Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 4, No. 11, November, 2018

Development of Traffic Noise Prediction Model in an Educational Urban Area

Hasan Mosa Al-Mosawe [a*], Dhirgham Alobaydi [b], Amjad Albayati [c]

[a] *University Lecturer, Civil Engineering Department, Al-Nahrain University, Baghdad, Iraq.*

[b] *University Lecturer, Department of Architectural Engineering, University of Baghdad, Baghdad, Iraq.*

[c] *Assistant Professor, Civil Engineering Department, University of Baghdad, Baghdad, Iraq.*

Received 15 August 2018; Accepted 16 October 2018

Abstract

This paper studies the problem of noise pollution on the roads of the campus of University of Baghdad in Baghdad, Iraq. Due to the continuous redevelopment process conducted on the masterplan of the university, the noise levels have significantly impacted the education environment. The purpose of this paper was thus to study the sources caused and maximized the noise levels at the campus and also formulate a prediction model, identified the guidelines used for designing or developing future campus masterplans. Then, the noise levels were measured based on three variables: skid number, vehicle speed, and distance from the classrooms at seven selected points of the main ring road surrounding the university campus. Finally, the finding has shown that the classrooms' locations of the new urban additions, built in the last two decades, were laid out in the prohibited distance of road-traffic noise. In addition to that, it has confirmed that students studying in these classrooms are exposed to noise levels beyond the legislative norms and codes. Further, studying the alternatives used to improve the performance of the education environment in the existing campus of University of Baghdad can be considered in the future research directions.

Keywords: Traffic Noise; Noise Pollution; University of Baghdad; Campus; Urban Area.

1. Introduction

Nowadays, all Iraqi university campuses are located close to the car and bus routes and continuously suffered from road-traffic noise levels, mainly in the recent years. Some of university buildings were defined by the boundaries of street layouts, while the others laid out based on standard distances found in the masterplans. The majority of these masterplans was adopted from Western design codes and norms driven from the European and American campuses such as the University of Baghdad (UB) [1, 2]. Then, the masterplans of university campuses were evolved and developed by local architectural groups (consultants and practitioners) authorized by Iraqi government institutions.

One of the most important periods in the evolution of university campuses' masterplans was when the democracy arrived, after 2003 when the funds were available, embraced some democratic ideals that wanted to express sentiments of freedom and openness of mind through the development of the built form of universities. With the unprecedented expansion of university campus in UB, the main focus of campus leaders was towards individual buildings rather than master plans, which underwent to standards. Urban developments at the education zone – i.e. areas inside the main ring road – of the masterplan increase the activities and traffic. So, instead of expanding outwardly of the main ring road or including adjacent lands, the new additions were occurred inwardly. As a result of that the education zone has become much denser and noisy. The density was happened by turning open spaces (green and public areas) into new building

* Corresponding author: hasan.al-mosawe@eng.nahrainuniv.edu.iq

http://dx.doi.org/10.28991/cej-03091183

extensions in order to accommodate the increased capacity. This will lead to increase the noise pollution problems. Some of them can be cited:

- Increase in the number of classrooms, notably new additional buildings inside the education zone;
- Increase in movement, notably student densities nearby the main entrances of colleges;
- Increase in the number of vehicles circulating in the main ring road and parking lots.

Hence, the increase in the classroom halls, in the number of student densities, and in the number of circulating vehicles have led to an increase in the road-traffic noise levels of campus that impacted the education environment.

In this regard, there is an essential literature focused on studying the noise pollution (sources, influences, and implications) in relation to the urban setting motivated many studies to address this problem in several countries. First, studies are included, but not limited to, influences of the road traffic noise emitted by vehicles insides the urban confines. Sommerhoff et al. (2004) [3] measured and assessed the noise pollution at different times of the year in the City of Valdivia, Chile and used day-evening-night level to describe long-term annoyance. Authors have concluded that the noise pollution is highly widespread in the streets due to the lack of using mitigated techniques and guidelines that should apply in the process of design and implementation to protect the health of citizens. In addition, Noise levels at five main streets of Thessaloniki, Greece were measured and described by Georgiadou et al. (2004) [4] at different times: ten minutes, one hour, and daily average. They found that the traffic noise levels were significant and causing the noise problems in all examined streets. Piccolo et al. (2005) [5] have examined the environmental noise pollution in 35 sites of Messina, Italy. Finding has shown that even in such medium size city like Messina, environment noise levels due to road traffic are higher than the limits set by Italian noise standards and policy.

