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Assessment of Level of Service and Acoustic Impacts of Road Segment in Sousse City

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Abstract: The accelerated growth of the urban population and the expansion of cities, the intensification of economic exchanges as well as environmental concerns have made road traffic and its management one of the major challenges of sustainable development which causes especially in urban areas a higher traffic noise levels. The traffic growth of goods and people is the main cause of the saturation of traffic lanes and the difference between transport demand and supply is the cause of peak-hours congestion in large agglomeration. Therefore, this paper reports a case study to determine the level of service in the city of Sousse- Tunisia and study the performance of the different models of traffic noise. In the first part, it is found that the measured noise is mostly due to traffic noise. The second part determines the level of service of the road. The third part; compares the performance (equivalent sound level, Statistical noise levels and Root Mean Squared Error (RMSE)) of the most known traffic noise models and closest to the measured sites “Burgess”, “Griffith & Langdon” and CSTB.

Keywords: Equivalent Sound Level, Road Traffic Noise, Level of Service, Noise Level Statistics

1. Introduction

Road traffic encompasses several factors, including the geometry of road infrastructure, the behavior of drivers, the diversity of vehicle flows, etc. Roads have environmental impacts amplified by the traffic of vehicles using them. High population density, environmental problems come from noise pollution [1], this is the most aggravating problem for the environment, roads have been identified as the main source of noise pollution [2]. Road noise is the absolute biggest source of noise nuisance. It affects the health of individuals, it costs society dearly. These nuisances are becoming more and more worrying because of the increase in motorization in urban areas. Noise has adverse effects on human health and can adversely affect the quality of life [3]. Reducing nuisance at source, controlling traffic, and protecting receptors are the best solutions to reduce the harmfulness of nuisances. In addition, there are several methods of a noise assessment. Traffic noise prediction models are used to predict sound levels generated from the highway [4-7]. However, road traffic noise has been studied in serveal countries such as Sydney, Egypt, Turkey and Jordan [8-11].

In the present work reports on a study of traffic noise measurements. This research evaluated the noise generated on two main roads of a case study in the city of Sousse-Tunisia. The paper is organized as follows. After a brief introduction, we present, in section 2, introduces some background information about noise measurements and performance measure to determine the level of service. Especially, it also presents a brief description of three road traffic noise models. The methodology used in this study is described in section 3 while section 4 outlines the results and discussions. Conclusion is summarized in section 5.

2. Background Information

Noise is the set of sounds produced by vibrations perceptible by hearing, generally, the noise is an unpleasant or annoying hearing sensation produced on the body by complex and disordered sound vibrations [12]. The objective of this part is to present the different prediction traffic noise models.

Road traffic is the main source of noise pollution [13], it is the collective sound energy of motor vehicles. The intensity of road traffic noise [14] is essentially a function of the volume and type of traffic (cars, trucks, etc.), the type of engine and tires, and the layout and coating of roads. The noise level is also dependent on the speed of vehicles and the driver's behavior.

The noise measurements are discussed the models Burgess, Griffith & Langdon and Centre Scientifique et Technique du Batiment [15].

2.1. Performance Measure to Determine the Level of Service

The LOS [16] or the quality of operation for a given facility is a direct function of usage level or the flow of the facility. Take the case of a highway; there are only vehicles on the road, depending on the geometric characteristics of the road and the vehicle conditions drivers are free to choose the speed they want. As the volume or flow level increases; traffic congestion develops and the speeds of drivers are reduced and may be approaching zero. Therefore, the flow levels clearly affect the quality of the transportation operation facility [17].

For many transportation facilities, the level of service of a section of the facility described with LOS A to LOS F the best conditions to the worst operating condition, and this LOS qualitative description depends on the quantitative performance measures, the speed delay and traffic density [18]. The six level of service are:

A: complete mobility between lanes, it is a free flow.

B: maneuverability is slightly restricted it is an acceptable free flow.

C: Constant flow and the capacity to maneuver between lanes are limited.

D: approaching unstable flow.

