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ARTCLES

Mapping Traffic Noise in Kuwait City*

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Abstract

Objectives: This study mainly aims to firstly predicting the traffic noise level using SoundPLAN 7.1 software, and secondly constructing traffic noise maps for Kuwait City during the daytime, evening, and nighttime periods on weekdays and weekends.

Method: Traffic noise maps were developed using the SoundPLAN 7.1 software and Geographic Information System (GIS) datasets and traffic information. The geo-data sets included ground topography, road design, asphalt type, 3-D building, and weather data sets. For model validation purpose, 24-hour field measurements of noise levels were collected at 13 locations distributed throughout Kuwait City using Casella CEL - 490 Sound Level Meters.

Results: The average percentage difference between field measurements monitored in October 2016 and predicted noise values was 1.9%. Both average predicted and measured noise values (65.1 and 66.2 dB(A), respectively) exceeded the established Kuwait Environmental Public Authority (KEPA) standard of 65 dB(A) under the category of “Traffic- Urban Residential with Commercial Sites” with 27.7% of the total coverage area of Kuwait city. The resulted traffic noise map showed similar spatial patterns for noise levels on weekends and weekdays because of the similarity in the traffic flow direction of the vehicles.

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Conclusion: The traffic noise level in Kuwait City exceeds the KEPA national standard limits during all periods of a day on both weekdays and weekends.

Keywords: Traffic, Noise, SoundPLAN 7.1 Software, GIS, Kuwait.

Introduction

The undesired sound produced by anthropogenic activities and affects surrounding the livings is considered as environmental noise pollution (Murphy et al., 2009); e.g., urban traffic flow that affects all aspects of the quality of life in large cities. Al-Mutairi et al. (2011) indicated that throughout most of the day the noise pollution levels along most roadways in Kuwait (in average 76.4 dBA) are above the Kuwait Environment Public Authority’s (KEPA) permitted standards, and during the rush hour periods, the noise level reaches 80 dBA. Due to the rapid increase in the volume of traffic in Kuwait City, it is hypothesized that exposure to traffic noise in the study area is considerably above the World Health Organization limits of 70 dBA for daytime exposure and 45 dBA for nighttime exposure (AL-Awadhi, 2014). Murphy et al. (2009) stated that if the traffic noise pollution is not mitigated then the adverse health effects could be directly associated with it. The exceedance of the noise exposure limits due to traffic flow and congestion may not only lead to direct but also cumulative adverse health effects (Carter, 1996; Muzet, 2007). Such negative effects may include anger, unhappiness, disappointment, rage emotions and cardiovascular disease risk (Babisch et al., 2005; Fields, 1998; Michaud et al., 2005; Murphy et al., 2009; Vlachokostas et al., 2012). Annoyance related to road traffic is of two types: (1) rolling noises caused by tire-road interactions and (2) propulsion noises caused by acceleration and deceleration of the vehicle. In general, factors controlling the traffic noise include vehicle type, engine type, traffic speed, pavement type, and distance to the noise source, barriers, topography and weather (Seong et al., 2011).

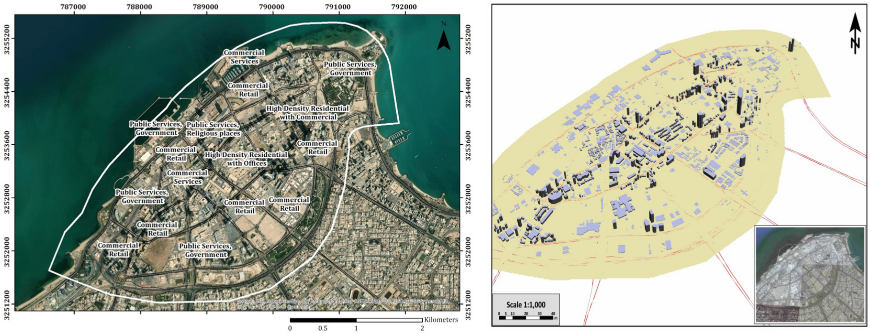
To assess noise produced by traffic flow in a city for large-scale and long-term environmental impacts, most researchers prefer using traffic noise simulation models rather than noise exposure sampling. Noise monitoring in the field limits the geographical scale of measurements thus it is not feasible to yield representative noise exposure levels for a whole city or residential area. In the past 20 years, large numbers of traffic noise simulation models have been developed, some of them use principal variables such as the traffic volume, distance from traffic lanes, mean vehicle speed, and percentage of heavy trucks (Steele, 2001), while the modified ones use extra methods, such as genetic algorithms (Gündoğdu et al., 2005), neural networks (Cammarata et al., 1995) and statistical methods (Sopasakis, 2004). Additionally, dynamic models (Sopasakis, 2004; De Coensel et al., 2005) have notably increased the prediction accuracy (Can et al., 2009), making it possible to better consider the effects of traffic signals (Yamaguchi et al., 1998), intersections (Abo-Qudais & Alhiary, 2007) and roundabouts (Chevallier et al., 2009). For better understanding and assessment of the level of exposure due to traffic noise in Kuwait City, this study aims to use a well-modified model named SoundPLAN 7.1. The assessment was carried out for different periods of the day on weekdays and weekend days, and accordingly a traffic noise map was produced. It is important to indicate that this study differs from the studies of Al-Mutairi et al. (2011) and Al-Awadhi (2014), both studies measured traffic noise levels along most roadways in Kuwait using Sound Level Meter (SLM), while this study used a well-modified model to predict traffic noise. Prior to this study, the authors used simple Software named “CUSTIC 2.0” for preliminary assessment of the traffic noise level in Kuwait City (Al-Awadhi and AlKandary, 2017).

