ROAD TRAFFIC NOISE MAPPING BASED ON FIELD MEASUREMENTS IN LOCATION THAT DO NOT HAVE A STANDARDIZED MODEL IN ALGERIA

Ali Boulemaredj*, Saifi Amel**
*) Assistant professor, Department of Architecture, Badji Mokhtar Annaba, Algeria
**) Doctoral student, Department of Architecture, University of 8 Mai 1945 Guelma, Algeria
e-mail: ali.boulemaredj@gmail.com

ABSTRACT

The present study addresses the issue of noise pollution in Algeria due to road traffic and the possible preventive means and solutions for its reduction to maintain an adequate sound environment in urban areas, especially next to residential ones. The main objective of this study is to establish an initial noise map for the Champs de Manoeuvre residential estate in Guelma, a medium-sized city in Algeria, by adopting a research methodology that involves applying a quantitative investigation by carrying out field measurements during the winter and the summer season, three times for one week, from 9:00 am to 5:00 pm, using a sound level metre to measure and calculate the weighted equivalent continuous sound pressure level LAeq for 10min, the statistical level L10, the maximum sound level Lmax, the Traffic noise index TNITNI and the Noise pollution level NPL. The results obtained from the measurement campaign showed the extent of the noise levels produced by road traffic in the vicinity of the residential buildings in the studied area, emitted mainly from passing vehicles, acceleration and the irrational usage of horns, which led to an LAeq level of 74 dB at the source, thus, exceeding the 70 and 55 dB thresholds set in both of the Algerian noise regulation and the World Health Organization noise guidelines. Subsequently, the noise mapping technique can help visualize the spatiotemporal distribution of noise, identify its primary sources and black spots in urban areas, and draw up direct action plans for fighting against this issue.

Keywords: *Noise pollution, noise mapping, road traffic noise, residential estate, Guelma*

INTRODUCTION

Road networks and infrastructures influence human health, notably air pollution and noise from traffic. They are a pertinent subject in urban context reconciliation. Presently, the stark fact is that noise pollution has developed into a significant environmental issue in metropolitan areas and that there is a link built between noise and health. Repeated or prolonged noise exposure is adversely found to be lowering people's quality of life, creating a type of nuisance for them and has adverse health effects, which can build over time (Ravindran et al., 2014), (Banerjee et al., 2008), (K & Deswal, 2023), (Ahmed et al., 2023), (Rossi et al., 2023). Reducing noise pollution is a significant concern from a socio-economic and health perspective because excessive noise, greater than 65 dB, is a problem that can cause a range of physiological and psychological health complications, representing a centre of interest of many clinical studies on noise-hazardous health effects. All scholars and epidemiologists agree on the necessity of addressing the issue of fighting against noise (Bluhm & Eriksson, 2011), (Mette et al., 2013), (Pyko et al., 2023), (WHO, 2018), (J.-P. et al., 2022), (Domazetovska et al., 2020).

Many nations around the world have implemented the needful laws and regulations to tackle this problem (Agency, 2020), (Human & al Dulaimi, 2023), (K & Deswal, 2023), (Popescu et al., 2011), (Popescu, 2023), (Boulemaredj & Haridi, 2022), (Murphy & King, 2014), (Schwela, 2023). It is recommended to initially minimize noise at its source and restrict its propagation by setting into place several direct and indirect measures, as well as by raising society's awareness through educational initiatives and public opinion surveys, while the main goal of these measures is to attempt to limit the emittance of noise and mitigate its levels, to the thresholds advised for hearing comfort indoors and outdoors. Consequently, the environmental acoustics research on the sound Environment presents a complex field caused by many sound sources and influenced by numerous acoustic factors (Hornikx, 2016). Also, it is a rapidly growing discipline that requires technological developments to analyze the noise environment at the population level.

By characterizing acoustic phenomena in space and time and considering the area most likely to be impacted by noise, this technique seeks to know how to diagnose and quantify the noise and examine its effects in that area. According to (Meller et al., 2023), urban noise levels from automobile traffic have significantly grown due to the cities' rapid urbanization and the resulting rise in the number of motor vehicles. It is vital to determine the noise levels to which people are exposed to analyze noise levels in cities, put noise control measures into place, or locate the problem in various metropolitan locations. To combat this type of pollution, a scientific approach based on the idea of noise mapping was required under the European Directive on Environmental Noise (ENDEND) 2002/49/ECEC, which applies to all European member states, almost 20 years ago (King & Murphy, 2016), (J. et al., 2022), (Benliay et al., 2019), (Murphy et al., 2020). This method has been employed to avoid or lessen the harmful consequences of noise exposure, particularly those caused by road traffic. It establishes a five-year cycle for creating and submitting strategic noise maps and management plans to the European Commission. Identifying and assessing the severity of noise problems at the local, regional, and national levels, as well as providing information on traffic and urban planning, are the main goals of noise maps (Akiladevi et al., 2015) (Alam et al., 2022). As cartographic depictions of the distribution of noise levels over time and space, noise maps are instruments with practical uses. They provide managers with accurate data on the sound Environment, and they are a valuable tool for sound forecasting and also a method of monitoring the sound quality of the current Environment (Dintrans & Préndez, 2013), (de Noronha Castro Pinto & Moreno Mardones, 2009), (Nourmohammadi et al., 2021).

Since Algeria's independence, national noise regulations have addressed noise as a problem that must be considered and managed, with the primary objective of protecting public health and tranquillity outside and inside buildings. However, since 1982 and up until the most recent regulation text released in 2018 by the Health Protection Law (J.O.R.A.J.O.R.A., 2018), the issue of noise pollution control has been briefly and generally handled by laws, decrees, and orders, whether in a city setting, on private property, or at the workplace. As a result, the Algerian Constitution's declaration of the right to a healthy urban environment, which includes noise, comfort and calm, needs to reflect daily life. The primary consequence is road construction, impolite horn or radio use by motorists, motorcycles and cars with silenced or altered exhaust systems, firecracker and pyrotechnic device explosions, loudspeaker entertainment, or commercial advertising. Even at night, the noise is continual, which is against the law (Rebah, 2018), (Rebah, 2022). Presently, in Algerian metropolises that do not have a standardized model for noise mapping, the urban soundscape, particularly around residential buildings, is subject to high levels of noise nuisance, exceeding the thresholds recommended by both international laws and national regulations at 55 dB during the day and 45 dB at night. Thus, noise is one of the primary sources of public complaints. Exceeding these thresholds leads to a deterioration in the living Environment. It also undermines hearing comfort, even inside the home, which requires favourable listening conditions in relation to the outside world. Relatively speaking, residents' expectations regarding their noise environment are much higher than in the past, with most residents of communal residential housing estates prioritizing their desire to live healthily in a comfortable environment. The need for improved environmental quality necessitates increased efforts to control noise using scientific tools to describe the actual urban soundscapes.

In light of this, the present study addresses the issue of noise pollution in Algeria due to road traffic to answer the next question: How can the Algerian government body develop road noise mapping without a national standardized model?

To tackle this problem the hypothesis set to solve this problem revolves around mapping road traffic-related noise by inspiration from international guidelines, previous studies and conventional standards.

In this study, the main objective is to provide an initial noise map created based on field measurements in a location like the Champ de Manoeuvre neighbourhood in Guelma (a city in Algeria), which does not have a standardized model or an official scheme for noise mapping, in a first step towards road noise abatement and mitigation, and the enforcement of the national regulation related to fighting against this issue.

THEORY / RESEARCH METHODS

Founded on a quantitative approach, this study focuses on field measurements to extract noise levels from road traffic. The next sections discuss the studied area characteristics, noise measurement protocol, and noise mapping process.

Studied area characteristics

The first significant urban extension planned is the Champ de Manœuvre neighbourhood, a newly developed urban residential area in Guelma, as shown in Figure 1. It includes both single-family homes and multi-family housing estates. The 1104-home program was carried out under the conditions prevailing at the time. Amenities came late, but for the most part, they were city-wide. Construction was carried out in two phases. The first of 480 homes was registered in 1975, and the second of 624 homes in 1984. It has an average density of 40-60 inhabitants/km2 and is currently growing at a rate of 3%. The residential buildings in this housing estate, built between 1986 and 1990, are constructed using a prefabricated system of ordinary reinforced concrete 25cm thick. They are oriented North. West - South. East, where they benefit from plenty of daily sunshine.