Second, studies that addressed the impacts of noise levels on the educational environment (the university campuses and classrooms) are attracted researchers. Otutu (2011) [6] measured the noise pollution at 22 locations in the campus of Delta State University, Abraka, Nigeria during and after working hours (8:00 am and 4:30 pm); the author found that the major source of noise came from the indiscriminate use of power plants to generate electricity and this is due to the constant power failures at the campus. In an educational environment, Zannin and Marcon (2007) [7] studied the measurements of background noise, reverberation time, and sound insulation and interviewed 62 teachers and 464 pupils to evaluate the acoustic comfort of the classrooms. Finding has shown that all interviewees considered the noise generated and the voice of the teachers in the neighboring classrooms as the main sources of annoyance inside the classroom.

Then, studies that showed the influences of physical properties of urban form and landscape elements – including buildings' forms, green areas, street configurations, and construction density – in producing the noise levels are focused. Guedes et al. (2011) [8] addressed the influence of urban shapes on the environmental noise and adopted acoustic simulations, using Sound PLAN software in the analysis, to examine the City of Aracaju, Brazil. Authors have found that physical characteristics of urban shapes, including construction density, the existence open spaces, and the shape and position of building forms exert a significant influence on the environmental noise.

Finally, the role of human activities including work, gather, and leisure in influencing traffic noise at urban settings. The study of Meng and Kang (2016) [9], used the site of Harbin, China as a case study to examine the noise levels, has shown how ignoring the effects of sound related to human activities and behavior can impact the acoustic comfort. In addition to that there are studies that adopted case study approaches have conducted in similar regional environments to the case of Baghdad City. Al-Ghonamy (2009) [10] conducted a study in a city in the Kingdom of Saudi Arabia, the research evaluated the traffic noise pollution at four major roads in the city. Findings showed that the noise level at the city is higher than the required levels by the standards at all the periods in the day. Jamrah et al. (2006) [11] also evaluated the traffic noise in the city of Amman at 28 locations and considered several variables affecting the noise which are: traffic volume, speed, percentage of heavy vehicles, road surface, gradient, obstructions, distance, noise path, intervening ground, effect of shielding, and angle of view. They developed a Calculation of Road Traffic Noise model (CRTN), and it was successful in prediction most of the locations selected for their study. Salameh and Imam (2014) [12] developed models to predict noise level in the city of Amman. They selected 20 locations in the city and they found that there are four significant factors that could affect road-traffic noise which are: traffic volume, percentage of heavy vehicle, vehicle speed, and pavement texture.

Khaki et al. (2015) [13] conducted a study to evaluate and select the appropriate pavement mixture type that results in lowest noise level and best performance. They measured the skid resistance of two types of mixtures (porous asphalt and conventional asphalt mixture) and concluded that the open graded mixtures exhibit less pavement noise than other types of mixtures. Surprisingly, they found that the increase in skid number (surface texture) would decrease the noise level; which is not completely true fact. Their investigation was based on a fixed distance from noise source 7.5 m and constant speed of vehicle 50 km/hr.

Ohiduzzaman et al. (2017) [14] introduced a testing technique to measure pavement noise on board, and they tested the accuracy and workability of the system. The Onboard Sound Intensity (OBSI) developed by them is found to be capable to measure the sound level of the pavement with good accuracy. They also found that the noise is increasing linearly with the speed of the vehicle.

