are possible for emitting noise at frequencies higher than 1 kHz (de León et al., 2020). Statistics released by the European Environment Agency (EEA, 2020), estimated that approximately 82 million people are exposed to noise levels induced by road traffic of about Lden ≥ 55 dB (Khan et al., 2021). Multiple factors can affect the level of traffic noise, such as the speed of vehicles, traffic volume, vehicle composition, driver behaviour, and as well as speed-reducers like speed humps (Kalansuriya et al., 2015).
Knowing the intensity of these emissions is critical, for studying the health effects on human life. Due to their adverse effect on human health, noise levels are the primary factor in terms of the environmental burden (Hänninen et al., 2014). Excessive occupational noise exposure causes auditory effects like permanent hearing loss, as it kills the nerve endings in our inner ear and higher exposure will result in more dead nerve endings. Noise-induced from traffic sources is the major contributor to non-auditory effects like stress, annoyance, sleep disorders, lack of concentration, physiological, and behavioural effects. Apart from that, road traffic noise also leads to cardiovascular disease, risk of stroke, diabetes, hypertension, blood pressure, pregnancy complications, and as well as loss of hearing (Singh et al., 2018). Several tools and techniques have been developed recently to study and estimate the amount of traffic noise levels emitted (Khan et al., 2018). GIS is one of the most promising techniques used for mapping and assessment of these noise levels.

2. Traffic calmers

Traffic calmers like speed humps play an important role in significantly affecting operational factors like lowering the speed of vehicles and contributing to the overall safety of motorists and other road users. The cross-section of the speed hump is shown in Figure 1, which followed the Qatar Highway Design Manual standards (QHDM) with respect to the geometrical features and dimensions (QHDM, 2015).

Figure 1: Speed hump profile, According to QHDM Standards (QHDM, 2015)



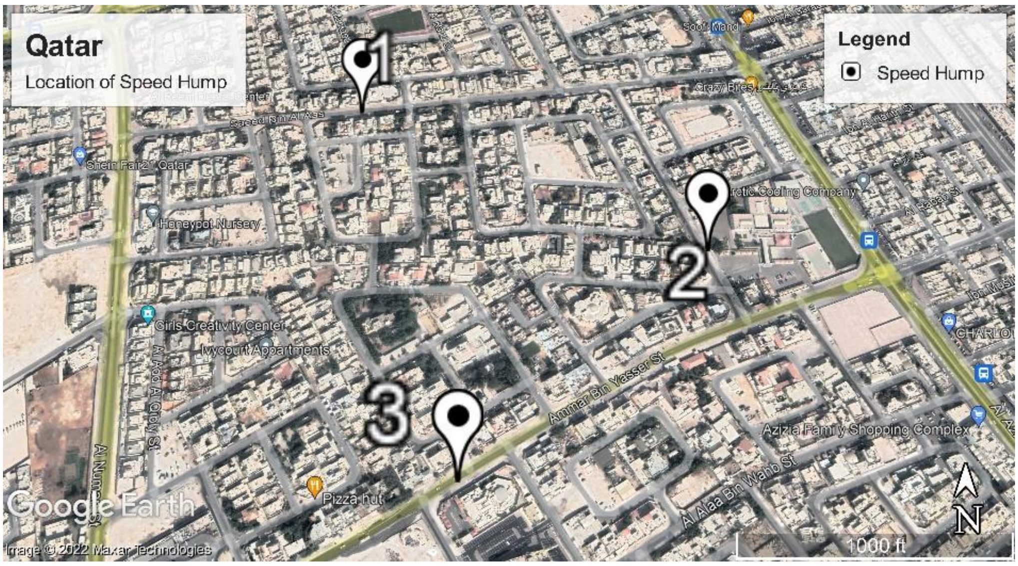
The major contributors to traffic noise levels are caused in the vicinity of the speed hump due to the abrupt deceleration, braking, and acceleration of vehicles while passing over them. Wewalwala and Sonnadara (2011) explained that the amount of noise radiated by a vehicle depends on its engine speed (rpm) and the vehicle speed (m/s). Due to the tendency of a vehicle to accelerate after passing the speed hump, both parameters increase, causing vehicles to emit more noise. Radhiah Bachok et al. (2017) found that driving behaviour has an impact on the significant emission of noise levels while passing a speed hump at greater speed causing a potential rise in the noise levels by 6 dB(A). Shwaly et al. (2018) studied the performance and effectiveness of speed humps based on public interest by conducting questionnaires among 1000 road user respondents in Egypt. The responses were analysed using the SPSS program and the results showed that 73.6% of the respondents believed that speed humps emitted additional noise, annoying nearby residents and road users. Rosli and Hamsa (2013) studied the impact of traffic volume in 3 road sections and noise emitted from road humps in Kuala, Lumpur. The correlation results clearly showed a consistent pattern in which the noise levels increased significantly at the humps with the increase in traffic volume with a measured noise level of 75.6 dB(A), 69.6 dB(A), and 72.7 dB(A) respectively. Behzad et al. (2007) investigated the effect of speed bumps on vehicle noise emissions. Experimental results showed that noise level concentration increased from 14 dB(A) to 19 dB(A) with an increase in height of the speed bump from 0.04 m to 0.055 m.

In general, different types of studies suggested that speed humps are the primary source of noise pollution from road traffic. Many studies have evaluated traffic emissions at various hump locations based on field measurements, modelling, or even simulation software (Abdur-Rouf and Shaaban, 2022). For an effective comparison of noise emissions from the hump, it is advisable to perform a simultaneous at-and-after hump study, where most of the site characteristics and traffic data stay the same. Accordingly, the overarching objective of this research is to study the impact of a speed hump on the effect of noise pollution with respect to traffic flow.