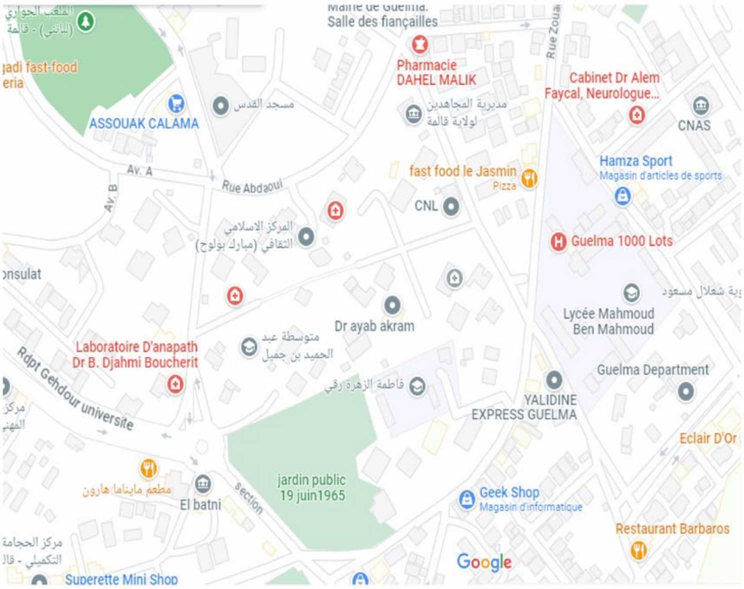

Figure 1. Satellite location of the studied area
Source: Google Maps, 2023

Noise measurement protocol

The duration and measurement times were analyzed in this research. As there is no local regulation in Algeria, analyzing the day and the measurement duration for the vehicular traffic noise data to produce maps was essential. The digital sound level

meter, Triplett 3550 Sonichek Pro (Triplett, 2020), was used to capture the sound pressure level (Lp), and in the calculation of the equivalent continuous weighted sound pressure level (LAeq). This CE-certified device complies with the RoHS directive, IEC651 (type 2) and ANSI S1.4 (type 2). It also features a PCPC interface via the Noise Logger Communication Tool software for viewing measured noise spectra. The measurement campaigns were carried out at the Champs de Manœuvre housing estate in Guelma, on the road network surrounding the estate, to highlight the noise profile of these roads according to the time of day. To achieve this, the road noise generated varied significantly along the entire length of the road studied due to the change in traffic volume, the gradient of the road and the gradual variation in screening. Thus, dividing this road network into five segments was essential, as presented in Figure 2 (Department of Transport: Welsh Office, 1988). This will help us produce a specific noise map for this urban area.
The characteristics of a road were essential factors to be considered. These factors included pavement type, flow speed, flow composition and gradient. With this in mind, the road to the Champs de Manœuvre housing estate is surfaced mainly with bituminous surfaces. The road has an average speed of 35 Km/h and a maximum speed not to be exceeded in the vicinity of the residential estate of 50 Km/h. The difference in gradient percentages that varied from 0 to 10% of the road network surrounding the Champs de Manoeuvre housing estate, divided by segments as previously presented in Figure 2, may influence the propagation of road noise. During ten (10) minutes of observation, the flow of vehicles passing nearby was monitored, and a large number of motorized vehicles (passenger cars, motorcycles, buses, trucks) were counted through this urban area using a hand-held counter, as shown in Table 1.

Table 1. Number of vehicles by segment

Segment	Light vehicles (LV)	Bikes	Buses	Heavy vehicles (HV)
I	146	21	13	3
II	140	24	10	1
III	157	20	11	1
IV	129	16	8	1
V	134	16	6	2

Source: Authors, 2023

In the research literature found on the process of measuring environmental noise, according to (Romeu et al., 2011), a typical procedure followed in pioneering experiments in the field of environmental studies is to carry out short-term measurements of varying duration (from 2 min to 2 h) at different intervals during the day and night. This procedure has remained a standard practice, with measurement durations ranging from 10 minutes to 1 hour (Barrigón Morillas et al., 2002), (Collins & Oviasogie, 2019) and (Bies et al., 2018). More recently, 24-hour measurements have been used to complement short-term measurements as the only means of estimating L_{day} (Alberola et al., 2005). Other studies have extended the duration of short-term measurements up to 8 hours (Li et al., 2002) and (Tsai et al., 2009).

According to (Murphy & King, 2014), the time interval of the measurements must be carefully considered. LAeq measurements recorded at 15-minute intervals over one week would provide a valuable picture of the noise environment.
In the final report published by (the USUS et al. Administration, 2018), it was stated that the ability to represent one-hour Leq with a shorter-term measurement is a crucial factor to consider when choosing the measurement duration to speed up research without compromising accuracy. The size of the variation in sound level will determine the duration of the measurement. The greatest predicted or observed difference between the minimum and maximum sound levels occurring at the measurement location during the worst noise hour can be used as a reference to determine the measurement duration. Furthermore, each road segment has four (04) measuring stations, 40 to 50m apart. Each station is set up on the sidewalk, almost 2m from the roadway, away from reflective surfaces, and the measuring device is mounted on a tripod at a height of 1.5m facing the passing by vehicles, as represented in Figure 2. Moreover, table 3 below shows all the selected measuring stations with their GPS coordinates, using Google Maps to identify their actual location quickly.

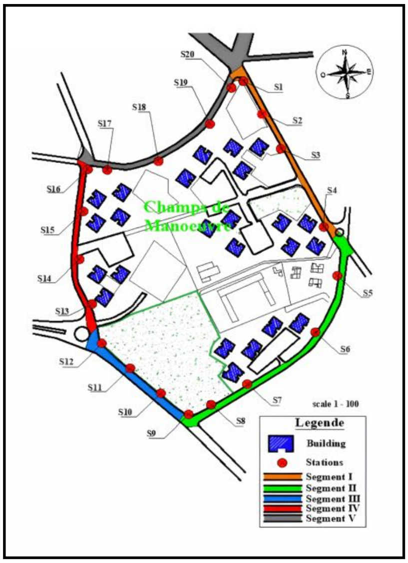

Figure 2. Location of the 20 measurement stations on the segmented roads
Source: Authors sketch, 2023

Table 3. Location of measuring stations according to GPSGPS coordinates

Station	GPSGPS coordinates	
S1	36°27'37.4"N	7°25'51.7"E
S2	36°27'36.2"N	7°25'52.5"E
S3	36°27'34.7"N	7°25'53.3"E
S4	36°27'30.9"N	7°25'55.7"E
S5	36°27'28.6"N	7°25'56.4"E
S6	36°27'26.0"N	7°25'55.0"E

Station	GPSGPS coordinates	
S7	36°27'23.8"N	7°25'51.5"E
S8	36°27'23.2"N	7°25'49.8"E
S9	36°27'23.1"N	7°25'47.3"E
S10	36°27'24.0"N	7°25'46.0"E
S11	36°27'24.9"N	7°25'44.9"E
S12	36°27'25.9"N	7°25'43.7"E
S13	36°27'27.9"N	7°25'42.9"E
S14	36°27'29.3"N	7°25'42.5"E
S15	36°27'31.9"N	7°25'42.8"E
S16	36°27'33.6"N	7°25'43.1"E
S17	36°27'33.5"N	7°25'44.4"E
S18	36°27'33.8"N	7°25'46.8"E
S19	36°27'35.8"N	7°25'50.0"E
S20	36°27'37.5"N	7°25'51.2"E

Source, Authors

The measurement campaign was carried out in 2022 in two periods: a winter period (February and March) and a summer period (June and July). Each month, measurements were taken three (03) times a week: Saturday - Tuesday - Thursday. By the standards, measurements were carried out under good weather conditions (clear sky, low wind, moderate temperature), from 9 am to 5 pm (reference interval), with an observation interval of around 1h30min for each segment. At each station, the direct measurement of LAeq lasted 10 minutes (measurement interval) and was repeated once.