Ohiduzzaman et al. (2018) [15] evaluated the pavement noise that is resulted from different types of vehicles in the state of Qatar. They used two sound level meters to measure the noise by placing them at specified locations in the study area. The study found that the heavy vehicles produces the highest sources of noise followed by buses forming a linear relationship between the speed of the vehicle and noise level.

Although the above literature has addressed various issues at different areas, studied the noise pollution, there is still enough room for enhancement and validation of the existing knowledge of this field using the case study of UB campus. This paper studied the road-traffic noise levels in the education environment of UB that witnessed important urban developments.

Many traffic noise level prediction models have been developed in European countries, the U.S., Brazil, and Japan; however, comparative work in the Middle Eastern countries is still rare. In Iraq, there is no much intention from the highway authority or planning department on the noise pollution of road traffic. The importance of this study is thus to investigate this matter and showing its consequences on the education environment by considering several variables as will be studied in this paper.

The paper was initiated by studying the noise levels around the ring road of UB campus and reviewing the relevant literature on the topic to identify the research gap. Then, the research question was defined: What are the variables that influence the noise levels at the campus of University of Baghdad? In the end, the main contribution of this paper is to develop a prediction model that provides a set of guidelines, defined the limits of prohibited zone of road-traffic noise, used for designing and developing campus areas and forming a sustainable learning environment.

This paper was included few limitations: first, analysis and measurement were restricted to the boundaries of UB campus, so other university campuses may suggest or reveal different outcomes if they have studied. Considering that many of these campuses were built inside urban blocks and surrounded by street layouts in commercial or residential areas, which varied from UB. Then, the study has not considered the green barriers (trees and shrubs) in the analysis. Finally, constriction materials, whether inside or outside classroom halls, have not accounted in the analysis.

2. Methodology

To achieve the objectives stated in this research, seven locations at the ring road of UB campus were selected to study the effect of three variables, including skid number, vehicle speed, and distance of the noise meter to the location, in influencing the noise levels.

2.1. Locations Selection

The locations were selected based on the change in surface texture, the nearby distance of classroom halls, and avoiding the presence of any speed reduction factor (such as bumps, pedestrian crossings, or bus stations), (Figure 1). Location 1 was selected to examine the new buildings, the classroom hall of the Biosciences Department, added to the education zone. It is located close to the campus ring road. Locations 2, 3, and 4 were chosen to investigate the noise levels of classroom halls of other departments in departments. These buildings were initially dedicated to be classrooms in the masterplan of UB. Location 5 was studied to assess the performance of noise levels in relation to the building of the Library of College of Engineering (LCE-UB). Locations 6 and 7 were selected because there are wide open areas around them, and they might be subjected for the new developments of UB campus in the future.

2.2. Data Measuring and Acquisition

The three variables have been examined at the selected seven locations to estimate the noise levels at each; Figure 2 shows the stages of measuring. British Pendulum test was conducted at each location to measure the skid number which is considered as one of the factors affecting the noise level.

A speed gun (Bushnell 101911) was used to measure the spot speed of vehicles passing each location. The gun was pointed in the direction of the moving vehicle, and the gun was set to measure the speed in km/hr. It sends signals to the moving objects and can capture any object moving in a speed more than 16 km/hr. Seven controlled speeds were used 30, 40, 50, 60, 70, 80, and 90 km/hr. at different distances from the sound level meter.

The third variable, the distance of the sound level meter to the location, was applied and five distances were considered in this research which are 0.5, 3, 7, 14, and 20 meters. Obviously, the closest the point to the noise source the highest the noise level measurement recorded.

Seven locations were assigned at the university campus to perform the study in, and statistical analysis was used to develop a model to estimate the noise level and to show the effectiveness of each variable on the noise pollution.