3. Methodology

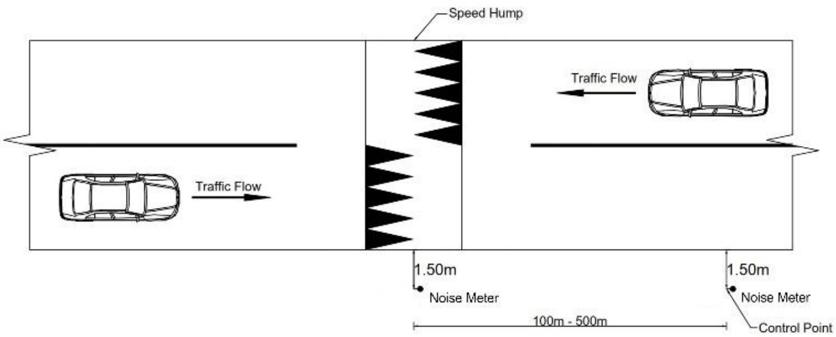
The study area consists of 3 different locations with 2-lane traffic (one lane in each direction) in which each location consists of a speed hump at the residential zone (locations 1 and 2) and at the school zone (location 3) with similar geographical features at Al-Aziziya, Doha-Qatar as shown in Figure 2. All 3 hump locations were selected in a way that, the cross-section of these humps followed Qatar Highway Design Manual (QHDM) standard concerning height and width (QHDM, 2015). Qatar has an aspiring, and well-defined development plan under the National Vision 2030 to spread overall infrastructure development across the transportation road network, education, sports, healthcare, and hospitality services. The primary source of transportation in Qatar is by road, therefore the country has a state-of-the-art road system undergoing rapid advancement along with the rise in population. Recent statistics showed a rapid increase in dependence on automobile usage and Qatar is currently among the list of countries which has the highest numbers of motor vehicles per capita (Shaaban et al., 2019).

Figure 2: Satellite view of the selected speed hump location



The parameters used in this study are to measure the noise level emitted at the hump and the control point (100 – 500 m from the hump) along with the traffic data. The noise level will be measured in terms of LAeq (A-weighted equivalent continuous noise levels in dB(A)) over a certain duration of time. It covers the full audio range (20 Hz to 20 kHz) perceivable by the human ear. The noise emission is measured using Cirrus Optimus Sound Level Meter CR:1710 with a data logging frequency rate for every 1s. The sound level meter was calibrated every time before undergoing data collection using a sound level calibrator CR:515. The noise level meter was placed at the centre of the speed hump and at the control point on the sidewalk assembled on a rigid tripod, kept at a height of 1.5 m (for noise), and at 1.5 m from the roadside as shown in Figure 3.

Figure 3: Instrument setup for Speed hump



The corresponding live traffic flow volumes and type of vehicles at the hump locations were measured using a video camera Count CAM 200 mounted on the streetlight in such a way that it captures the vehicles passing through the hump and control point. The data collection was conducted on weekdays for 8-hours per location (6:00 – 14:00) by considering all the peak and off-peak hours. Qatar's morning peak hours range from 6:00 -8:00 when people commute to their office and school, while the afternoon peak is from 12:00 -14:00 when people commute back to their homes at the end of school and office hours. Weather data like the ambient temperature (°c), and relative humidity (%) were recorded. The overall mean ambient temperature, and relative humidity during the data collection period from the site were 39.37 °C and 64.6%.

4. Traffic noise level

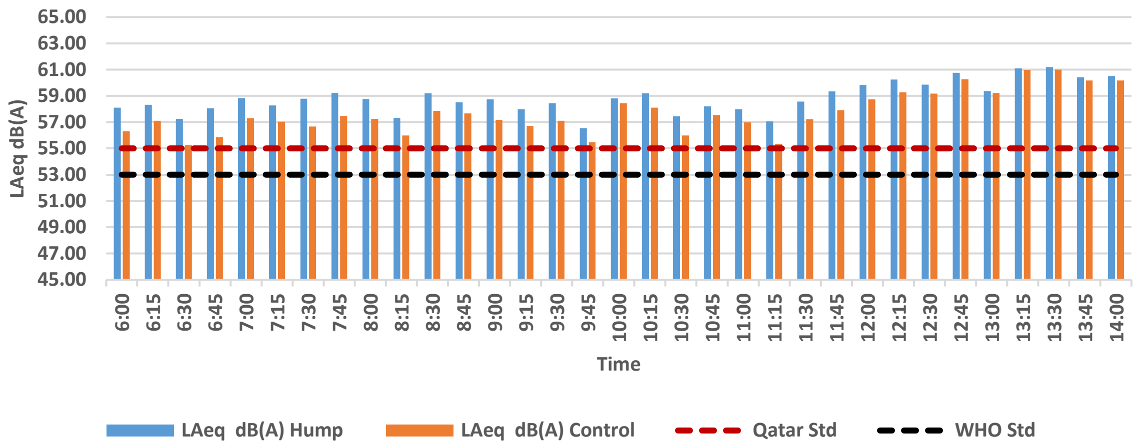
Comparative analyses were conducted to find out the noise level generated by vehicles while passing over the hump with respect to the control point. Initially, the mean 8-hour traffic noise level data were compared to the World Health Organization (WHO) standard for the allowable noise level at the daytime threshold of 53 dB(A) and along with Qatar's standard allowable noise level at the daytime threshold of 55 dB(A) (WHO, 2018). Later, the traffic flow data was extracted at 15-minute intervals for 8-hours and the classification of vehicles was split into 7 categories namely passenger car (PC), sports utility vehicle (SUV), pickup (PU), Motorcycle (MC), heavy-duty (HD), small bus (SB) and large bus (LB). The overall mean noise levels were statistically compared with corresponding traffic flow at the speed hump and the control point to observe the relationship between the two variables by regression analysis and by using paired T-test.

4.1. Location 1 (Residential Zone)

The 8-hour traffic noise level data at the hump and control location were recorded at 15-minute intervals with a data logging frequency of 1 second. The recorded overall mean LAeq for 8-

hour traffic noise level data showed that at the hump the traffic noise was 58.80 dB(A) and at the control was 57.64 dB(A). The reported data indicated that the hourly mean noise levels were slightly above the acceptable threshold standards recommended by WHO and the local standards of Qatar as shown in Figure 4. The noise levels at the hump ranged between 56 dB(A) and 62 dB(A), while at the control site ranged between 55 and 60 dB(A). The maximum fluctuation in noise levels was recorded during the afternoon peak, in which hump noise levels generated 91.2 dB(A), while at control was 89.3 dB(A), probably due to the presence of tuned vehicles or sports cars.