Study Area

Kuwait city is located in the eastern part of the state of Kuwait and has approximately 60300 inhabitants (approximately 1.36% of the Kuwait population) and a surface area of 14.05 km^2 (4292 inhabitants/km^2) (Kuwait-Public Authority for Civil Information, 2018); i.e., a small-sized Mediterranean urban area. Due to rapid development, the city is exposed to traffic noise pollution (AL-Awadhi, 2014). Major industries and airport are existed far away from the city; thus, they do not contribute to the ambient noise in the local inner-city area, however, higher population density is surrounding the Kuwait City. Although there is no routine noise monitoring in the city, few studies showed that environmental noise caused by urban traffic flow and congestion has become a major environmental concern to residents (AL-Awadhi, 2014). The field study carried out by Al-Awadhi (2014) showed that Kuwait City is exposed to high level of noise specifically along the roadway edges reaching 70-75dBA. The routes in the city include different types of roadways, characterized by slow speeds and frequent stops that pass through residential, shopping and high-density governmental buildings (Figure 1). In general, traffic counting for the city indicates a moderate traffic load along most roadways and may reach a high load during rush hour periods.

Figure 1

Major roads in Kuwait City (a) with a border given by the white line and (b) a 3-D model of the main buildings in the city



(a) (b)

Methods and Materials

Traffic noise exposure assessment was carried out using SoundPLAN 7.1 software, which is produced by Sound PLAN International, LLC. This software incorporates several computer programs, including the calculation of road traffic noise (CRTN) algorithm. Accordingly, traffic noise maps were developed using the model and Geographic Information System (GIS, version 10.2) datasets and traffic information. The geo-data sets, which are commonly required for noise modeling, included ground topography, road design, asphalt type, traffic volume, 3-D building, and weather condition data sets. The meteorological data were obtained from Kuwait International Airport and covered the same period as the traffic counts. Table 1 gives the statistical descriptions of the temperature, relative humidity, and wind speed and direction measured in October 2016.

Table 1

Kuwait International Airport meteorological in October, 2016

Weather condition	Maximum	Minimum	Mean
Temperature (°C)	16.63	5.48	11.81
Relative humidity (%)	90.67	20.50	51.14
Wind speed (m/s)	5.68	0.79	3.48
Wind dirction	South West		

The main input variables used in this study were road geometries including height of surrounding buildings (assuming same type of construction material), and traffic counts obtained from the Ministry of the Interior-Traffic Department. In October 2016, all vehicle size categories were counted atomically across 30 main asphaltic roadways (2 and 3 lanes types) in the city, for a period of one week (Figure 2). Appendix A summarizes the outputs of the counting in term of average hourly of vehicles travelling at each roadway; the average number of vehicles ranged from 17 to 3333 vehicle per hour. As other input for the model, road surface attenuation was assumed to be 0.0 (0%); i.e., flat, and the maximum speed of vehicles was chosen to be between 60 to 80 km/hr. In addition, the following assumptions were made regarding the input data:

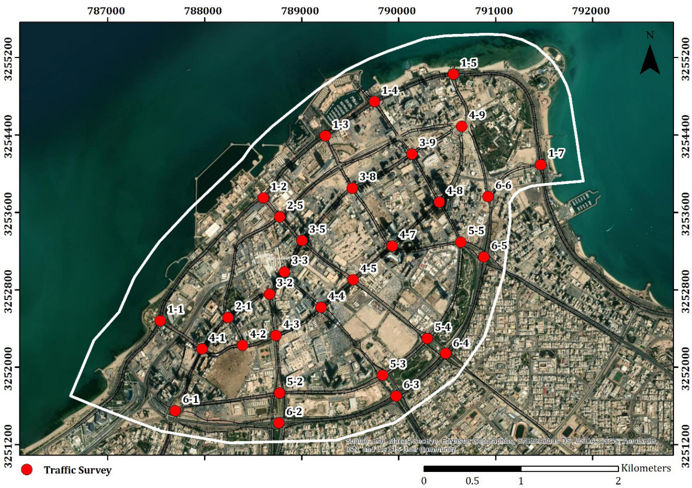
1- The surrounding buildings are acoustically impermeable.

2- All roads are made of dense-grade asphalt.

3- Background noise in the city was neglected.