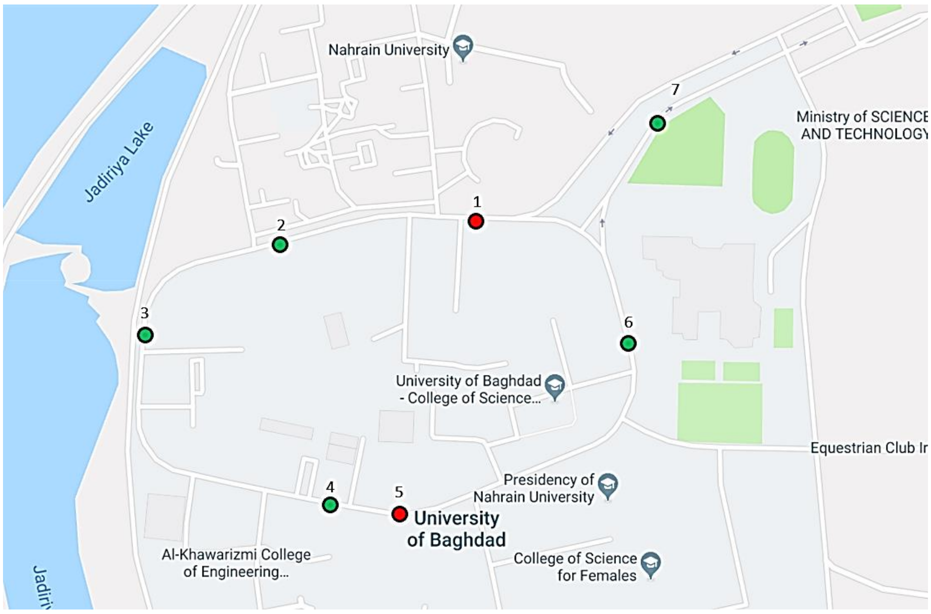

Figure 1. Locations of noise measurements at UB campus ring road

The measurements of noise levels were conducted for a time period of daytime (07:00 AM – 09:00 AM) considered as the high rush hours, according to the Environmental Noise Chapter of Iraq [16].

Figure 1. (a) British Pendulum; (b) measuring vehicle speed; (c) noise level meter

3. Results and Discussion

As the vehicle speed considered one of the main noise sources, the seven speeds were statically analysed with response to noise. The analysis has showed that the noise is very dependent on the vehicle speed. The skid number was less dependent on the noise level followed by the distance to the location, which occupied the lowest dependency. However, all the parameters were effective to the noise level. Figure 2 shows the relationship between each variable and the noise level (points in the plots represent the average value of several readings). It can be noticed that the speed is simply linearly related with noise (this is conforming to Ohiduzzaman et al (2017) [14] and Ohiduzzaman et al (2018) [15]) while the other two variables have exponential relationship. It is evident that there are other factors may also affect the noise performance due to skid resistance (such as vehicle tires) and distance (like any other mechanical objects or human activities). As the speed goes up the engine sound becomes louder and will dominate the sound level and would decrease the effect of other factors. This is the main justification of the degree of dependency to the noise.