Noise Parameters

Sound pressure levels were measured at each measuring station with an A frequency weighting and a "Fast" time weighting. The first noise indicator used primarily in this study to evaluate and analyze noise is the continuous equivalent sound pressure level (LAeq), which designates the energy level produced by a given sound source over some time, with an A frequency weighting reflecting the sensitivity of the human ear to the noise heard. LAeq level is given by the following formula:

$$LAeq, Te = 10\log\left[1/Te \int_0^{Te} 10^{\wedge}LA(t)/10.\, dt\right.$$

$$LAeq, Te = 10\log\left[1/Te \int_0^{Te} 10^{\wedge}LA(t)/10.\, dt\right]$$

Statistical noise indicators such as L10 were targeted; the sound level exceeded 10% of the measurement time. This indicator generally characterizes noise variation as a function of time, such as noise variation due to road traffic and background noise (Bies et al., 2018). Also, the maximum sound level L_{max}, which is the maximum sound level a sound source can produce over a given period, was targeted in this study. LAeq alone is an inadequate descriptor of annoyance caused by fluctuating noise. Various noise parameters, such as Traffic Noise Index (TNITNI) and noise Pollution Level

(NPL), have been used for analysis, mapping, and planning purposes (Sheetal et al., 2023) and (Titu et al., 2022). NPL index is replaced particularly for the highly fluctuating road traffic noise, and it is used to measure the unhappiness brought on by road traffic noise. It consists of two terms: the amount of aggravation caused by variations in LAeq and the second is a measurement of that increment. NPL can be expressed as follows for a Gaussian distribution of noise levels (Shalini & Kumar, 2018), (Pronello & Camusso, 2012). Moreover, NPL is an environmental pollution indicator for physiological and psychological disturbances in the human body. It is calculated via the following formula:

$$(NPL) = Leq + (L10 - L90)$$

Traffic Noise Index (TNITNI) is a technique used to gauge responses to traffic noise irritation. The above threshold criterion is defined as the value of TNITNI over 74 dB (A) and is calculated using the formula below (Nipa et al., 2022) (Jamrah et al., 2006). It is calculated following this formula:

$$(TNI) = 4 * (L10 - L90) + L90 - 30(TNI) = 4 * (L10 - L90) + L90 - 30$$ Or

$$(TNI) = 4(L10 - L90) + Leq(TNI) = 4(L10 - L90) + Leq$$

Noise mapping process

In accordance with European directive E.N.DE.N.D. 2022/49/ECEC (Agency, 2020), (Murphy et al., 2020) and (King & Murphy, 2016), the creation of a 2D type A cartographic representation in the form of two models: in labels with the indication of the values of LAeq calculated at each measuring station, and in coloured isophone curves, the general interest is to present acoustic data globally and visually, with their geolocalizations, identifying the black areas to be treated. Subsequently, it makes it possible to constitute a policy for fighting against noise emissions and its mitigation at the source and informing the population of noise exposure health effects.
In the case of the Champs de Manoeuvre neighbourhood, a noise map based on periodic measurement campaigns provides valuable information for decision-makers to assess noise mitigation measures at the source through preventive or repressive solutions. The establishment of this kind of illustrative map was by using a colour scale as presented in Table 4 and as defined by the French standard NF S31-130 (Afnor, 2008), and in compliance with the French ministerial order of April 4 2006, related to the establishment of noise maps and environmental noise prevention plans. The map was produced using geo-referenced data taken from the Open Street Map platform (elevation data, building footprints and heights), road traffic data, D.G.M. (Digital Ground Model) calculations, and noise levels recorded in hourly intervals.

Table 4. Noise mapping colour scale

Sound levels (dB)	Colour
Less than 50	White
50 – 55	Green

Sound levels (dB)	Colour
55 – 60	Yellow
60 – 65	Orange
65 – 70	Red
70 – 75	Lavender Purple
More than 75	Purple

Source: (Gouleme & Boutin, 2009)

RESULTS AND DISCUSSION

After establishing adequate noise measurements over a period of four months; two months in winter (February and March), and two months in summer (June and July), by measuring sound levels on three days for each month, during the day at 20 stations, distributed along the main two-lane roads, and close to the Champs de Manoeuvre residential buildings. The results obtained from this phase are presented in the following sections.

Noise measurement results of February

According to Table 5, the overall results of noise measurements along the road at the 20 stations from 9:00 am to 5:00 pm revealed that $LAeq_{,10min}$ level during the weekend day (Saturday, February 12) varied between 51 dB and 70 dB. Only at stations 1, 2, 5, 7, 12, 13, 17 and 18 (i.e., 40%) were high sound levels between 67 dB and 70 dB recorded, while at the rest of the stations, a lower $LAeq_{,10min}$ level was captured, due to the low volume of traffic over the weekend. However, during the weekday (Tuesday, February 15), very high $LAeq_{,10min}$ levels were recorded, ranging from 66 dB to 89 dB, and during the second weekday of measurements (Thursday, February 17), the $LAeq_{,10min}$ sound level ranged from 59 dB to 83 dB. These results were recorded at almost all measuring stations on the five road segments, similar to the results of (collins & oviasogie, 2019). The leading cause of this increase in noise levels was the sheer volume of vehicle traffic passing through this urban area, particularly in segments I, II and V, as well as the behaviour of drivers, particularly at red light stops and intersections.
February measurement campaigns also showed high levels of L10, which fluctuated during the weekend day between 65 dB and 75 dB at 12 stations (i.e. over 50%), mainly on segments I and II. On the other hand, on weekdays (Tuesday 15th and Thursday 17th), L10 levels fluctuated between 67 dB - 92 dB and 63 dB - 90 dB, respectively, marking a high and significant variation during 8 hours of measurements at the 20 stations chosen for this operation, and which could easily create a feeling of discomfort and annoyance for residents of the Champs de Manœuvre housing estate, due to the high sound intensity emitted by road traffic noise. Moreover, as shown in Table 5, the February measurement campaign also targeted L_{max}, which was recorded on weekend days with values varying between 55 dB (station 11) and 85 dB (station 12), belonging to segment III at an intersection marked by the presence of a red traffic

light. In addition, higher values were recorded on the other two days of the week, reaching up to 90 dB and 99 dB (stations 14 and 15), generally due to the passage of heavy goods vehicles such as buses, the intense passage of motorcycles, unjustified acceleration, and the repeated honking by drivers of light vehicles. The responsible authorities must compulsorily sanction this behaviour in an effective and vital move to combat noise pollution and reduce it at the source.

Table 5. $LAeq_{,10min}$, Lmax and L10 measurement values in the 20 stations in February

LAeq,10min			**Lmax**			**L10**		
Week end	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**
70,0	71,0	72,5	78,0	81,0	83,0	75,0	74,0	76,0
66,0	66,0	76,0	73,0	76,0	87,0	69,0	68,0	80,0
64,0	69,0	82,0	73,0	79,0	93,0	67,0	74,0	85,0
60,0	72,0	78,0	65,0	81,0	88,0	62,0	74,0	80,0
69,0	73,0	80,0	78,0	83,0	90,0	71,0	76,0	83,0
64,0	67,0	81,6	73,0	81,0	92,5	68,0	67,0	84,7
66,0	78,0	73,0	74,0	86,0	83,0	69,0	81,0	76,0
60,0	78,0	58,0	65,0	84,0	66,0	62,0	80,0	61,0
64,0	74,0	60,5	69,0	86,0	69,0	66,0	74,0	63,0
60,0	73,0	74,0	68,0	83,0	83,0	63,0	76,0	76,7
51,0	79,0	70,4	55,0	95,0	79,0	53,0	78,0	73,0
70,0	70,0	79,0	85,0	83,0	88,7	69,0	72,0	81,6
67,0	68,0	83,0	75,0	76,0	93,0	69,0	72,0	85,7
57,0	83,0	65,0	64,0	100,0	73,6	60,0	76,0	67,7
59,0	89,0	78,7	68,0	100,0	88,0	64,0	92,0	81,0
63,0	79,0	87,8	69,0	95,0	98,0	66,0	79,0	90,0
65,0	77,0	69,6	73,0	90,0	78,0	68,0	80,0	72,0
65,0	77,0	77,0	73,0	90,0	90,0	68,5	81,0	81,0
58,0	77,0	60,7	66,0	90,0	72,0	61,5	80,0	64,8
57,0	85,8	73,0	64,5	99,0	85,7	60,0	88,0	77,0

Source: Authors, 2023

Table 6 below demonstrates the noise indicator values for NPL and TNITNI, calculated according to the abovementioned formulae. It was observed that NPL index values on the weekend day varied on all 20 stations between 65 dB and 85 dB. In contrast, these values increased on weekdays up to 104,7 dB recorded at station 20, indicating remarkable noise pollution in this residential area. On the other hand, the TNITNI index values were completely elevated at all stations during the three days of measurement, reaching a maximum value of 176 dB, notably at station 15 in segment IV, which consequently indicated a powerful flow of road traffic, which is the leading cause of noise in urban areas and is characterized by fluctuations in traffic flow during the day, due to changes in its kinematic characteristics, notably speed, acceleration and deceleration, and subsequently provoking a sense of annoyance and noise discomfort among residents. Similar results were found in a study in India (Roy, 2022) with severely elevated NPL and TNI TNI levels, relating to high noise pollution from road traffic and annoyance to residents. The results of these two indicators can provide a critical database for urban planning and road categorization and for better management of noise emissions in residential areas, particularly in the city of Guelma.