Figure 2

Traffic survey locations in Kuwait City



Geographic Information System (GIS) was utilized to transfer the results of the model as shapefiles to produce noise maps for Kuwait City, with a10-m spatial resolution, The Universal Transverse Mercator (UTM) is used in GIS (ArcMap) software to assign coordinates to each layer. The layers data include: traffic survey locations as point layers, building locations as polygon layer, noise monitoring locations as point layer, and road survey locations as polyline layer. All the layers are created in GIS software (ArcMap) with WGS 84 / UTM zone 38N coordinate system. The output data created in Soundplan software consisted of three layers, during daytime (7:00 to 2:00 pm), evening (2:00 to 10:00 pm), and nighttime (10:00 pm to 7:00 am) periods, which are exported as polygon layers to ArcMap. Each polygon consists of spatial references with definite value in the attribute Table.

To construct the noise maps, the following three main components were prepared:

1. A digital elevation model (DEM) with real coordinates (UTM system) using Google Earth (a background bitmap), topographic variations ranged from 3 to 20 m.

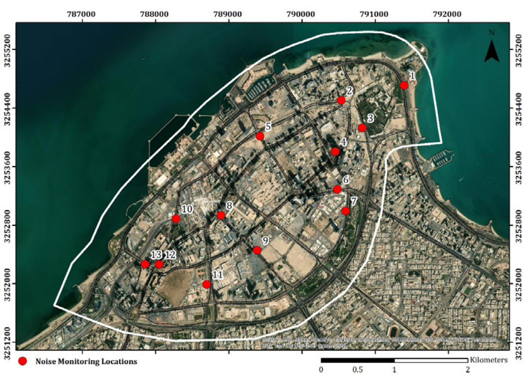
2. Obstacles that could impact on sound absorption coefficient such as buildings. Usage, height, number of inhabitants/floors for each building were specified separately in the software, building heights ranged from 3 to 246 m.
3. Roads widths (3.75 m, in average).

Other input data on the base map included the following:

1. Traffic load and speed.
2. Road slope; all roads are specified as flat and asphalt surfaces (porous surface) in the software.

For model validation, the Casella CEL - 490 Sound Level Meter (SLM) was used for noise measurements at 13 locations in the study area (Figure 3). The locations were selected to measure traffic noise away from any other noise source like people, machines or working area. Post and pre-calibration were performed for the SLM for each measurement done at a height of 1.5 m form the ground, with a distance of at least 1.5 m from the traffic noise source. The SLM's microphone was equipped with full environmental protection measures to mitigate the effects of adverse weather conditions. Measurement samples, recorded every 15 seconds, were obtained for a period of 24 hours at each location, then averaged values for three periods of a day (daytime, evening and nighttime) were determined to compare them with predicted values by the model.

Figure 3
Locations of noise measurements in Kuwait City.



Results and Discussion

Spatial Distribution of Noise Levels

The spatial distributions of traffic noise levels, in Kuwait City, during the daytime, evening and nighttime on weekdays and weekend days are illustrated in the output maps presented in Figures 4 and 5. Spatially, the maps show that the maximum exposure to traffic noise is found along the main roads where congestion and intense traffic flow occur. The spatial patterns for noise levels on weekends and weekdays are generally similar because of the similarity in the traffic flow direction of the vehicles. Notably, vehicles mainly flow in and out of Kuwait City on weekend days for entertainment and shopping purposes and on weekdays for work and business purposes.

The highest and lowest average levels of traffic noise predicted during the three time periods on both weekdays and weekend days are presented in Table 3. Table 3 indicates that average noise level on weekdays during the daytime, evening and nighttime is 2 dBA higher than that on weekend days, especially at road intersections due to slow vehicle movement. This difference is mainly due to the higher volume of the traffic flow on weekdays than on weekends. The average traffic noise levels predicted during the daytime on weekdays and weekend days are higher than those in the evening and nighttime by 1 and 10 dBA, respectively. This difference is largely due to the lower traffic volume at night compared to those in the evening and morning.