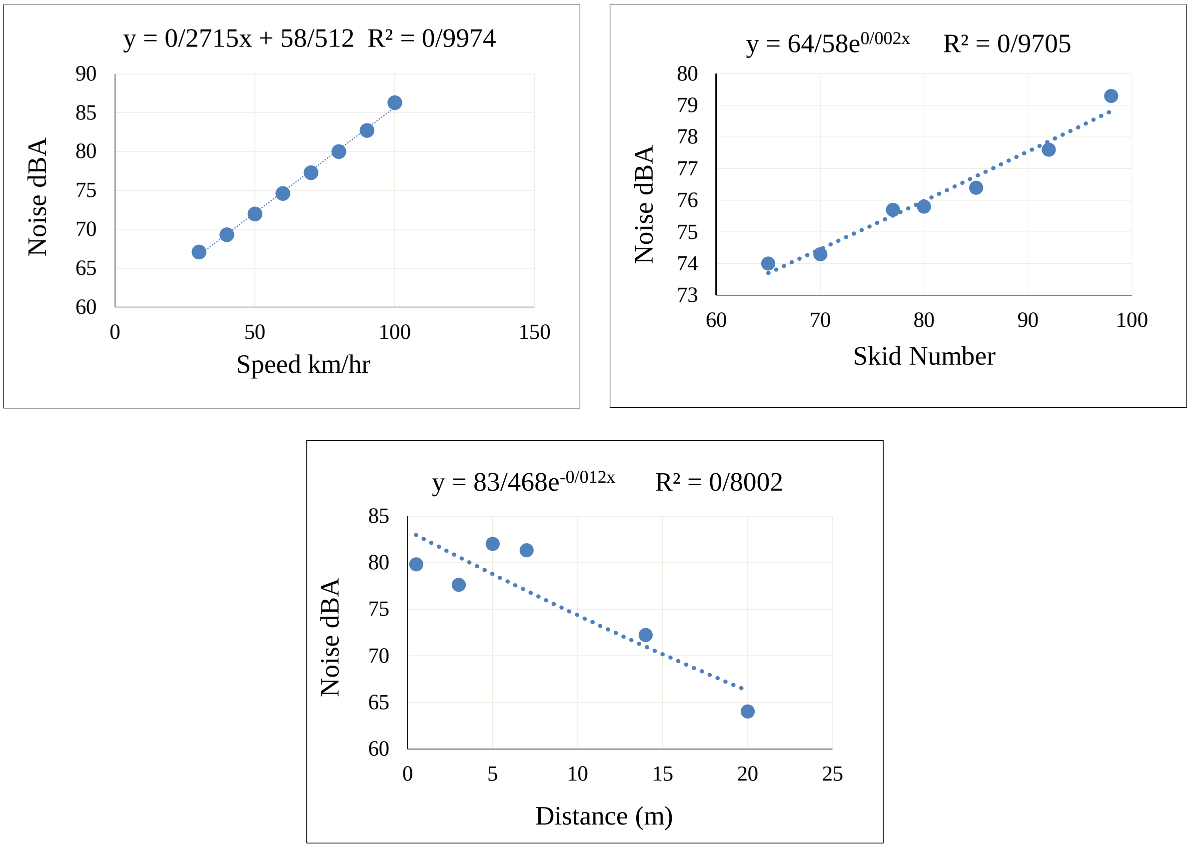

Figure 2. Relationship between each variable and the noise level

The noise level was ranged from around 50 to 90 dBA which is considered as a very high sound level. The skid number relationship to the noise level is found to be directly proportional unlike to that obtained by Khaki et al. (2015) [13]. The obtained relationship by Khaki et al. (2015) [13] is indirectly proportional to the noise at a constant speed and distance 50 km/hr and 7.5 m respectively. To further investigate this contradictory in the relationship trend, data interpretation of the skid number and speed with the noise level was thoroughly studied. The data file was sorted based on the distance, and the average skid number and average noise were calculated for each speed. The obtained results which shown graphically in Figure 4 revealed that the vibration of vehicle due to the rough surface texture, which represented by high skid number, has had an essential impact on the noise level. The high speed of vehicle incorporated with high vibration resulted in higher noise level than those for low speed and thus this result is could be considered as more reliable.