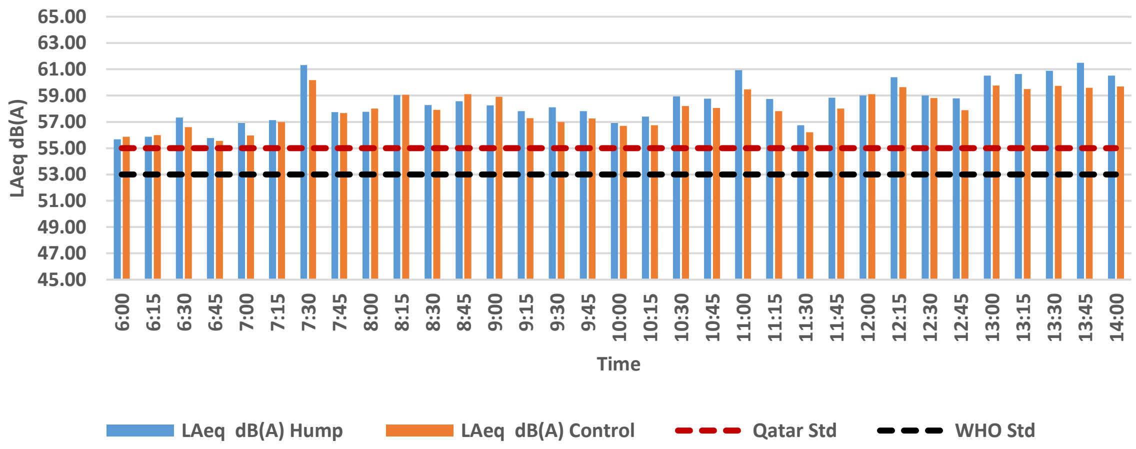
Figure 4: Location (1), Avg LAeq dB(A) – Hump vs Control



4.2. Location 2 (Residential Zone)

The mean LAeq for 8-hour traffic noise level data at the hump and at the control was 58.54 dB(A) and 58.07 dB(A). The data always showed that the hourly mean noise levels during the measurement period were above the standards recommended by WHO and the local standards of Qatar as shown in figure 5. The noise levels at the hump ranged between 55 dB(A) and 62 dB(A), while at the control site ranged between 55 and 60 dB(A). The maximum fluctuation in noise levels was recorded during the afternoon peak, in which hump noise levels generated 88.9 dB(A), while at control was 87.4 dB(A) which is probably due to the high traffic volume that occurred during the end of the school and office hours.

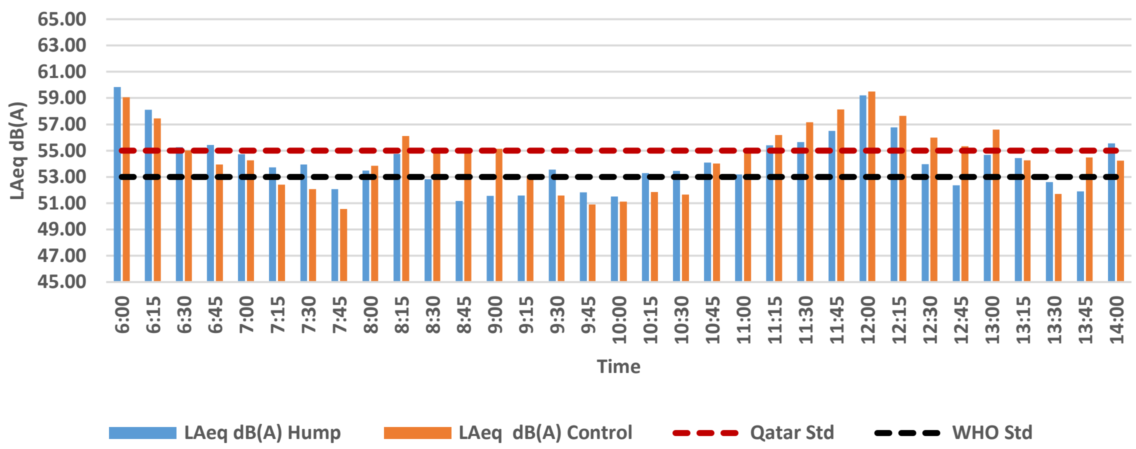
Figure 5: Location (2), Avg LAeq dB(A) – Hump vs Control



4.3. Location 3 (School Zone)

The mean LAeq for 8-hour traffic noise level data at the hump and at the control was 54.19 dB(A) and 54.56 dB(A). The data showed that the hourly mean noise levels during increased vehicle flow were almost within the standards recommended by WHO and the local standards of Qatar as shown in Figure 6. The noise levels at the hump ranged between 51 dB(A) and 60 dB(A), while at the control site ranged between 50 and 60 dB(A). The maximum fluctuation in noise levels was recorded during the afternoon peak, in which hump noise levels generated 94.9 dB(A), while at control was 84.4 dB(A).