Figure 4
Noise map of road traffic on weekdays in Kuwait City

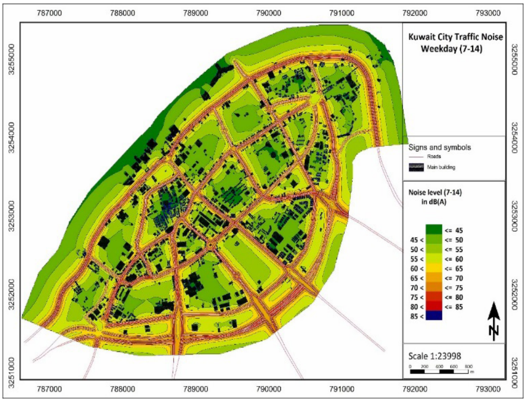
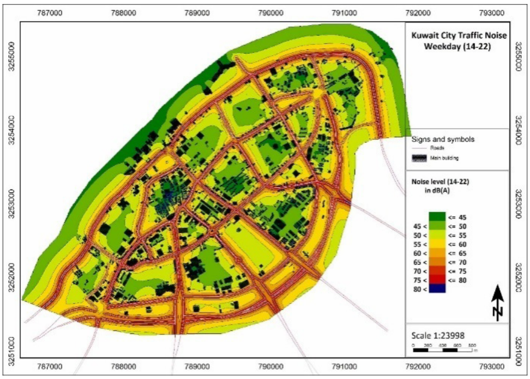
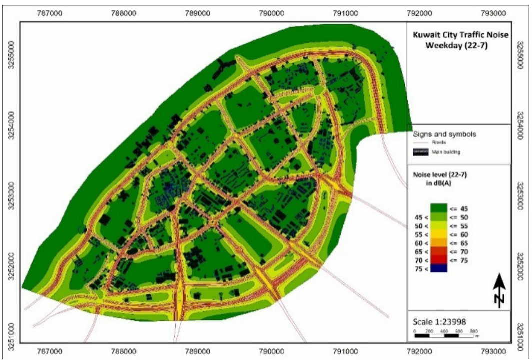
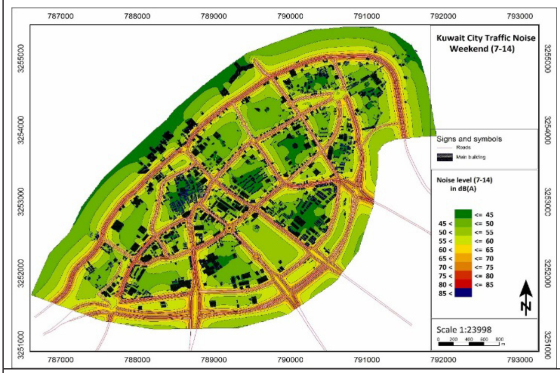
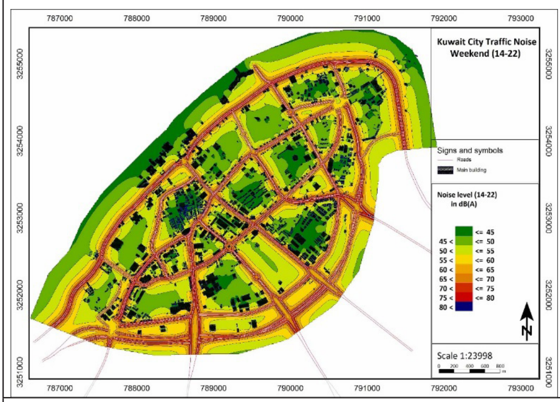
	**Daytime (7 am-2 pm)**
	**Evening (2-10 pm)**
	**Nighttime (10 pm-7 am)**

Figure 5

Noise map of road traffic on weekends in Kuwait City



Daytime (7 am-2 pm)



Evening (2-10 pm)

Nighttime (10 pm-7 am)

Table 3
Model noise level outputs (dBA) for three daily periods on weekends and weekdays, in Kuwait City during October, 2016

Noise period	Daytime (7 am-2 pm)			Evening (2-10 pm)			Nighttime (10 pm-7 am)		
	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.
Weekdays	88.0	58.0	30.0	87.0	57.0	29.0	78.0	48.0	20.0
Weekend	87.0	56.0	29.0	86.0	55.0	28.0	77.0	46.0	19.0

The GIS tool was used to calculate the percentage of the area covered by several ranges of noise levels in Kuwait City. Based on these ranges, Table 4 presents the percentage of each range of noise level during the daytime, evening and nighttime on weekdays and weekends. Table 4 indicates that the surface coverage of the traffic noise exposure of less than or equal to 55 dBA in Kuwait City averages 64.5 and 67.1% on weekdays and weekends, respectively. Additionally, a higher range from 56 to 70 dBA covers 27.1 and 26.4% of the total study area on weekdays and weekends, respectively, and the highest noise level (above 70 dBA) was observed for a relatively small coverage area (8.3%). At night, the traffic noise exposure of less than or equal to 55 dBA in Kuwait City constitutes 72.3% of the total surface coverage on weekdays and 73.0% on weekends, and the highest traffic noise level above 70 dBA accounts for an insignificant portion of the total area (less than 0.03%). These findings coincide with the limited traffic during nighttime compared to that during the day and evening.

Table 4
Percentage of the study area influenced by each noise level (dBA) percentage for three-day periods on weekdays and weekend days in Kuwait City

Daytime (7 am-2 pm)			Evening (2-10 pm)			Nighttime (10 pm-7 am)		
Noise (dBA)	Area (%)		Noise (dBA)	Area (%)		Noise (dBA)	Area (%)	
	Weekday	Weekend		Weekday	Weekend		Weekday	Weekend
<45	21.6	24.5	<45	22.7	25.4	<45	34.9	35.1
45-50	23.6	24.9	45-50	23.7	24.8	45-50	22.0	22.0
50-55	19.3	17.7	50-55	18.9	17.4	50-55	15.4	15.9
55-60	11.9	11.2	55-60	11.7	11.0	55-60	11.9	13.3
60-65	8.5	8.2	60-65	8.4	8.2	60-65	12.4	11.9
65-70	6.7	7.0	65-70	6.7	7.2	65-70	3.4	1.8
70-75	6.9	5.8	70-75	6.8	5.5	>75	0.03	0.01
75-80	1.4	0.6	>80	1.1	0.5			
>85	0.01	0.00						