Table 6. Noise pollution index values (NPL/ TNI) for the 20 stations in February

NPL			TNI		
Weekend	**Week day 01**	**Week day 02**	**Weekend**	**Week day 01**	**Week day 02**
83,5	82,4	84,6	124,0	117,0	121,0
77,0	76,8	89,0	111,0	109,0	127,0
75,0	93,0	95,6	105,0	166,0	136,5
65,0	79,6	86,0	81,0	101,0	109,0
75,7	82,8	90,0	95,0	110,5	120,0
78,6	80,0	91,8	121,6	120,0	122,0
76,0	90,0	82,0	105,0	126,0	110,0
65,0	84,5	65,5	79,0	102,7	87,5
71,0	81,0	68,0	91,2	102,0	91,0
67,0	84,6	84,0	78,7	118,0	113,0
58,0	95,0	79,6	131,7	142,0	107,0
85,0	81,6	89,5	114,0	116,0	120,6
79,0	81,0	94,0	86,6	119,7	126,8
65,0	97,0	73,8	119,6	139,0	99,6
74,7	111,0	89,0	97,0	176,0	120,0
71,7	94,6	99,0	97,0	140,0	133,6
76,5	94,5	78,8	110,0	146,0	106,0
76,7	95,0	95,0	111,0	149,0	149,0
68,7	94,5	75,0	99,0	146,0	118,0
67,0	104,7	90,5	97,0	161,6	141,8

Source: Authors, 2023

Noise measurement results of March

According to Table 7, the overall results of noise measurements along the road divided into segments in the 20 stations from 9:00 am to 5:00 pm in March revealed that $LAeq_{,10min}$ level during the weekend day (Saturday the 12th) varied between 58,9 dB and 70.6 dB. Only at stations 1, 2, 3, 4, 5, 15, 16, 17 and 18 (i.e. 40%) high sound levels of 65 dB and 70 dB were recorded, while the rest of the stations had lower $LAeq_{,10min}$ levels, due to the low volume of road traffic on weekend days. However, during the weekday (Tuesday the 8th) very high $LAeq_{,10min}$ levels were recorded, ranging from 65,7 dB to 77,7 dB, and during the second weekday of measurement (Thursday the 10th), $LAeq_{,10min}$ ranged from 51,5 dB to 84,2 dB. These results were recorded at almost all stations on the five road segments. Although the resulting level of $LAeq_{,10min}$, was high and exceeded the thresholds recommended by regulations, it was observed that these values are more or less reduced compared with the results recorded in February. Nevertheless, road noise dominated the noise landscape.

In addition, the measurements in March also targeted L10. Its levels fluctuated during the weekend between 59,6 dB at station 9 and 76 dB at station 4, belonging to segments I and III, respectively. On the other hand, on weekdays (Tuesday 8th and Thursday 10th), L10 levels varied between 68,6 dB – 78,3 dB and 63,5 dB – 87,3 dB, respectively, marking a high and significant variation during 7h of measurement on the 20 stations chosen for this operation, due to the high noise intensity emitted by road traffic noise, which subsequently implied the recording of high sound levels and the marking of a rigorous sound profile of the road investigated.

Furthermore, the measurement campaign in March also pinpointed L_{max}, which was recorded on weekend days with values ranging from 64,6 dB (station 14 - segment IV) to 82,3 dB (station 3). In addition, higher values were recorded on the other two weekdays, reaching up to 95,3 dB (station 4 - segment I), generally due to the passage of heavy goods vehicles such as buses, the intense passage of motorcycles, unwarranted acceleration and the repeated honking of vehicle drivers. Noise levels on weekdays were remarkably high due to the frequency of vehicle traffic, unlike on weekends.

Table 7. $LAeq_{,10min}$, Lmax and L10 measurement values in the 20 stations in March

LAeq,10min			**Lmax**			**L10**		
Week end	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**
69,9	70,8	72,3	78,5	80,1	84,5	74,3	74,4	75,0
66,3	70,3	72,7	74,2	79,3	86,0	69,2	74,4	74,2
65,6	71,3	81,5	82,3	80,4	92,0	76,0	74,6	85,6
70,6	76,8	84,2	77,1	88,5	95,3	73,6	76,6	87,3
66,2	71,0	74,2	75,0	80,8	84,3	68,5	74,1	77,3
60,1	73,6	76,7	68,2	84,7	87,1	62,3	77,0	79,8
61,4	76,5	68,8	69,6	90,3	78,4	63,5	77,3	71,8
58,9	77,7	65,2	66,8	89,6	74,4	61,0	79,5	68,2
57,7	72,2	67,9	65,5	83,6	77,4	59,7	74,9	71,0
60,2	71,9	69,9	68,3	84,9	78,5	63,2	76,0	74,3
63,3	73,3	69,1	71,7	84,0	77,7	66,4	76,3	73,5
64,6	73,9	77,8	73,1	84,1	87,0	67,7	78,3	82,3
61,3	68,8	65,7	69,5	80,6	74,0	64,3	72,5	70,0
57,8	69,1	51,5	64,6	78,1	58,4	60,0	72,0	55,3
65,0	73,7	64,8	73,6	85,4	73,0	68,2	77,2	69,1
68,0	72,3	72,3	77,0	82,7	81,0	71,2	75,7	76,7
68,7	71,3	73,0	77,7	80,4	81,9	72,0	75,4	77,5
65,3	67,3	64,4	73,0	77,9	70,3	68,5	69,0	66,9
61,7	65,7	61,1	70,0	74,2	66,7	64,7	68,6	63,5
60,4	67,4	72,9	68,5	90,3	79,4	63,5	77,8	75,6

Source: Authors

Table 8 below shows the results of NPL and TNITNI values for March. NPL index values on the weekend day ranged across all 20 stations from 63 dB to 88,8 dB (station 3 - segment I). However, these values rose on both weekdays to 103,7 dB, reported on stations 3 and 4, showing exceptional noise pollution in this residential area. On the other hand, for TNITNI index, these values were quite high at all stations throughout the three measurement days, reaching a maximum value of 169,2 dB in particular at station 3 (segment I), which subsequently implies a powerful flow of road traffic, which is the main source of noise in urban areas and is characterized by variations in traffic volume over the day due to variations in its characteristics (speed, acceleration and deceleration, type of energy "diesel engine"). As a result, it can cause annoyance and a feeling of discomfort among residents.

Table 8. Noise pollution index values (NPL/ TNI) for the 20 stations in March

NPL			TNI		
Weekend	**Week day 01**	**Week day 02**	**Weekend**	**Week day 01**	**Week day 02**
82,6	87,8	87,8	120,8	134,4	13,4
77,4	89,3	89,3	111,1	139,1	139,2
88,8	103,4	103,4	137,8	169,2	169,2
76,7	103,7	103,7	95,4	162,3	162,3
72,4	83,5	83,5	91,1	111,5	111,5
65,7	86,4	86,3	82,8	115,3	115,3
67,1	77,5	77,4	84,5	103,5	103,5
64,3	73,5	73,5	81,0	98,2	98,2
63,0	76,5	76,5	79,4	102,2	102,2
67,3	82,6	82,6	89,2	120,8	120,8
70,8	81,8	81,7	93,7	119,6	119,6
72,3	91,9	91,9	95,6	134,3	134,3
68,5	77,7	77,7	90,8	113,7	113,7
65,0	61,0	61,0	86,6	89,4	89,4
72,8	76,7	76,6	96,3	112,3	112,3
76,1	85,4	85,4	100,7	124,9	124,9
77,0	86,3	86,3	101,8	126,2	126,3
76,7	70,1	70,1	111,2	87,3	87,3
69,0	66,1	66,6	91,4	82,9	82,9
67,6	79,4	79,4	89,5	98,8	98,8