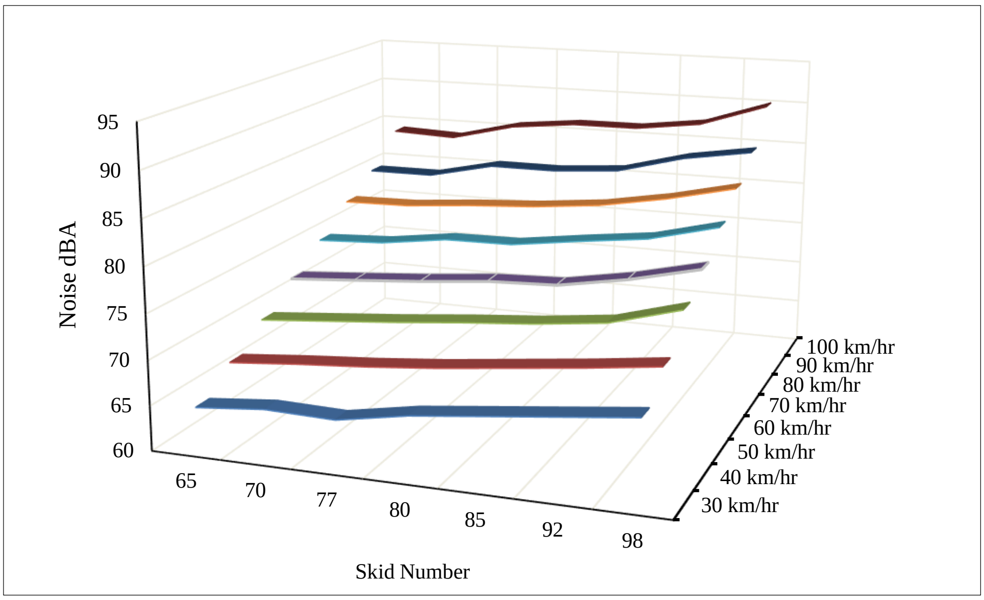

Figure 3. Relationship of Skid Number and Noise level at different Speeds

3.1. Statistical Model

As mentioned earlier in this research, a statistical model was built to accommodate these parameters and link them to the noise level. A simple linear regression was used for this matter (using Minitab 16) and resulted in the following model:

$$\text{noise dBA} = 52.1 - 0.828\ D + 0.271\ v + 0.163\ SN \tag{1}$$

Where;

D: distance to the test location SN: skid number v: vehicle speed

The model showed a reasonable prediction to the noise level as shown in Figure 4. The points are accumulated around the 1-1 line which represent a good ability of prediction.

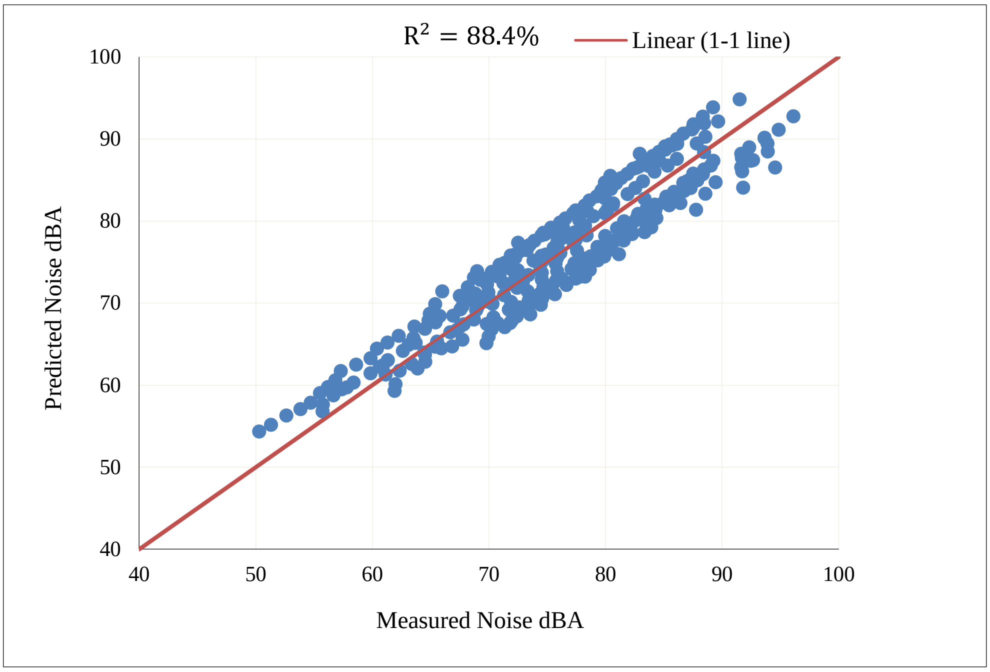

Figure 4. Prediction model results

Other statistical indicators were also plotted such as normal probability plot and residuals Figure 6.