Comparison of Predicted Noise Levels and Regulation Standards

Noise standards in Kuwait were established as part of Law 21/1995 and amended in Law 16/1996, and later by the Environmental Protection Law No. 42 of 2014. The established KEPA standards are presented in Table 5. The KEPA standards for ambient noise clearly adopt a restricted noise standard limit for evening time (55 dBA). Ambient noise levels exceeding the standard (Table 5 under the Urban Residential with Commercial section) during nighttime on weekdays and weekends constitute 27.7 and 27% of the total coverage area of Kuwait City, respectively. Additionally, the noise levels exceeding the allowable limit during the evening (60 dBA) cover 27.7 and 27.0% of the total surface area on weekdays and weekends, respectively, and during the daytime (65 dBA), the exceedance was less, at 15.0 and 13.4% of the total surface area on weekdays and weekends, respectively. The produced noise maps for Kuwait City can clearly indicate that most of significant noise violations occur in areas adjacent to the roads and around commercial areas. In the residential areas, the high noise levels occurred at approximate distance of 10 to 50m.

Table 5
Kuwait Environmental Public Authority (KEPA) ambient noise standards

Land use classification	Applicable standard Leq(A) (dBA)		
	Day 7:00 am-2:00 pm	Evening 2:00 to 10:00pm	Night 10:00 pm to 7:00 am
Maximum limits allowed in external environments			
Residential – villas & suburbs	50-55	50-55	40-50
Residential – urban	55-62	50-60	50-55
Urban residential with commercial	60-65	55-60	45-55
Industrial & commercial areas	70	65-70	60-65

Model Validation

For validation purpose, the field measurements of noise at the pre-selected locations (Figure 3) were compared with the model calculations during daytime, evening and night time periods. The results of the compression are shown in Table 6. The results demonstrate that, in general, measured and predicted values are almost in agreement; the average calculated values are slightly under predicted comparing with the averages field measured values at all locations by 1.3 and 1.0 dBA on weekdays and weekends, respectively. This finding was expected simply because the background noise in the study area was neglected in the calculation model. Moreover, the average percentage differences between measured and predicted values are remarkably small, i.e., 1.9 and 1.5% on weekdays and weekends, respectively. Such differences are related to the influence of volume traffic variation during different periods of a daytime and on weekdays and weekends as well as to weather conditions, building heights, roads status, obstacles such as trees, and signs. Generally speaking, the slight differences between the calculated and predicted noise confirms the fact that Kuwait City is exposed mainly to traffic noise more than other forms of noise.

Table 6
Noise level (dBA) predictions and measurements at 13 locations on week-ends and weekdays in Kuwait City, during October, 2016

Location	Period	Prediction		Measurement		Difference error		Error%	
		Week days	Week end	Week days	Week end	Week days	Week End	Week days	Week End
1	7 am-2 pm	70.3	69.2	68	65.4	2.3	3.8	3.4	5.8
	2–10 pm	69.9	68.8	67.1	63.9	2.8	4.9	4.2	7.7
	10 pm– 7 am	60.8	59.8	64.9	60.2	-4.1	-0.4	-6.3	-0.7
2	7 am-2 pm	68.6	66.4	65.3	62.6	3.3	3.8	5.1	6.1
	2–10 pm	68.2	66	65	65.6	3.2	0.4	4.9	0.6
	10 pm– 7 am	59.1	56.9	64.1	60.5	-5	-3.6	-7.8	-6.0
3	7 am-2 pm	71.5	69.8	73.1	69.6	-1.6	0.2	-2.2	0.3
	2–10 pm	71.1	69.4	72.5	72.4	-1.4	-3	-1.9	-4.1
	10 pm– 7 am	62.1	60.3	68.6	65.1	-6.5	-4.8	-9.5	-7.4
4	7 am-2 pm	64.7	64.5	65	62.6	-0.3	1.9	-0.5	3.0
	2–10 pm	64.3	64.1	63.4	61.4	0.9	2.7	1.4	4.4
	10 pm– 7 am	55.2	55.1	62.9	59.8	-7.7	-4.7	-12.2	-7.9
5	7 am-2 pm	68.16	64.2	68.1	62.3	0.06	1.9	0.1	3.0
	2–10 pm	67.8	63.8	66.7	65.4	1.1	-1.6	1.6	-2.4
	10 pm– 7 am	60.7	58.1	63	60	-2.3	-1.9	-3.7	-3.2
6	7 am-2 pm	73.7	72.3	74.4	72.4	-0.7	-0.1	-0.9	-0.1
	2–10 pm	73.3	72.2	73.7	73.5	-0.4	-1.3	-0.5	-1.8
	10 pm– 7 am	64.2	63.1	71.5	64.4	-7.3	-1.3	-10.2	-2.0
7	7 am-2 pm	68.8	65.5	66.6	62.5	2.2	3	3.3	4.8
	2–10 pm	68.4	65.2	68.1	67.1	0.3	-1.9	0.4	-2.8
	10 pm– 7 am	59.3	56.2	55.1	58.7	4.2	-2.5	7.6	-4.3
8	7 am-2 pm	64.13	63.8	64.2	65.5	-0.07	-1.7	-0.1	-2.6
	2–10 pm	63.77	63.4	63.7	65.7	0.07	-2.3	0.1	-3.5
	10 pm– 7 am	54.68	53.3	64.3	62.7	-9.62	-9.4	-15.0	-15.0