Source: Authors

Noise measurement results of June

$LAeq_{,10min}$ level during the weekend day (Saturday 25) ranged from 53,7 dB (station 13 - segment IV) to 70,4 dB, as reported in Table 9 from the overall results of noise

measurements, along the road divided into segments at the 20 stations from 9:30 am to 4:30 pm in June. Only stations 1, 4, 5, 6, 7, 9, 10, 16, 17, 18 and 19 (i.e. 51%) recorded high noise levels above 65 dB, while the other stations recorded lower levels (below 65 dB) of $LAeq_{,10min}$. This difference can be explained by the fact that weekends saw a drop in most commercial activities and vehicle numbers. A very high $LAeq_{,10min}$ level of 78,3 dB (station 4 - segment I), was recorded on Week Day 01 (Tuesday). On Week Day 02 (Thursday), the $LAeq_{10min}$ level varied widely from 66,8 dB (Station 9 - Segment III) to 89,7 dB (Station 7 - Segment II). Almost all measuring stations along the five road segments produced values above the permissible threshold of 70 dB on both weekdays.
June measurements also focused on L10. Table 9 shows that over the day of the weekend, L10 levels varied between 55,7 dB (Station 13 - Segment IV) and 73,6 dB. (Station 1 - segment I). On the other hand, during the working days (Tuesday 28 and Thursday 30), L10 levels varied between 63,8 dB (station 20 - segment V) and 79,4 dB (station 1 - segment I), and 68,3 dB (station 9 - segment III) and 86,3 dB (station 7 - segment II), respectively, indicating a high and significant variation during seven h measurement at the 20 stations selected for this operation, due to the rigorous sound profile of the road studied and the high intensity of traffic noise. Furthermore, L_{max} was also recorded for the June measurement campaign. On the weekend day, L_{max} values ranged from 64,6 dB (station 14 - segment IV) to 89,2 dB (station 5 - segment II). In addition, higher values were recorded on the other two days of the week, reaching up to 102 dB (station 4 - segment I/ week day 01) and 114 dB (station 7 - segment II/ week day 02), generally due to the passage of heavy goods vehicles such as buses, the intense passage of motorcycles, unwarranted acceleration and the repeated honking by vehicle drivers. Noise pollution on weekdays was remarkably high, due to the frequent passage of mainly diesel-powered vehicles and cars, unlike on weekends.

Table 9. $LAeq_{,10min}$, Lmax and L10 measurement values in the 20 stations in June

$LAeq_{,10min}$			**Lmax**			**L10**		
Week end	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**
70,0	75,8	77,7	83,1	89,7	98,5	73,6	79,4	80,0
64,1	75,1	80,4	85,5	88,8	104,4	65,4	78,7	79,8
63,7	68,3	77,7	83,4	81,5	100,8	70,1	72,2	84,7
69,6	78,3	79,9	84,9	102,0	100,2	69,1	78,5	81,5
70,4	73,5	82,2	89,2	96,5	101,6	72,6	74,3	82,1
68,1	70,8	80,6	86,5	87,0	100,1	70,4	72,5	81,8
66,7	65,7	89,7	84,8	81,2	114,6	69,0	67,6	86,3
62,4	71,6	79,2	79,7	86,3	99,2	64,9	69,4	79,8
66,5	69,0	66,8	65,5	84,0	84,6	68,1	70,5	68,3
60,2	72,2	69,4	68,3	88,5	85,1	62,0	74,7	72,1
57,0	66,6	66,6	71,7	89,8	81,6	59,8	75,8	69,1
56,4	70,6	70,6	73,1	86,2	86,2	58,3	72,8	73,0

LAeq,10min			**Lmax**			**L10**		
Week end	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**
53,7	71,6	67,2	69,5	87,2	82,3	55,7	73,6	69,4
59,4	68,3	77,3	64,6	91,6	93,8	61,2	68,6	79,1
63,8	75,5	78,7	73,6	93,5	97,0	68,2	75,2	78,0
68,3	74,0	79,7	77,0	96,0	102,4	70,4	74,7	79,6
67,9	77,2	77,2	77,7	89,5	89,5	71,1	79,4	79,4
69,3	73,2	81,1	73,0	92,4	101,2	71,4	75,0	82,1
66,2	74,4	69,5	70,0	94,5	89,2	68,5	73,8	69,6
64,0	78,0	75,8	68,5	81,0	95,6	66,5	63,8	75,3

Source: Authors, 2023

Table 10 below shows June's noise indicator values for NPL and TNITNI. NPL values on the weekend ranged from 62,4 dB to 84,8 dB at all 20 stations. However, it raised on both weekdays to 119,7 dB reported at station 7 - segment II/ week day 02, showing exceptional noise pollution in this residential area. On the other hand, TNITNI calculated values were relatively high at all stations throughout the three measurement days, reaching a maximum value of 209,9 dB, particularly at station 7 - segment II, which implies a very high flow of road traffic in this segment.

Table 10. Noise pollution index values (NPL/ TNI) for the 20 stations in June

NPL			**TNI**		
Weekend	**Week day 01**	**Week day 02**	**Weekend**	**Week day 01**	**Week day 02**
82,2	88,9	100,0	118,6	128,1	167,2
77,2	88,0	105,2	116,5	126,9	179,7
81,0	80,2	107,4	133,0	115,9	196,6
83,4	92,6	106,1	124,8	135,8	184,8
84,9	87,1	109,7	128,4	127,9	192,0
82,2	86,6	107,6	124,4	133,8	188,6
80,5	80,4	119,7	121,8	124,5	209,9
75,4	86,4	104,4	114,2	130,9	180,1
77,2	80,1	77,7	109,3	113,3	110,4
69,9	84,1	81,1	99,1	119,7	116,3
66,2	82,4	81,2	94,0	129,7	124,8
65,5	85,7	91,3	93,0	131,1	153,0
62,4	85,6	80,6	88,7	127,6	120,9
69,0	82,5	92,6	97,8	125,2	138,5
74,1	95,6	106,1	105,0	155,8	188,2
84,6	88,5	102,5	135,0	131,9	170,8
84,8	92,5	101,0	131,3	138,4	171,8
81,1	89,5	107,3	125,8	138,3	186,0
78,5	91,4	93,8	121,8	142,4	166,5

79,2	94,5	103,8	128,5	143,8	187,5

Source: Authors, 2023

Noise measurement results in July

$LAeq_{,10min}$ level during the weekend day (Saturday 16th) ranged from 57,9 dB (station 19 - segment V) to 73,7 dB, as shown in Table 11, from the overall results of noise measurements along the road divided into segments at the 20 stations from 9:00 am to 5:00 pm in July. Only stations 12, 19 and 20 (i.e. 15%) recorded noise levels below 65 dB, while the other stations recorded higher $LAeq_{,10min}$ levels (above 65 dB). This difference can be referenced to the fact that weekends saw an increase in most commercial activities and vehicles during the summer season. A very high $LAeq_{,10min}$ level of 76,3 dB (station 7 - segment II) and 77,15 dB (station 18 - segment V) was recorded on Tuesday. Similarly, on Thursday (July 21), the $LAeq_{,10min}$ level ranged from 66,6 dB (station 11 - segment III) to 89,6 dB (station 7 - segment II). Almost all measuring stations along the five road segments produced values above the permissible threshold of 70 dB on both weekdays. The measurements carried out in July also focused on the L10 level. During the weekend day, L10 levels ranged from 59,7 dB (Station 9 - Segment III) to 73,1 dB. (Station 7 - segment II).On the other hand, on working days (Tuesday 19th and Thursday 21st), L10 levels varied between 59 dB (Station 19 - Segment V) and 73,1 dB (Station 7 - Segment II), and 69,6 dB (Station 19 - Segment V) and 86,2 dB (Station 7 - Segment II), respectively, indicating a high and significant variation during seven h measurement at the 20 stations selected for this operation, due to the stringent sound profile of the road studied and the high intensity of traffic noise. L_{max} was also recorded during the July measurement campaign, with a maximum value of 90 dB reported on a weekend day (station 2 - segment I). In addition, higher values were captured on the other two days of the week, reaching up to 97,1 dB (station 7 - segment II) on Tuesday and 114,5 dB (station 7 - segment II) on Thursday, generally due to the passage of heavy goods vehicles such as buses, the intense passage of motorcycles, unwarranted acceleration and the repeated honking of vehicle drivers. Noise levels on weekdays were remarkably high due to the frequency of vehicle traffic, unlike weekends.