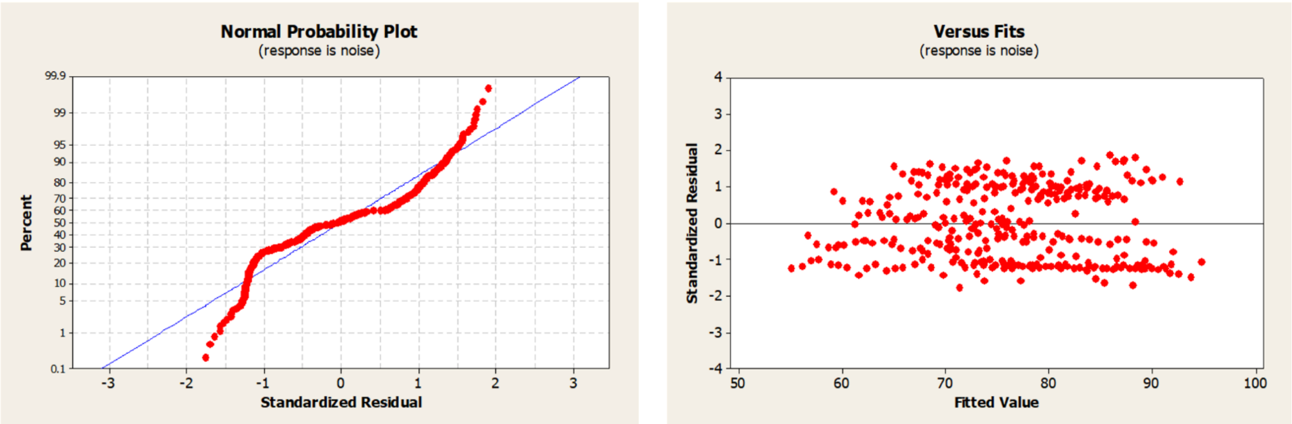

Figure 5. Statistical indicators for the model

The accepted noise level at the university classroom halls environment is limited by Eggenschwiler (2005) [17] as not more than 35 dBA to have a reasonable teaching environment. Therefore, the distance of the classroom hall to the main road, which is the main source of noise in normal conditions, should be considered. The model achieved in this research does consider estimating the noise with respect to the distance to the noise source.

Figure 1 showed the university map with the survey locations, it has been noted that the two locations pointed with red dots have a distance to the classroom halls of 35 and 30 m. This would result in slight noisy environment (50 dBA) at the classroom halls.

4. Conclusion

This paper has examined the daytime patterns of the traffic noise pollution in the education area (the campus of UB in Baghdad, Iraq) by studying the variables: skid number, vehicles speed, and distance from buildings as influential factors impacted the levels of noise at seven locations. A statistical model was developed in this paper to predict and assess the noise levels at the university classrooms considering the three variables.

It has been found that five of the examined locations (colored by green in the map) were avoided the road-traffic noise and considering the noise guideline levels that would cause serious annoyance and study disturbance. In contrast, the rest two locations (colored by red in the map) were very vulnerable to the road-traffic noise. It should be mentioned here that the two locations were developed or modified to be classroom halls by campus designers and engineers who ignored the prohibited limits of traffic noise and land use plan. Open public spaces and green areas have turned to be classroom halls and impacted the campus density. Most of the developed and modified areas were exposed to sever of road-traffic noise levels and ignoring the future extensions of the masterplan.

5. Acknowledgements

The authors would like to thank the Consulting Engineering Bureau at University of Baghdad (CEB-UB) for assistance with the field work.

6. Conflicts of Interest

The authors declare no conflict of interest.

7. References

[1] Coulson, Jonathan, Paul Roberts, and Isabelle Taylor. University planning and architecture: The search for perfection. Routledge, 2015.

[2] Dober, Richard P. Campus Planning Handbook. 1996.