Figure 6: Location (3), Avg LAeq dB(A) – Hump vs Control

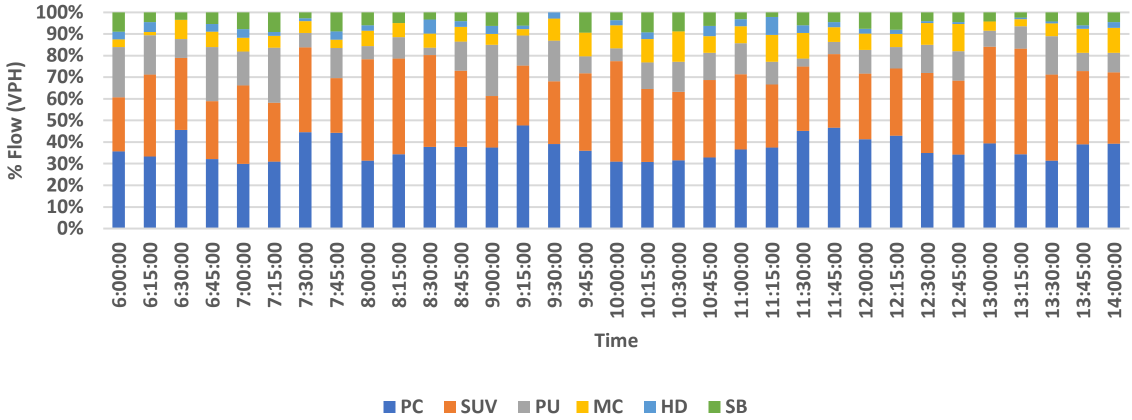


5. Traffic flow and vehicles composition

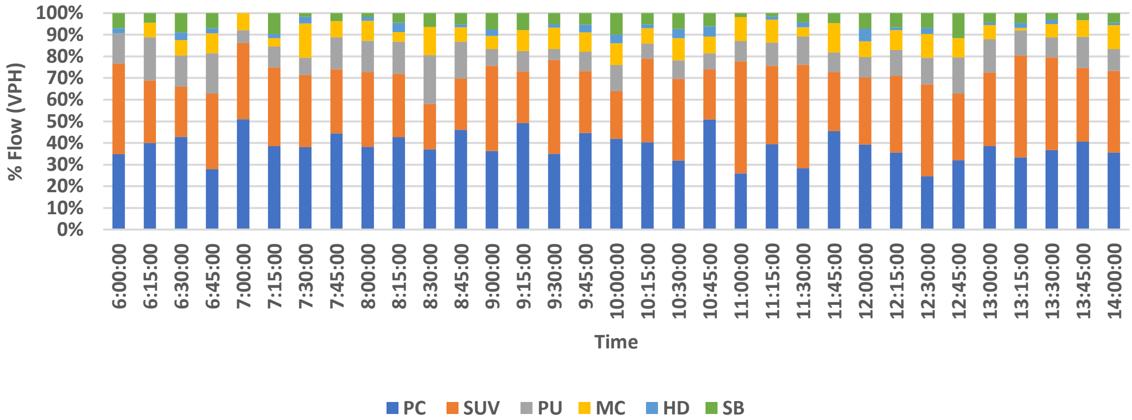
The hourly traffic counts were collected, and it was expected that the vehicle classification significantly contributed to the overall noise levels. Then traffic data were categorized into 7 vehicle groups (PC, SUV, PU, MC, HD, SB, LB). The 15-minute percent traffic composition for a period of 8-hours was extracted from all 3 locations as shown in Figure 7. The extracted data showed that for all the locations PC and SUV had the highest composition during the measurement period. Location (1) had the highest percentage of PC, SUV, and PU about 37%, 35%, and 12% compared to other locations. While HD comparatively had the least count among all 3 locations. The highest 15-minute traffic count was during the afternoon peak (13:00:00- 14:00:00) accounting for 125 (location 1), 98 (location 2), and 90 (location 3) vehicles with a flow rate of 500 vph, 392 vph and 360 vph. Location (1) recorded the maximum count of SUVs of about 61 vehicles which was the highest of all time. Only location 3 had LB vehicles of a total count of 68 in which morning and afternoon peaks accounted for a maximum LB count of 12 vehicles. The total count of vehicles during the analysis period for all the locations gave about 2488 (location 1), 2154 (location 2), and 1168 (location 3) vehicles. The extracted data showed that for all 3 locations PC and SUV contributed to the highest demand for vehicles compared to other vehicle categories throughout the measurement duration. Location (1) contributed 826 of PC and 739 SUVs, while location (2) showed 969 of PC and 917 SUVs, finally, location (3) gave 369 of PC and 560 SUVs. Considering this it can be concluded that PC and SUV vehicles would be the most responsible contributors to the overall noise levels.

Figure 7: Percent Traffic Volume Composition for the Three Locations

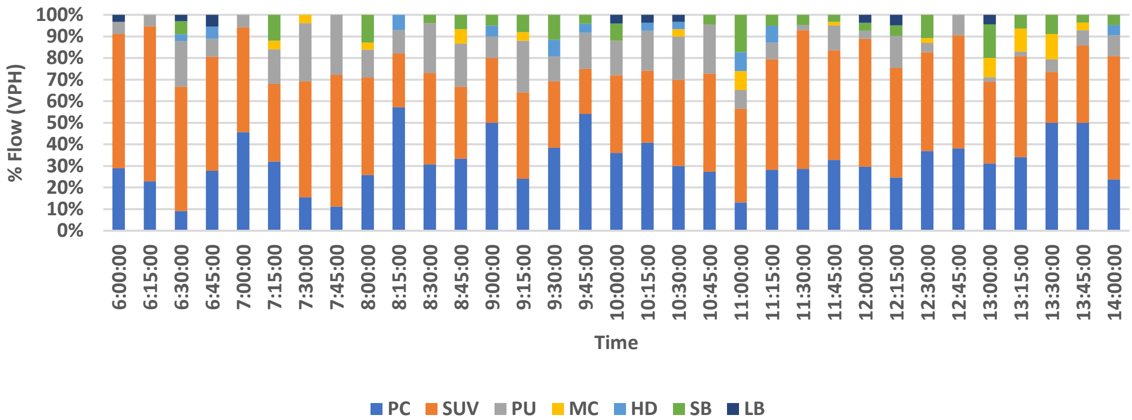
(a) Location (1)



(b) Location (2)



(c) Location (3)



6. Traffic noise levels versus traffic flow

Table 1 shows the mean 15-minute traffic noise levels at the hump and the control for the 3 locations with their respective traffic flow (vph) for a period of 8-hours from 6:00 to 14:00. In general, all 3 locations showed a similar pattern of data. The late morning hours (8:00 – 11:00) and the afternoon hours (12:00 – 14:00) had the lowest and highest traffic noise levels along with the traffic flow.