Table 11. $LAeq_{,10min}$, Lmax and L10 measurement values in the 20 stations in July

$LAeq_{,10min}$			**Lmax**			**L10**		
Week end	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**	**Week-end**	**Week day 01**	**Week day 02**
68,0	75,8	80,5	89,5	89,5	103,8	68,8	68,8	79,8
67,8	74,8	80,3	90,0	90,0	104,4	68,8	68,8	79,8
66,5	73,5	81,5	86,9	86,9	100,8	73,0	73,0	84,6
66,8	74,7	79,9	84,9	84,9	100,1	69,1	69,1	81,5
68,4	72,2	82,2	86,1	86,1	101,6	69,6	69,6	82,1
67,3	71,0	80,6	84,8	84,8	100	69,3	69,3	81,7
73,7	76,3	89,6	97,1	97,1	114,5	73,1	73,1	86,2
67,9	67,9	79,2	86,3	86,3	99,2	69,4	69,4	79,8
66,5	66,5	66,8	65,5	81,2	84,6	59,7	68,1	68,3

LAeq,10min			Lmax			L10		
Week end	Week day 01	Week day 02	Week-end	Week day 01	Week day 02	Week-end	Week day 01	Week day 02
69,2	69,2	69,4	68,3	85,1	85,1	63,2	71,8	72,1
66,6	66,5	66,6	71,7	81,6	81,6	66,4	68,9	69,1
63,7	70,5	70,6	73,1	78,33	86,1	67,7	66,1	72,9
67,2	67,2	67,2	69,5	82,3	82,3	64,3	69,4	69,4
68,3	68,3	77,3	64,6	91,6	93,8	60,0	68,6	79,1
68,5	72,4	78,7	73,6	85,8	96,9	68,2	69,0	78,0
69,3	71,6	79,7	77,0	90,6	102,3	71,2	70,4	79,6
66,6	66,6	77,2	77,7	77,8	89,4	72,0	69,0	79,3
69,3	77,2	81,1	73	88	101,2	68,5	71,4	82,1
57,5	62,8	69,5	70	75,6	89,2	64,7	59	69,6
62,8	70,7	75,8	68,5	81	95,5	63,5	63,8	75,3

Source: Authors

Table 12 below shows the noise indicator values for NPL and TNITNI, calculated for July. NPL index values on the weekend day ranged across all 20 stations from 71,2 dB to 90,6 dB, but these values raised on both weekdays to 93,2 dB and 119,7 dB reported at station 7 - segment II, showing an exceptional level of noise pollution in this residential area. On the other hand, for the TNITNI index, these values were relatively high at all stations throughout the three measurement days, reaching a maximum value of 209,9 dB in particular at station 7 - segment II, which subsequently implies a very high flow of road traffic on this segment.

Table 12. Noise pollution index values (NPL/ TNI) for the 20 stations in July

NPL			TNI		
Weeken d	Week day 01	Week day 02	Weeken d	Week day 01	Week day 02
81,6	89,4	105,1	122,5	130,25	179
81,7	88,65	105,2	123,2	130,14	179,7
84,5	91,5	107,4	138,7	145,63	196,5
80,6	88,5	106,1	122,0	130	184,8
83,3	87	109,6	128,1	131,85	192
81,8	85,5	107,6	125,4	129	188,5
90,6	93,2	119,7	141,3	144	209,9
82,7	82,7	104,4	127,2	127,17	180,1
77,2	77,2	77,7	109,3	109,3	110,4
80,6	80,6	81,1	114,9	114,86	116,25
80,9	80,9	81,2	123,9	124	124,7
77,5	84,3	91,2	118,8	125,6	153
80,7	80,7	80,6	121,3	121,25	120,85
82,5	82,5	92,6	125,2	125,2	138,45
86,9	90,8	106	142,1	146	188,2

NPL			TNI		
Weekend	**Week day 01**	**Week day 02**	**Weekend**	**Week day 01**	**Week day 02**
79,9	85,7	102,4	119,8	126,2	170,8
84,8	79,9	101	131,3	119,8	171,8
71,2	92,6	107,3	112,0	139,14	185,9
79,2	76,4	93,7	128,5	117,25	166,4
79,2	87,13	103,7	128,5	136,25	187,5

Source: Authors, 2023

In summary, the research outcomes reveal significant variations in noise pollution levels along the primary roads of the Champs de Manoeuvre housing estate in Guelma. These variations stem from diverse anthropogenic activities within the vicinity. Notably, the impact of noise exposure on an individual's health is widely acknowledged, with adverse effects contingent on sensitivity, frequency, and intensity of exposure. Understanding these dynamics is crucial for devising an effective noise mitigation strategy. Similar results were found in the city of Oran (Hamou et al., 2014) as well as the city of Biskra (Berkouk et al., 2020) (Bouzir et al., 2017), and in Guelma (Boulemaredj et al., 2022), where high noise levels provoked annoyance and feeling of stress and anger for the residents. Also, they exceeded the thresholds set by national acoustic regulations at 70 dB, international standards, and the WHO organization at 55 dB for outdoor noise in the vicinity of residential areas. In Kuwait, 47 roadway locations were subjected to a 20-minute assessment of urban traffic noise pollution repeated three to five times. Numerous noise characteristics were calculated, and it was shown that traffic noise levels exceeded the typical outdoor limit most of the time, especially on freeways and arterial roads (Al-Mutairi et al., 2009). Additionally, as stated by (World Health Organization (WHO), 2018), a noise level of 65 dBA generates deep tension, while a noise level of 55 dBA causes mild stress, excitement, dependency, and discomfort. The human body is expected to release biological morphine at a sound level of 80 dBA, producing a pleasure sensation that could eventually become addiction. (Hunashal & Patil, 2012).

Noise map of the Champs de Manœuvre neighbourhood area

The findings of this study align with previous research conducted by (Alam et al., 2021), (Alam et al., 2022), and (Ammar et al., 2023). Our research, which involved mapping noise levels during both winter and summer periods, underscores the prevalence of road noise as a dominant factor in the Champs de Manoeuvre housing estate. Notably, during the summer, noise levels frequently surpassed 74 dB. It can also be noticed that traffic junctions (traffic roundabouts) are the main sources of noise emitted using transport. In another study on environmental noise mapping in Taiwan (Tsai et al., 2009), the authors set up their measurement campaigns in winter as well as summer, at 345 stations following three periods of the day (morning, evening and night). Analysis of this noise exposure study revealed that over 90% of the population of Tainan City is subject to excessive noise, as determined by the US Department of Housing and Urban Development. Therefore, the results of this study demonstrate that noise maps could help analyze noise in urban environments.

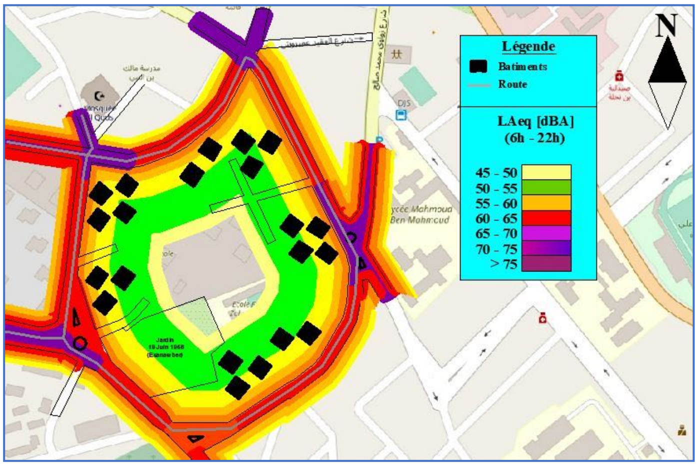

Figure 3. Noise map with isophorone curves during the winter period
Source: Authors, 2022

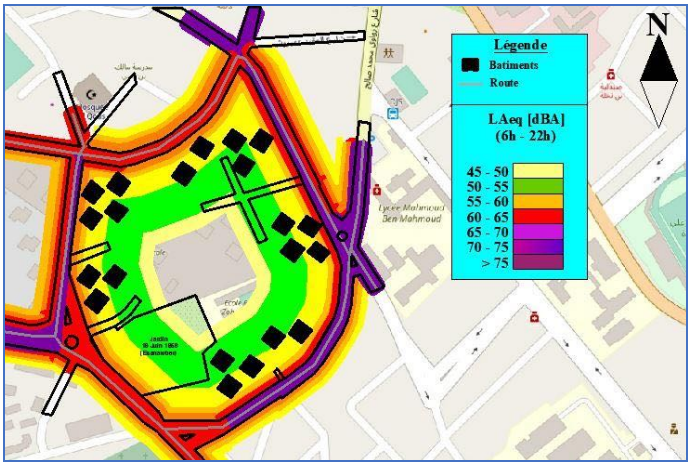

Figure 4. Noise map with isophorone curves during the summer period
Source: Authors, 2022

To synthesize, this study started by identifying practical and population-based gaps on the issue of noise, specifically in the Algerian setting, yet inspired by earlier works conducted in numerous countries around the world. Therefore, it can be seen as an initial contribution to noise abatement and to set action plans by policy-makers and as work complementary to national studies regarding the amount of documentation presented in this study, in a step to encourage other researchers to spread the use of noise mapping approach, based on field surveys. Some of this study's limitations are attributable to the fact that this subject is very little present in the

Algerian scientific literature, and given that it has been pointed out briefly in the national legislation texts, with a remarkable lack in terms of noise parameters, noise measurement protocol, and up-to-date regulations. Another limitation of this research relates to the statistical analysis of the data obtained. Further restriction corresponds with the availability of information or advanced technology, such as acquiring complete access to international standards or books that provide valuable details on noise measurement methodology or having fully licensed software to develop noise simulation.