Cont. Table 6

Noise level (dBA) predictions and measurements at 13 locations on weekends and weekdays in Kuwait City, during October, 2016

Location	Period	Prediction		Measurement		Difference error		Error%	
		Week days	Week end	Week days	Week end	Week days	Week End	Week days	Week End
9	7 am-2 pm	73.2	70.5	71.7	68.1	1.5	2.4	2.1	3.5
	2–10 pm	72.9	70.2	68	70.5	4.9	-0.3	7.2	-0.4
	10 pm– 7 am	63.8	61.1	65.6	63.6	-1.8	-2.5	-2.7	-3.9
10	7 am-2 pm	69.2	67.4	66.9	66.2	2.3	1.2	3.4	1.8
	2–10 pm	68.9	67.1	68.3	66.3	0.6	0.8	0.9	1.2
	10 pm– 7 am	59.7	57.8	63.5	65.1	-3.8	-7.3	-6.0	-11.2
11	7 am-2 pm	64.8	64.3	65.6	65.2	-0.8	-0.9	-1.2	-1.4
	2–10 pm	64.4	63.9	67.3	66.7	-2.9	-2.8	-4.3	-4.2
	10 pm– 7 am	55.7	54.8	63.3	62.6	-7.6	-7.8	-12.0	-12.5
12	7 am-2 pm	72.1	71.8	75.9	72	-3.8	-0.2	-5.0	-0.3
	2–10 pm	71.7	71.4	73.3	72.8	-1.6	-1.4	-2.2	-1.9
	10 pm– 7 am	62.7	62.3	71.1	71.6	-8.4	-9.3	-11.8	-13.0
13	7 am-2 pm	68.4	67.6	68.3	64.6	0.1	3	0.1	4.6
	2–10 pm	68.04	67.2	67.4	65.1	0.64	2.1	0.9	3.2
	10 pm– 7 am	58.9	58.1	60.7	55.1	-1.8	3	-3.0	5.4
Average (dBA)		65.8	64.3	67.1	65.3	-1.3	-1.0	-1.9%	-1.5%

Conclusions

Reliable maps illustrating the traffic noise levels were produced for Kuwait City using *SoundPLAN* 7.1 software. The outputs efficiency of the model was validated using noise measurement in the field. The produced traffic noise maps can assess the efficiency of any future strategies for improving noise control. In summary, the following conclusions can be drawn from this study:

1. The traffic noise level in Kuwait City exceeds the KEPA national standard limits during all periods of a day on both weekdays and weekends. The results demonstrate that government noise regulations (55-65 dBA) are violated in up to 27.7% of the total area of Kuwait city; i.e., mostly in commercial areas than residential areas.
2. As a recommendation to achieve sustainable transport and reduce noise pollution, shifting the travel mode away from private automobiles to public transit systems is required.
3. It is mostly possible to reduce the noise level by imposing new land use regulations in Kuwait City, or use more noise isolation materials.

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Compl iance with Ethical Standards

- Conflict of Interest: The authors declare that they have no conflict of interest.
- Informed Consent: Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

REFERENCES

Abo-Qudais, S., & Alhiary, A. (2007). Statistical Models for Traffic Noise at Signalized Intersections. *Building and Environment*, *42*(8), 2939–2948.

Al-Awadhi, J. M. (2014). Noise Levels in Kuwait City. *Journal of the Gulf and Arabian Peninsula Studies*, *40* (154), 17–28.

Al-Awadhi, J. M & AlKandary, D. S. 2017. Mapping and validation of noise level in Kuwait City. *Transactions on Science and Technology*, *4*(1), 38 – 47.

Al-Mutairi, N. Z., Al-Attar, M. A., & Al-Rukaibi, F. S. (2011). Traffic-Generated Noise Pollution: Exposure of Road Users and Populations in Metropolitan Kuwait. *Environmental Monitoring and Assessment*, *183*(1), 65–75.

Babisch, W., Beule, B., Schust, M., Kersten, N., & Ising, H. (2005). Traffic Noise and Risk of Myocardial Infarction. *Epidemiology*, *16*(1), 33–40.

Cammarata, G., Cavalieri, S., & Fichera, A. (1995). A Neural Network Architecture for Noise Prediction. *Neural Networks*, *8*(6), 963–973.

Can, A., Leclercq, L., Lelong, J., & Defrance, J. (2009). Accounting for Traffic Dynamics Improves Noise Assessment: Experimental Evidence. *Applied Acoustics*, *70*(6), 821–829.