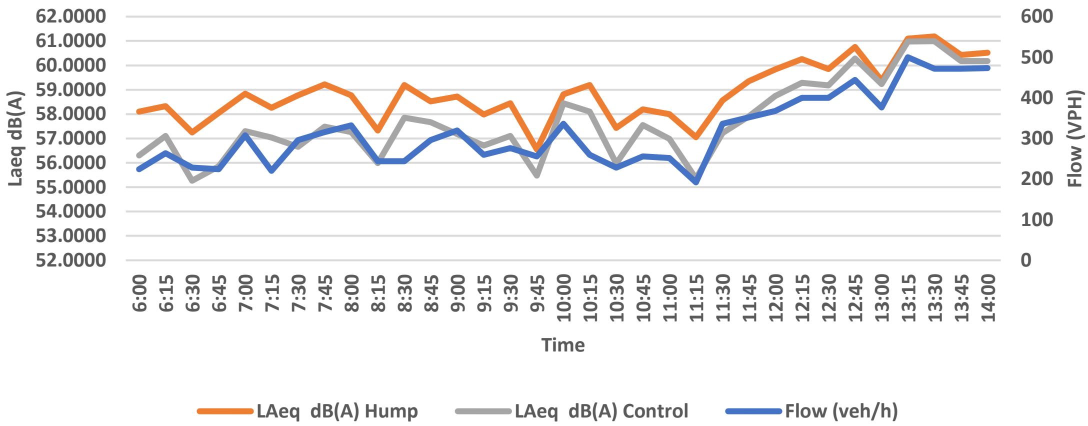
Table 1: 15-Minute Traffic Noise LAeq (Hump and Control) and Traffic Flow

Time		Location 1			Location 2			Location 3		
Time From	Time To	LAeq Hump	LAeq Control	Flow (VPH)	LAeq (Hump	LAeq Control	Flow (VPH)	LAeq Hump	LAeq Control	Flow (VPH)
6:00	6:15	58.097	56.307	224	55.679	55.863	172	59.85	59.054	360
6:15	6:30	58.323	57.100	264	55.862	55.987	180	58.12	57.456	228
6:30	6:45	57.249	55.265	228	57.319	56.605	224	55.26	55.023	132
6:45	7:00	58.054	55.853	224	55.767	55.541	172	55.44	53.950	144
7:00	7:15	58.843	57.305	308	56.913	55.956	204	54.73	54.275	140
7:15	7:30	58.262	57.036	220	57.145	56.989	208	53.73	52.409	100
7:30	7:45	58.778	56.664	296	61.313	60.171	252	53.96	52.077	104
7:45	8:00	59.222	57.481	316	57.751	57.662	216	52.07	50.553	72
8:00	8:15	58.766	57.258	332	57.776	58.007	220	53.49	53.843	124
8:15	8:30	57.333	55.987	244	59.043	59.057	272	54.75	56.106	112
8:30	8:45	59.188	57.848	244	58.282	57.914	248	52.84	55.178	104
8:45	9:00	58.529	57.672	296	58.583	59.100	304	51.16	54.838	60
9:00	9:15	58.726	57.187	320	58.251	58.919	264	51.56	55.150	80
9:15	9:30	57.986	56.712	260	57.828	57.283	252	51.58	53.104	100
9:30	9:45	58.450	57.105	276	58.099	56.990	240	53.55	51.594	104
9:45	10:00	56.549	55.479	256	57.812	57.261	224	51.82	50.892	96
10:00	10:15	58.807	58.441	336	56.908	56.698	200	51.51	51.128	100
10:15	10:30	59.195	58.097	260	57.407	56.744	228	53.28	51.853	108
10:30	10:45	57.436	55.975	228	58.934	58.204	276	53.45	51.664	120
10:45	11:00	58.199	57.547	256	58.777	58.071	260	54.10	54.012	88
11:00	11:15	57.991	56.980	252	60.933	59.478	216	53.20	55.073	92
11:15	11:30	57.050	55.354	192	58.750	57.821	264	55.41	56.183	156
11:30	11:45	58.562	57.220	336	56.734	56.202	184	55.66	57.163	168
11:45	12:00	59.347	57.904	352	58.839	58.015	264	56.51	58.140	244
12:00	12:15	59.835	58.744	368	59.017	59.105	336	59.20	59.489	324
12:15	12:30	60.250	59.280	400	60.393	59.639	304	56.78	57.646	244
12:30	12:45	59.845	59.175	400	59.005	58.805	292	53.97	56.002	184
12:45	13:00	60.758	60.279	444	58.787	57.878	312	52.38	55.326	84
13:00	13:15	59.371	59.230	376	60.522	59.765	364	54.69	56.607	180
13:15	13:30	61.094	60.974	500	60.643	59.485	348	54.43	54.267	188
13:30	13:45	61.186	60.993	472	60.895	59.747	392	52.60	51.707	136
13:45	14:00	60.421	60.174	472	61.498	59.603	364	51.90	54.478	112
Average		**58.803**	**57.645**	**311.000**	**58.483**	**57.955**	**258.000**	**54.155**	**54.570**	**143.375**