CONCLUSIONS

The Champs de Manoeuvre housing estate in Guelma was subjected to a noise mapping procedure, as part of this research study as a starting point for the state's ability to tackle noise pollution, from a preventive perspective. In order to visualize the spatiotemporal distribution of noise and locate noisy black spots, to help in providing action measures for urban design and to preserve public peace in the outdoor Environment, this study aimed to the possibility of producing a noise map based on field measurements, in a location without a standardized model or scheme to follow. It also aimed to encourage the application of national acoustic regulations, in which noise level thresholds were set. It has been recognized that a significant portion of the noise nuisance measured in this residential estate was strongly linked to noise emitted primarily from passing vehicles, particularly on road segments I, II, and IV, and the unreasonable driving behaviour of drivers (horns, acceleration, sudden braking), mainly in the summer months (June and July). As a result, LAeq levels exceeded 70 dB, which gives a significant chance of provoking a feeling of irritation, stress, and anger in the residents. In the end, the government's consideration of the acoustic aspect in the building of multi-family housing and the protection of the outdoenvironmententent should represent a crucial step in the fight against noise pollution, to provide citizens and residents with sufficient auditory comfort and enable them to maintain a comfortable living environment.

REFERENCES

Afnor. (2008). NF S31-130. https://www.boutique.afnor.org/fr-fr/norme/nf-s31130/acoustique-cartographie-du-bruit-en-milieu-exterieur-elaboration-des-cartes/fa151801/32365

Agency, E. E. (2020). Environmental noise in Europe—2020—European Environment Agency [Publication]. EEA. https://www.eea.europa.eu/publications/environmental-noise-in-europe

Ahmed, A., Khan, F., Ahmed, M., Ismail, M. A., & Ahmad, N. (2023). Exposure of Road Users to the Traffic Noise in Urban Environment- Insights from a Mega Metropolitan City. International Journal of Environmental Science and Technology. https://doi.org/10.1007/s13762-023-04924-7

Alam, P., Ahmad, K., Khan, A. H., Khan, N. A., & Dehghani, M. H. (2021). 2D and 3D mapping of traffic-induced noise near major roads passing through densely populated South Delhi, India residential areas. PLOS ONE, 16(3), e0248939. https://doi.org/10.1371/journal.pone.0248939

Alam, P., Mazhar, Mohd. A., Ahmad, K., Aslam, Z., Afsar, S., & Husain, A. (2022). Comparative assessment of road traffic noise through 2D noise mapping: A case study of an urban area. Frontiers in Sustainability, 3, 1069445. https://doi.org/10.3389/frsus.2022.1069445

Alberola, J., Flindell, I. H., & Bullmore, A. J. (2005). Variability in road traffic noise levels. Applied Acoustics, 66(10), 1180–1195. https://doi.org/10.1016/j.apacoust.2005.03.001

Al-Mutairi, N., Alrukaibi, F., & P, K. (2009). Measurements and Model Calibration of Urban Traffic Noise Pollution. American Journal of Environmental Sciences, 5. https://doi.org/10.3844/ajessp.2009.613.617

Ammar, A., Garoum, M., & Bybi, A. (2023). Methodology and Acoustic Measurement Campaign of Road Noise: Case of the Agdal District – Rabat City. Civil Engineering and Architecture, 11, 1059–1082. https://doi.org/10.13189/cea.2023.110238

Banerjee, D., Chakraborty, S. K., Bhattacharyya, S., & Gangopadhyay, A. (2008). Evaluation and Analysis of Road Traffic Noise in Asansol: An Industrial Town of Eastern India. International Journal of Environmental Research and Public Health, pp. 5, 165–171. https://doi.org/10.3390/ijerph5030165

Barrigón Morillas, J. M., Gómez Escobar, V., Méndez Sierra, J. A., Vílchez Gómez, R., & Trujillo Carmona, J. (2002). An environmental noise study in the city of Cáceres, Spain. Applied Acoustics, 63(10), 1061–1070. https://doi.org/10.1016/S0003-682X(02)00030-0

Benliay, A., Özyavuz, M., Çabuk, S., & Gunes, M. (2019). Use of noise mapping techniques in urban landscape design. Journal of Environmental Protection and Ecology, 20, 113–122.

Berkouk, D., Bouzir, T. A. K., Maffei, L., & Masullo, M. (2020). Examining the Associations between Oases Soundscape Components and Walking Speed: Correlation or Causation? Sustainability, 12(11), Article 11. https://doi.org/10.3390/su12114619

Bies, D. A., Hansen, C. H., & Howard, C. Q. (2018). Engineering noise control (Fifth edition). CRCCRC Press, Taylor & Francis Group.

Bluhm, G., & Eriksson, C. (2011). Cardiovascular effects of environmental noise: Research in Sweden. Noise and Health, 13(52), 212. https://doi.org/10.4103/1463-1741.80152

Boulemaredj, A. (2023). La rénovation acoustique des logements collectifs – Cas de la cité Champs de Manœuvre, Guelma [PhD Thesis, 8 mai 1945 Guelma]. http://dspace.univ-guelma.dz/jspui/handle/123456789/14267

Boulemaredj, A., Haridi, F., & Bouttout, A. (2022). Assessment of Noise Pollution and Discomfort Levels of the Residents of the Champs De Manoeuvre Neighbourhood, Guelma, Algeria. International Journal of Innovative Studies in Sociology and Humanities, 7(6), 170–179. https://doi.org/10.20431/2456-4931.0706016

Boulemaredj, A., & Haridi, F. Z. (2022). La pollution sonore en Algérie: Le décalage entre le cadre juridique et la réalité. Revue du droit public algérien et comparé, 8(2), 8–17. https://www.asjp.cerist.dz/en/article/208217

Bouzir, T. A. K., Zemmouri, N., & Berkouk, D. (2017). Assessment of Noise Pollution in the City of Biskra, Algeria. 11(12), 5.

Collins, A. & Oviasogie. (2019). Noise Levels and Periods of Noise Experience within Residential Environment in Benin City, Nigeria. I.O.S.R.I.O.S.R. Journal of Environmental Science, Toxicology and Food Technology, 13(12), 26–31. https://www.semanticscholar.org/paper/Noise-Levels-and-Periods-of-Noise-Experience-within-Collins/8798902b786228ea49a65df7fe20b6a7faafc350

de Noronha Castro Pinto, F. A., & Moreno Mardones, M. D. (2009). Noise mapping of densely populated neighbourhoods—Example of Copacabana, Rio de Janeiro—Brazil. Environmental Monitoring and Assessment, 155(1), 309–318. https://doi.org/10.1007/s10661-008-0437-9

Department of Transport: Welsh Office. (1988). Calculation of road traffic noise. H.M.S.O.H.M.S.O.

Dintrans, A., & Préndez, M. (2013). A method of assessing measures to reduce road traffic noise: A case study in Santiago, Chile. Applied Acoustics, 74(12), 1486–1491. https://doi.org/10.1016/j.apacoust.2013.06.012

Domazetovska, S., Phd, M., Gavriloski, V., & Petreski, Z. (2020, December 1). Analysis of the noise impact in urban areas in the city of Skopje. https://doi.org/10.48465/fa.2020.0600

Faulkner, J. P., & Murphy, E. (2022). Road traffic noise modelling and population exposure estimation using CNOSSOS-EU: Insights from Ireland. Applied Acoustics, p. 192, 108692. https://doi.org/10.1016/j.apacoust.2022.108692

Faulkner, J.-P., & Murphy, E. (2022). Estimating the harmful effects of environmental transport noise: An EUEU. Study. Science of The Total Environment, p. 811, 152313. https://doi.org/10.1016/j.scitotenv.2021.152313

Gouleme, J., & Boutin, C. (2009). PLAN DE PREVENTION DU BRUIT DANS L'ENVIRONNEMENT DE LA COMMUNE DE BERRE L'ETANG (13) (RA-080019-04-A; p. 30).