Carter, N. L. (1996). Transportation Noise, Sleep, and Possible After-Effects. *Environment International*, *22*(1), 105–116.

Chevallier, E., Leclercq, L., Lelong, J., & Chatagnon, R. (2009). Dynamic Noise Modeling at Roundabouts. *Applied Acoustics*, *70*(5), 761–770.

De Coensel, B., De Muer, T., Yperman, I., & Botteldooren, D. (2005). The Influence of Traffic Flow Dynamics on Urban Soundscapes. *Applied Acoustics*, *66*(2), 175–194.

Fields, J. M. (1998). Reactions to Environmental Noise in an Ambient Noise Context in Residential Areas. *The Journal of the Acoustical Society of America*, *104*(4), 2245–2260.

Gündoğdu, Ö., Gökdağ, M., & Yüksel, F. (2005). A Traffic Noise Prediction Method Based on Vehicle Composition Using Genetic Algorithms. *Applied Acoustics*, *66*(7), 799–809.

Kuwait Environment Public Authority [KEPA] (2017). Standards for Noise Exposure limits in different environments, Decision 5/2017. https://epa.org.kw/Portals/0/PDF/qarar5-2017.pdf.

Michaud, D. S., Keith, S. E., & McMurchy, D. (2005). Noise Annoyance in Canada. *Noise Health*, *7*(27), 39–47.

Murphy, E., King, E. A., & Rice, H. J. (2009). Estimating Human Exposure to Transport Noise in Central Dublin, Ireland. *Environment International*, *35*(2), 298–302.

Muzet, A. (2007). Environmental Noise, Sleep and Health. *Sleep Medicine Reviews*, *11*(2), 135–142.

Seong, J. C., Park, T. H., Ko, J. H., Chang, S. I., Kim, M., Holt, J. B., Mehdi M. R. (2011). Modeling of Road Traffic Noise and Estimated Human Exposure in Fulton County, Georgia, USA. *Environment International*, *37*(8), 1336–1341.

Sopasakis, A. (2004). Stochastic Noise Approach to Traffic Flow Modeling. *Physica A: Statistical Mechanics and its Applications*, *342*(3), 741–754.

Steele, C. (2001). A Critical Review of Some Traffic Noise Prediction Models. *Applied Acoustics*, *62*(3), 271–287.

Vlachokostas, C., Achillas, C., Michailidou, A. V., & Moussiopoulos, N. (2012). Measuring Combined Exposure to Environmental Pressures in Urban Areas: An Air Quality and Noise Pollution Assessment Approach. *Environment International*, *39*(1), 8–18.

Yamaguchi, S., Kamaguchi, M., Saeki, T., & Kato, Y. (1998). A Practical Probability Expression for Road Traffic Noise Level Around Traffic Signals. *AcoustLett*, *21*(7), 136–143.

Appendix A

Traffic Survey Counts in Kuwait City during October, 2106

Location		Weekdays			Weekend		
		7 am -2 pm	2-10 pm	10 pm-7am	7 am -2 pm	2-10 pm	10 pm-7am
1-1	A	3262	2432	445	1617	2323	635
	C	2022	1322	169	712	1318	178
1-2	A	2600	2084	403	1437	2108	493
	B	1569	1205	154	892	1150	160
1-3	A	3074	2203	384	1258	2104	612
	B	316	170	22	93	41	17
1-4	A	3014	2072	383	1092	2013	642
	D	347	420	98	281	480	193
1-5	B	2289	1148	287	654	1370	448
1-7	A	1776	1652	214	712	1462	381
	C	2549	1270	332	691	1644	521
3-1	A	1068	855	94	490	702	83
	B	1444	1236	194	901	1140	171
3-2	A	1746	1541	236	1016	1348	232
3-3	A	2039	1562	243	959	1278	225

Cont. Appendix A

Traffic Survey Counts in Kuwait City during October, 2106

Location		Weekdays			Weekend		
		7 am -2 pm	2-10 pm	10 pm-7am	7 am -2 pm	2-10 pm	10 pm-7am
3-5	A	1628	1117	181	739	822	152
	D	1646	1235	155	749	1014	148
3-8	A	1344	1084	179	652	823	154
	D	887	562	102	339	386	144
3-9	D	1163	866	145	514	781	151
4-1	A	1861	1704	217	1985	1879	232
	B	1610	1313	187	1501	1347	181
	D	825	671	85	927	782	82
4-2	A	1583	1111	120	585	845	130
	B	1594	1075	145	749	914	119
4-3	A	1514	1381	172	860	1209	159
	B	1348	1069	104	783	1060	143
4-4	A	1735	1282	165	728	1058	131
	B	926	950	172	755	637	150
	D	1174	1125	116	660	939	106