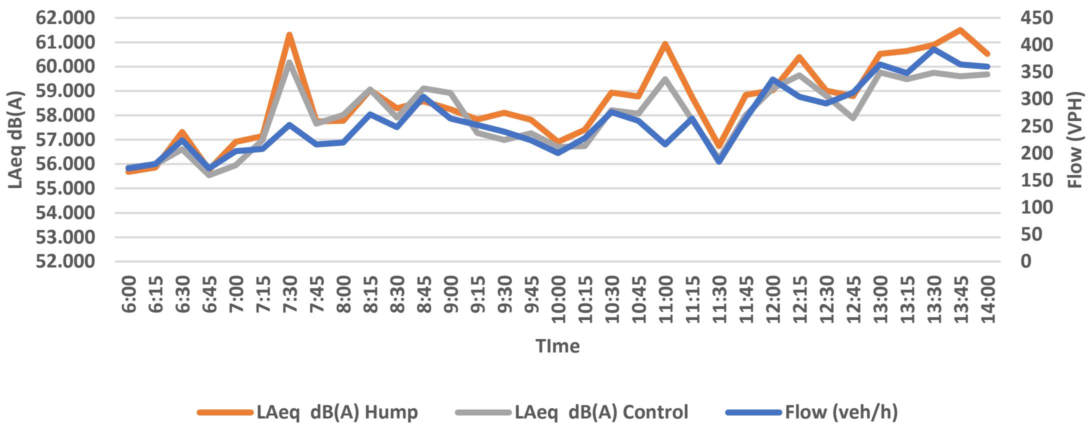
Figure 8 shows the graph of 15-minute traffic noise levels with traffic flow plotted as combined line graphs, to observe the relationship between noise levels at hump and control with traffic flow data. The relationship showed the lowest and highest traffic noise levels significantly corresponded to traffic flow patterns. For instance, location 1 at 11:15 – 11:30, had the least traffic flow (192 vph) with the least noise levels at hump and control of around 55~57 dB(A), while at 13:15 – 13:30, had the highest traffic flow (500 vph) with noise levels of 60~61 dB(A). Location 2 at 13:30 – 13:45, had the highest traffic flow (392 vph) with the highest noise levels at hump and control of around 59~ 61 dB(A). Similarly, location 3 during the morning peak at 06:00-06:15, had the highest traffic flow (360 vph) with noise levels at hump and control of around 59~60 dB(A). It can be noticed at location 3 (school zone) that the noise level at the control point is higher than the hump most of the time this is because, during the off-peak hours, there is a high tendency for vehicles to accelerate after passing the hump. Therefore, noise levels are seen elevated at the control point in which the higher the speed higher will be the noise emission. Whereas, during peak hours high demand for vehicles outside the school premises causes queues on the road. Further, it can be also noticed that a great number of curbside parked vehicles are present (visualised through the camera) besides the school for pick-up, which contributed to the elevated noise levels at the control point. By this, it can be concluded that traffic noise levels were significantly impacted by vehicle flow data.

Figure 8: LAeq (Control and Hump) vs Traffic Flow

(a) Location (1)



(b) Location (2)



(c) Location (3)

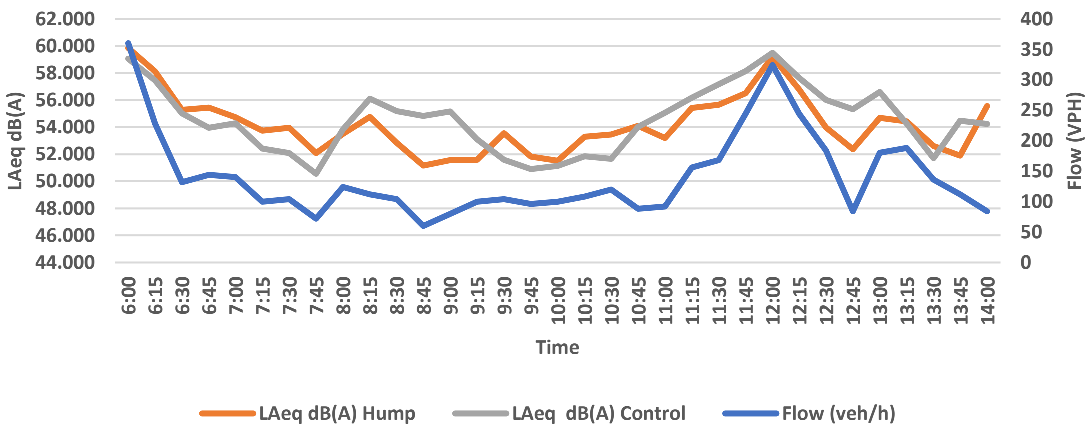


Table 2 shows the statistical regression analysis data for all locations at hump and control points with respect to traffic flow along with the aggregated correlation of all 3 locations.
For the regression analysis, the independent Variable selected will be flow (vph) and the dependent variable will be LAeq (at Hump and Control points). The *P*-value in the regression analysis is based on the following hypothesis:

- The Null Hypothesis, H_o = There is no statistically significant relationship between flow (vph) and LAeq dB(A).
- The Alternative Hypothesis, H_A = There is a statistically significant relationship between flow (vph) and LAeq dB(A).

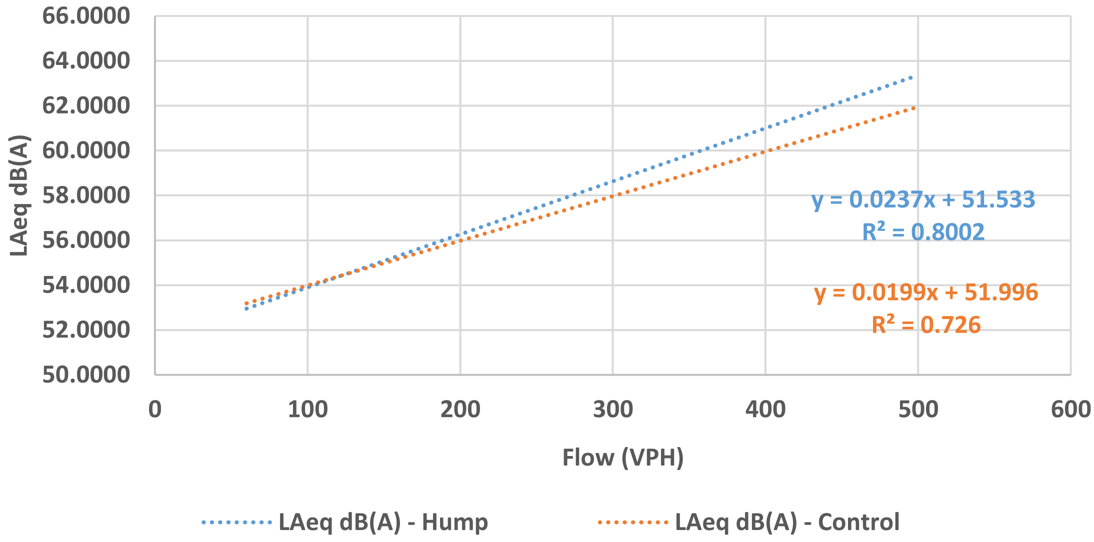
Location 1 had a considerably significant strong correlation where the *P*-values were less than 0.05 at hump and control point and R^2 values were 0.817 and 0.854 respectively. Whereas in location 2, the correlation between traffic noise levels (hump and control) and traffic flow had a considerably lower R^2 value of 0.657 and 0.664. This is probably because of lesser demand for vehicles during the off-peak hours causing the vehicles to move at higher speed and thereby increasing the overall noise emissions. While at location 3, the control point had the least correlation of R^2 value of 0.552. This can be explained by the high demand for curbside parked vehicles near the control point beside the school for pick-up during the end of school hours, causing excessive noise emission from the motor engine. It can also be noticed from the regression model that the y-intercept estimate is above 50 dB(A) for all cases, it is because the ambient noise factor from the surrounding environment acting on the noise level meter has a significant effect on the overall noise levels. The Cirrus Noise level meter is a very sensitive class-1 Optimus green environmental noise level meter cable for detecting ambient noise.