[3] Sommerhoff, Jorge, Manuel Recuero, and Enrique Suárez. “Community Noise Survey of the City of Valdivia, Chile.” Applied Acoustics 65, no. 7 (July 2004): 643–656. doi:10.1016/j.apacoust.2004.01.003.

[4] Georgiadou, E., K. Kourtidis, and I. Ziomas. "Exploratory traffic noise measurements at five main streets of Thessaloniki, Greece." Global NestI International Journal 6, no. 1 (2004): 53-61.

[5] Piccolo, A., D. Plutino, and G. Cannistraro. “Evaluation and Analysis of the Environmental Noise of Messina, Italy.” Applied Acoustics 66, no. 4 (April 2005): 447–465. doi:10.1016/j.apacoust.2004.07.005.

[6] Otutu, Oseji Julius. "Investigation of environmental noise within campus 2, Delta State University, Abraka, Nigeria." IJRRAS 6, no. 2 (2011): 223-228.

[7] Zannin, Paulo Henrique Trombetta, and Carolina Reich Marcon. “Objective and Subjective Evaluation of the Acoustic Comfort in Classrooms.” Applied Ergonomics 38, no. 5 (September 2007): 675–680. doi:10.1016/j.apergo.2006.10.001.

[8] Guedes, Italo C. Montalvão, Stelamaris R. Bertoli, and Paulo H.T. Zannin. “Influence of Urban Shapes on Environmental Noise: A Case Study in Aracaju — Brazil.” Science of the Total Environment 412–413 (December 2011): 66–76. doi:10.1016/j.scitotenv.2011.10.018.

[9] Meng, Qi, and Jian Kang. “Effect of Sound-Related Activities on Human Behaviours and Acoustic Comfort in Urban Open Spaces.” Science of the Total Environment 573 (December 2016): 481–493. doi:10.1016/j.scitotenv.2016.08.130.

[10] Al-Ghonamy, Abdulaziz I. "Assessment of traffic noise pollution in Al-Khobar, a typical city in the Kingdom of Saudi Arabia." Sci. J. King Faisal Univ. (Basic Appl. Sci.) 10 (2009): 165-180.

[11] Jamrah, Ahmad, Abbas Al-Omari, and Reem Sharabi. “Evaluation of Traffic Noise Pollution in Amman, Jordan.” Environmental Monitoring and Assessment 120, no. 1–3 (June 2, 2006): 499–525. doi:10.1007/s10661-005-9077-5.

[12] Salameh, Bassam, and Rana Imam. "Developing Roadway Traffic Noise Prediction Models for the City of Amman." Journal of American Science 12 (2014): 23-30.

[13] Ali, Mansour Khaki, Esmael Forouhid Amir, Zare Mehdi, and Pirbastami Amirali. “Regression Analysis of Pavement Surfaces Textures on Noise Pollution.” Scientific Research and Essays 10, no. 9 (May 15, 2015): 313–325. doi:10.5897/sre2015.6226.

[14] Ohiduzzaman, M, O Sirin, and E Kassem. “Assessment of Tire-Pavement Noise by Using On-Board Sound Intensity (OBSI) Method in the State of Qatar.” Bearing Capacity of Roads, Railways and Airfields (June 21, 2017). doi:10.1201/9781315100333-139.

[15] Ohiduzzaman, Md, Okan Sirin, and Emad Kassem. "Evaluation of traffic noise in the State of Qatar." In Advances in Materials and Pavement Prediction: Papers from the International Conference on Advances in Materials and Pavement Performance Prediction (AM3P 2018), April 16-18, 2018, Doha, Qatar, p. 249. CRC Press, 2018.

[16] Acoustic Standards for Building Guidelines in Iraq, Ministry of Construction and Housing and Ministry of Planning, Republic of Iraq, first edition, published by alwaqf alhaditha (2013) M.B.A. 503.

[17] Eggenschwiler, Kurt. "Lecture Halls-Room Acoustics and Sound Reinforcement." In Forum Acusticum, Budapest, pp. 2059-2064. 2005.