Cont. Appendix A

Traffic Survey Counts in Kuwait City during October, 2106

Location		Weekdays			Weekend		
		7 am -2 pm	2-10 pm	10 pm-7am	7 am -2 pm	2-10 pm	10 pm-7am
4-5	A	1970	1502	190	820	1185	187
	D	1839	1604	212	993	1354	213
4-7	A	1066	945	110	490	754	108
	D	1769	1431	217	795	1023	190
4-8	A	763	565	99	441	596	130
	D	953	845	125	478	695	136
4-9	A	1128	859	176	480	819	248
	D	1705	1411	213	695	1031	185
	E	785	574	110	364	397	100
5-2	A	3125	2584	362	1895	2400	400
	B	744	428	88	328	355	94
5-3	A	1453	942	99	503	727	70
	D	1442	1030	123	475	780	128
5-4	A	747	567	39	271	396	41
	D	2033	1562	164	854	1231	154

Cont. Appendix A

Traffic Survey Counts in Kuwait City during October, 2106

Location		Weekdays			Weekend		
		7 am -2 pm	2-10 pm	10 pm-7am	7 am -2 pm	2-10 pm	10 pm-7am
5-5	A	1699	1526	228	820	1215	243
	D	2053	1981	303	1266	1649	282
6-1	A	2537	2451	336	2557	2209	316
	B	1217	1009	95	811	928	80
	C	1284	941	235	994	798	186
	D	1484	1451	283	866	1186	218
	F	145	140	16	120	117	15
6-2	A	3170	2751	427	2089	2201	440
	B	1654	1172	147	801	819	113
	C	3252	2081	363	1260	1703	205
6-3	A	1626	1499	260	698	1158	200
	B	2845	1702	439	1634	1778	337
	D	3842	2465	370	1552	2049	267
6-4	A	1192	1029	150	510	1053	149
	B	1334	783	109	433	605	83
	D	1951	1574	153	892	1220	142

Cont. Appendix A

Traffic Survey Counts in Kuwait City during October, 2106

Location		Weekdays			Weekend		
		7 am -2 pm	2-10 pm	10 pm-7am	7 am -2 pm	2-10 pm	10 pm-7am
6-5	A	2422	2027	404	1121	1931	345
	B	3333	2598	638	1949	2811	543
	D	3285	3268	491	1972	3017	509
6-6	A	2984	2725	526	1420	2118	456
	B	401	412	79	170	453	120
	D	87	96	14	47	75	17

إعداد خريطة الضوضاء الناتجة عن الحركة المرورية بمدينة الكويت*

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ملخص

الأهداف: هدف هذا البحث هو (1) التنبؤ بمستوى الضجيج في مدينة الكويت باستخدام تطبيق SoundPLAN 7.1، (2) إعداد خريطة الضوضاء الناتجة عن الحركة المرورية بمدينة الكويت لتقييم التعرض لمستويات الضجيج الناتجة عن هذه الحركة في الفترات: الصباحية، المسائية وساعات الليل خلال أيام الأسبوع وأيام نهاية الأسبوع.

المنهج: تم استخدام البرمجية SoundPLAN 7.1 ونظم المعلومات الجغرافية (GIS) ومعلومات حركة السير لإنتاج خرائط الضوضاء. شملت البيانات المستخدمة في نمذجة مستويات الضجيج: خريطة تضاريسية، وتصميم الطريق، ونوعية الإسفلت المستخدم في الطرق، والمباني ثلاثية الأبعاد، وحجم الحركة المرورية في الطرق، بالإضافة إلى بيانات الأرصاد الجوية، وللتأكد من صحة نتائج النمذجة، تم أخذ قياسات أرضية لمدة 24 ساعة لمستويات الضوضاء عن طريق استخدام جهاز Casella CEL - 490 Sound Level Meter (SLM) لـ 13 موقعاً موزعة في مدينة الكويت.

النتائج: بمقارنة القياسات الميدانية (أكتوبر 2016) مع قياسات النمذجة للمواقع نفسها تبين أن القيم اختلفت بفارق 1.9%. تبين استنتاجات الدراسة أن متوسط مستويات الضجيج (65.1 ديسبل للقياسات الميدانية و 66.2 ديسبل لقياسات النمذجة) قد تجاوزت المعايير الدولية والمحلية التابعة للهيئة العامة للبيئة في دولة الكويت، وهي 65 ديسيبل، وتندرج أسفل قائمة الحركة المرورية للمناطق الحضرية السكنية والتجارية وبمساحة تغطية 27.7% من مساحة مدينة الكويت. أوضحت خريطة الضوضاء الناتجة عن الحركة المرورية وجود تشابه بنمط توزيع مستويات الضجيج خلال أيام الأسبوع وأيام نهاية الأسبوع؛ نظراً لثبات حركة سير المركبات واتجاهها.

الخاتمة: مستويات الضجيج الناتجة عن حركة المرور تجاوزت المعايير المحلية التابعة للهيئة العامة للبيئة في دولة الكويت في جميع فترات اليوم سواء خلال أيام الأسبوع أو أيام نهاية الأسبوع.

الكلمات المفتاحية: حركة مرور، ضوضاء، تطبيق SoundPLAN 7.1، GIS، الكويت.

* هذا العمل مدعوم من قبل منحة جامعة الكويت البحثية رقم [SE02 / 15].
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