Table 2: Regression Data for LAeq (Hump and Control) vs Traffic Flow

Location ID	Position	P-Value	Significance	Regression Model	R^2 Value
LOCATION 1	Hump	< 0.05	Significant	y = 0.0123x + 54.971	0.817
	Control	< 0.05	Significant	y = 0.0172x + 52.298	0.854
LOCATION 2	Hump	< 0.05	Significant	y = 0.0216x + 52.901	0.657
	Control	< 0.05	Significant	y = 0.0183x + 53.238	0.664
LOCATION 3	Hump	< 0.05	Significant	y = 0.0268x + 50.400	0.757
	Control	< 0.05	Significant	y = 0.0253x + 50.978	0.552
AGGREGATED	Hump	< 0.05	Significant	y = 0.0237x + 51.533	0.800
	Control	< 0.05	Significant	y = 0.0199x + 51.996	0.725

Figure 9 shows the aggregated traffic noise levels of all 3 locations with respect to the traffic flow. It is clearly obvious from the plot that, the noise levels at the speed hump were considerably higher than the noise levels at the control point. When the traffic flow increased the corresponding noise levels at the speed hump and control point increased. A strong positive correlation of traffic noise levels with the traffic flow was seen at the speed hump of R^2 value of 0.80 than at the control point of R^2 value of 0.72. From this, it can be concluded that noise levels were elevated at speed humps compared to control points.

Figure 9: Aggregated Flow vs LAeq



The noise data were also analysed for comparing the statistical difference between the noise levels at the hump and at the control points using paired t-test, in which all assumptions for normality were satisfied. The *P*-value in the paired t-test is based on the following hypothesis:

- The Null Hypothesis, H_o: $\mu_1 = \mu_2$, No significant difference between LAeq (Hump) and LAeq (Control).
- The Alternative Hypothesis, H_A: $\mu_1 \neq \mu_2$, Significant difference between LAeq (Hump) and LAeq (Control).

Where μ_1 = LAeq (Hump), μ_2 = LAeq (Control)

Table 3 shows the results of paired t-test for all locations conducted to compare the differences in noise levels between the hump and the control point.

Table 3: Paired Samples t-test

Location ID	Position	t-critical	t-stat	df	P-Value (two-tail)	Significance
LOCATION 1	Hump Control	2.039	11.497	31	< 0.05	Significant
LOCATION 2	Hump Control	2.039	5.160	31	< 0.05	Significant
LOCATION 3	Hump Control	2.039	-1.411	31	> 0.05	Not Significant

The change in the noise level for location (1) was statistically significant at the hump and control point with t (31) = 11.497, *P*-value < 0.05. As well, the change in the noise level for location (2) was also statistically significant at the hump and control with t (31) = 5.160, *P*-value < 0.05. While the increase in the noise level for location (3) was statistically insignificant at the control point with t (31) = -1.411, *P*-value > 0.05. The lack of significance for this location (3) is because of the elevated noise levels at the control point than at the speed hump. The reason behind this is due to the high speed of vehicles during the off-peak hours and as well as the high demand of vehicles during the peak hours causing vehicles to queue up near the control point.

7. Conclusion

In this study, the traffic noise levels (LAeq) and traffic flow (vph) at the speed hump and at the control point were collected at 3 different locations near residential and school zone in Doha, Qatar. The data collection was conducted on weekdays for 8-hours per location (6:00 – 14:00) by considering all the peak and off-peak hours. The objective of this research is to study the impact of speed humps on noise pollution with respect to traffic flow. For this purpose, an effective comparison of traffic noise levels from the speed hump was performed with a simultaneous at and after hump study, where most of the site characteristics and traffic data stayed the same. Based on field data computation, the overall mean traffic noise levels for all 3 locations exceed slightly the World Health Organization (WHO) standard for the allowable noise level at the daytime threshold of 53 dB(A) and along with Qatar's standard allowable noise level at the daytime threshold of 55 dB(A) due to the vehicle fleet mix. The 8-hour traffic flow data was extracted at 15-minute intervals and was split according to the vehicle composition. It was found that for all the locations PC and SUVs contributed to the highest demand of vehicles during the measurement period.

The combo-line chart for all 3 locations depicted that, traffic noise levels clearly correspond to the highest and lowest traffic flow, in which noise levels followed the trend pattern according to the traffic flow data. The noise level data at the residential zone (locations 1 and 2) followed a constant trend at the hump and control points. Whereas the school zone (location 3) had a significant jump in traffic noise during morning and afternoon peak hours due to a greater number of buses and vehicles approaching the school. The overall mean noise levels were compared with corresponding traffic flow at the speed hump and the control point to observe the relationship between the two variables using regression analysis. A strong positive correlation was obtained at all locations except for location 3 with a comparatively lower correlation of R^2 value at the control point of 0.552. This was probably due to the less demand for vehicles during the off-peak hours causing the vehicles to move at higher speed and along with the high demand of curbside parked vehicles besides the school premises for pick-up also considerably contributed to the elevated noise levels at the control point than at the hump. The regression analysis for aggregated traffic noise levels and traffic flow data for all 3 locations showed a strong positive correlation at hump and control points of R^2 values of 0.80 and 0.72 respectively.