Hamou, A., Abderrahim, H., & Keciba, H. (2014). Etude des nuisances sonores dans la ville d'Oran. Communication science et technologie, 3(1), 01–08. https://www.asjp.cerist.dz/en/article/183012

Hornikx, M. (2016). Ten questions concerning computational urban acoustics. Building and Environment, pp. 106, 409–421. https://doi.org/10.1016/j.buildenv.2016.06.028

Human, J., & al Dulaimi, Y. (2023). Noise problems for land use in the city of Fallujah. Al-Anbar University Journal For Humanities, 20, 414–434. https://doi.org/10.37653/juah.2023.178177

Hunashal, R. B., & Patil, Y. B. (2012). Assessment of Noise Pollution Indices in the City of Kolhapur, India. Procedia - Social and Behavioral Sciences, 37, 448–457. https://doi.org/10.1016/j.sbspro.2012.03.310

Jamrah, A., Al-Omari, A., & Sharabi, R. (2006). Evaluation of Traffic Noise Pollution in Amman, Jordan. Environmental Monitoring and Assessment, 120(1), 499–525. https://doi.org/10.1007/s10661-005-9077-5

J.O.R.A.J.O.R.A. (2018). Algeria—Loi n° 18-11 du 2 juillet 2018 relative à la santé. International Labor Organization. http://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=en&p_isn=107479

K, S., & Deswal, S. (2023). A Comprehensive Review of Noise Measurement, Standards, Assessment, Geospatial Mapping and Public Health. Ecological Questions, 34, 1–26. https://doi.org/10.12775/EQ.2023.035

King, E., & Murphy, E. (2016). Environmental noise – 'Forgotten' or 'Ignored' pollutant? Applied Acoustics, pp. 112, 211–215. https://doi.org/10.1016/j.apacoust.2016.05.023

Li, B., Tao, S., & Dawson, R. W. (2002). Evaluation and analysis of traffic noise from the main urban roads in Beijing. Applied Acoustics, 63(10), 1137–1142. https://doi.org/10.1016/S0003-682X(02)00024-5

Meller, G., Magalhães de Lourenço, W., Melo, V., & Grigoletti, G. (2023). Use of noise prediction models for road noise mapping in locations that do not have a standardized model: A short systematic review. Environmental Monitoring and Assessment, 195, 1. https://doi.org/10.1007/s10661-023-11268-9

Mette, S., Kim, O., Anne, T., & Ole, R.-N. (2013). Road traffic noise and risk for breast cancer. I.S.E.E.I.S.E.E. Conference Abstracts. https://doi.org/10.1289/isee.2013.O-4-28-01

Murphy, E., Faulkner, J. P., & Douglas, O. (2020). Current State-of-the-Art and New Directions in Strategic Environmental Noise Mapping. Current Pollution Reports, p. 6. https://doi.org/10.1007/s40726-020-00141-9

Murphy, E., & King, E. A. (2014). Environmental Noise Pollution: Noise Mapping, Public Health, and Policy. Newnes.

Nipa, N., Seddique, A., Hossain, Md. M., & Amin, A. (2022). GISGIS Based Mapping and Assessment of Noise Pollution in Gazipur City, Bangladesh. Australian Journal of Engineering and Innovative Technology, 4, 121–129. https://doi.org/10.34104/ajeit.022.01070115

Nourmohammadi, Z., Lilasathapornkit, T., Ashfaq, M., Gu, Z., & Saberi, M. (2021). Mapping Urban Environmental Performance with Emerging Data Sources: A Case of Urban Greenery and Traffic Noise in Sydney, Australia. Sustainability, 13(2), Article 2. https://doi.org/10.3390/su13020605

Popescu, D. (2023). A study of the Romanian framework and the challenges in implementing the noise mapping legislation. Archives of Acoustics. https://doi.org/10.24425/aoa.2023.145233

Popescu, D., R.E, T., & Moholea, I. (2011). The Urban Acoustic Environment—A Survey for Road Traffic Noise. Carpathian Journal of Earth and Environmental Sciences, 6, 285–292.

Pronello, C., & Camusso, C. (2012). A Review of Transport Noise Indicators. Transport Reviews, 32(5), 599–628. https://doi.org/10.1080/01441647.2012.706332

Pyko, A., Roswall, N., Ögren, M., Oudin, A., Rosengren, A., Eriksson, C., Segersson, D., Rizzuto, D., Andersson, E., Aasvang, G. M., Engström, G., Gudjonsdottir, H., Jørgensen, J., Selander, J., Christensen, J., Brandt, J., Leander, K., Overvad, K., Eneroth, K., & Pershagen, G. (2023). Long-Term Exposure to Transportation Noise and Ischemic Heart Disease: A Pooled Analysis of Nine Scandinavian Cohorts. Environmental Health Perspectives, 131, 17003. https://doi.org/10.1289/EHP10745

Ravindran, G., Baskar, G., Keerthana, S., N., C., V., S., S., & Kannan, T. (2014). Assessment and analysis of traffic noise in urban area—Tirupur City, Tamilnadu, India. Pollution Research, 33, 79–88.

Rebah, M. (2018, January 13). Pollution sonore en Algérie: Un problème de santé publique ignoré. Journalistes Écrivains pour la Nature et l'Écologie. https://www.jne-asso.org/2018/01/13/pollution-sonore-en-algerie-un-probleme-de-sante-publique-ignore/

Rebah, M. (2022, April 29). Algérie: Gaspillage alimentaire et nuisances sonores. Journalistes Écrivains pour la Nature et l'Écologie. https://jne-asso.org/2022/04/29/algerie-gaspillage-alimentaire-et-nuisances-sonores/

Romeu, J., Genescà, M., Pàmies, T., & Jiménez, S. (2011). Street categorization for the estimation of day levels using short-term measurements. Applied Acoustics, 72(8), 569–577. https://doi.org/10.1016/j.apacoust.2010.09.012

Rossi, D., Mascolo, A., & Guarnaccia, C. (2023). Road Traffic Noise Predictions using L10 Modelling with a Multilinear Regression Calibrated on Simulated Data. International Journal of Mechanics, 17, 51–56. https://doi.org/10.46300/9104.2023.17.8

Roy, M. (2022). Evaluation of Environmental Noise in Urban Areas: A Noise Pollution Assessment Approach. Medicon Agriculture & Environmental Sciences. https://doi.org/10.55162/MCAES.02.012

Schwela, D. (2023). Guidelines for Environmental Noise Management in Developing Countries. https://doi.org/10.5772/intechopen.109952

Sheetal, D., S., & Thakar, A. (2023). Assessment of Noise Levels in Different Residential, Industrial and Commercial Areas of Jammu City, India. https://doi.org/10.53550/EEC.2023.v29i01s.008

Titu, A. M., Boroiu, A. A., Mihailescu, S., Pop, A. B., & Boroiu, A. (2022). Assessment of Road Noise Pollution in Urban Residential Areas—A Case Study in Piteşti, Romania. Applied Sciences, 12(8), Article 8. https://doi.org/10.3390/app12084053

Triplett. (2020). SoniChekTM Pro Professional Compact Sound Level Meter: Reads 30 to 130dBr, 31.5Hz to 8kHz Frequency Range - (3550). Triplett Test Equipment & Tools. https://www.triplett.com/products/3550-sonichek-pro-professional-compact-sound-level-meter

Tsai, K.-T., Lin, M.-D., & Chen, Y.-H. (2009). Noise mapping in urban environments: A Taiwan study. Applied Acoustics, 70(7), 964–972. https://doi.org/10.1016/j.apacoust.2008.11.001

USUS Federal Highway Administration. (2018). Noise Measurement Handbook (FHWA-HEP-18-065; p. 205). https://www.trb.org/Main/Blurbs/178011.aspx

WHO. (2018). Environmental Noise Guidelines for the European Region (2018). https://www.euro.who.int/en/health-topics/environment-and-

health/noise/publications/2018/environmental-noise-guidelines-for-the-european-region-2018
World Health Organization (WHO). (2018). WHO Housing and Health Guidelines—Executive Summary. WHO. https://www.who.int/publications-detail-redirect/WHO-CED-PHE-18.10

This Page is Intentionally Left Blank