The noise data were also checked for comparing the statistical difference between the noise levels at the hump and at the control point using paired t-test. The change in the noise level at locations (1 and 2) was statistically significant with P-value < 0.05, while location (3) was not statistically significant with a P-value > 0.05, due to the same above-mentioned Hence, to sum up, it was clear that speed humps considerably increased traffic noise levels when compared to control points.

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9. References

Abdur-Rouf, K., Shaaban, K., 2022. A Before-and-After Traffic Noise Analysis of a Roundabout Converted to a Signalized Intersection. Arabian Journal for Science and Engineering. https://doi.org/10.1007/s13369-022-06778-6

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., Stansfeld, S., 2014. Auditory and non-auditory effects of noise on health. The Lancet 383, 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Behzad, M., Hodaei, M., Alimohammadi, I., 2007. Experimental and numerical investigation of the effect of a speed bump on car noise emission level. Applied Acoustics 68, 1346–1356. https://doi.org/10.1016/j.apacoust.2006.07.003

Charfeddine, L., Yousef Al-Malk, A., Al Korbi, K., 2018. Is it possible to improve environmental quality without reducing economic growth: Evidence from the Qatar economy. Renewable and Sustainable Energy Reviews 82, 25–39. https://doi.org/10.1016/j.rser.2017.09.001

de León, G., Del Pizzo, A., Teti, L., Moro, A., Bianco, F., Fredianelli, L., Licitra, G., 2020. Evaluation of tyre/road noise and texture interaction on rubberised and conventional pavements using CPX and profiling measurements. Road Materials and Pavement Design 21, S91–S102. https://doi.org/10.1080/14680629.2020.1735493

Del Pizzo, L.G., Bianco, F., Moro, A., Schiaffino, G., Licitra, G., 2021. Relationship between tyre cavity noise and road surface characteristics on low-noise pavements. Transportation Research Part D: Transport and Environment 98, 102971. https://doi.org/10.1016/j.trd.2021.102971

Hänninen, O., Knol, A.B., Jantunen, M., Lim, T.A., Conrad, A., Rappolder, M., Carrer, P., Fanetti, A.C., Kim, R., Buekers, J., Torfs, R., Iavarone, I., Classen, T., Hornberg, C., Mekel, O.C.L., 2014. Environmental burden of disease in Europe: Assessing nine risk factors in six countries. Environmental Health Perspectives 122, 439–446. https://doi.org/10.1289/ehp.1206154

Kalansuriya, C.M., Pannila, A.S., Sonnadara, D.U.J., 2015. Traffic composition and variability of road traffic noise levels in the vicinity of Colombo, Sri Lanka. J Natl Sci Found 43, 135–140. https://doi.org/10.4038/jnsfsr.v43i2.7941

Khan, J., Ketzel, M., Jensen, S.S., Gulliver, J., Thysell, E., Hertel, O., 2021. Comparison of Road Traffic Noise prediction models: CNOSSOS-EU, Nord2000 and TRANEX. Environmental Pollution 270, 116240. https://doi.org/10.1016/j.envpol.2020.116240

Khan, J., Ketzel, M., Kakosimos, K., Sørensen, M., Jensen, S.S., 2018. Road traffic air and noise pollution exposure assessment – A review of tools and techniques. Science of the Total Environment 634, 661–676. https://doi.org/10.1016/j.scitotenv.2018.03.374

Li, T., 2018. Literature review of tire-pavement interaction noise and reduction approaches. Journal of Vibroengineering 20, 2424–2452. https://doi.org/10.21595/jve.2018.19935

QHDM, 2015. Qatar Highway Design Manual, Ministry of Transport, Doha, Qatar, 2015.

Radhiah Bachok, K.S., Kadar Hamsa, A.A., bin Mohamed, M.Z., Ibrahim, M., 2017. A theoretical overview of road hump effects on traffic noise in improving residential well-being. Transportation Research Procedia 25, 3383–3397. https://doi.org/10.1016/j.trpro.2017.05.224

Shaaban, K., Abou-Senna, H., Elnashar, D., Radwan, E., 2019. Assessing the impact of converting roundabouts to traffic signals on vehicle emissions along an urban arterial corridor in Qatar. Journal of the Air and Waste Management Association 69, 178–191. https://doi.org/10.1080/10962247.2018.1526137

Shazwani ROSLI, N., Azeez KADAR HAMSA, A., 2013. Evaluating the Effects of Road Hump on Traffic Volume and Noise Level at Taman Keramat Residential Area, Kuala Lumpur.

Shwaly, S., AL-Ayaat, A., Zakaria, M.H., 2018. Public Evaluation of Speed Humps Performance and Effectiveness. Civil Engineering Journal 4, 1206. https://doi.org/10.28991/cej-0309168

Singh, D., Kumari, N., Sharma, P., 2018. A Review of Adverse Effects of Road Traffic Noise on Human Health. Fluctuation and Noise Letters 17, 1–12. https://doi.org/10.1142/S021947751830001X

Sun, K., De Coensel, B., Echevarria Sanchez, G.M., Van Renterghem, T., Botteldooren, D., 2018. Effect of interaction between attention focusing capability and visual factors on road traffic noise annoyance. Applied Acoustics 134, 16–24. https://doi.org/10.1016/j.apacoust.2018.01.001

Wewalwala, S.N., Sonnadara, D.U.J., 2011. Traffic Noise Enhancement due to Speed Bumps, Sri Lankan Journal of Physics.

WHO, 2018. WHO environmental noise guidelines for the European Region.

Yang, W., He, J., He, C., Cai, M., 2020. Evaluation of urban traffic noise pollution based on noise maps. Transportation Research Part D: Transport and Environment 87, 102516. https://doi.org/10.1016/j.trd.2020.102516