E: unstable flow, the flow becomes irregular.

F: Collapse flow. The vehicles move with every vehicle in front of it at a steady pace.

The basic freeway segment applied a set of steps to estimate the LOS. The methodology can be applied directly to provide the target LOS for a given demand volume [19]. Figure 1 summarized the steps of automobile methodology for the road segment.

2.2. Road Traffic Noise Models (Burgess, Griffith and Langdan and CSTB Model)

Many models were proposed to estimate the traffic noise of roads in different environments such as Basic statistical models, Burgess model, Griffiths & Langdon model, CSTB model, CoRTN model, RLS 90 Model, CNR model, NMPB routes model, Stl 86+ model, ASJ model, and FHWA model [15].

Based on the traffic noise measurements on our study site, this study compares the performance of three road noise models: Burgess, CSTB and Griffith & langdan.

Burgess model [4] was used. in Sydney. It presents the equivalent sound level (Leq), it estimates the noise environment to one value of sound level for any required duration. It is designed to perform the sound source as a single number which is expressed by the following equation:

$$L_{eq} = 55.5 + 10.2\log(Q) + 0.3P - 19.3\log(D) \quad (1)$$

where Q is the traffic flow;

P is the heavy vehicles percentage;

D is the distance between the receivers to the noise source.

The Griffiths & Langdon model [20] used a method starting from the percentile level to the equivalent level:

$$L_{eq} = L_{50} + 0.018\,(L_{10} - L_{90})^2 \quad (2)$$

$$\text{with } L_{10} = 61 + 8.4\log(Q) + 0.15\,P - 11.5\log(D)$$

$$L_{50} = 44.8 + 10.8\log(Q) + 0.12\,P - 9.6\log(D)$$

$$L_{90} = 39.1 + 10.5\log(Q) + 0.06\,P - 9.3\log(D)$$

where L_{10} is the level overtakes for 10% of the time;

L_{90} is the noise at the site is only. below this level for 10% of the time.

The French "CSTB" [5] proposed a model which seeks a formula based on the average L_{50} to determine the equivalent emission level.

$$L_{eq} = 0.65\,L_{50} + 28.8 \quad (3)$$

$$\text{with } L_{50} = 11.9\log Q_{eq} + 31.4 \text{ if Q < 1000 veh/h in urban road}$$

$$L_{50} = 15.5\log(Q) - 10\log(L) + 36 \text{ in urban road.}$$

where Q_{eq} is the equivalent vehicular flows.

From the previous models, general expression of the acoustic equivalent level can be derived as:

$$L_{eq} = A \log Q\left[1 + \frac{P}{100}(n-1)\right] + b\log(d) + C \quad (4)$$

with

$$Qeq = Q * \left[1 + \frac{P}{100}(n-1)\right]$$

where A, B and C are coefficients and n is the acoustic equivalent.

3. Methodology

The city of Sousse contains a number of roads with a high traffic activity, especially during peak periods. There are major and minor roads that ensure the movement of people and goods. The choice of the study road is justified, on the one hand, by its location in the network road, so it connects the entrance to different areas. Figure 2 shows the areas related to the study road. On the other hand, it is located in a residential area which always poses a noise problem for the inhabitants.

The study area which is expressed in green (Figure 2), located approximately next to roundabout Sahloul “Tadjikistan Street” until Shoes Center Commercial Local. The length of section road is 438 m, the width of section road is 7 m.

The traffic data comes from a counting carried in the site from 7.30 am to 8.30 am, from 11.30 am to 12.30 pm and from 17 pm to 18 pm for 7 days. Monday 06/07/2020 to Sunday 12/07/2020. The traffic data collected by video to determine the traffic flow.

In the processing of videos, we were able to determine the vehicle flow of light vehicles, heavy vehicles, two-wheelers, and pedestrians every 5 min of the counting period for the two lanes exiting the road. We notice that, during peak hours 7:30 am - 8:30 am, 11:30 am - 12:30 pm and 5 pm - 6 pm, users are divided into four categories.

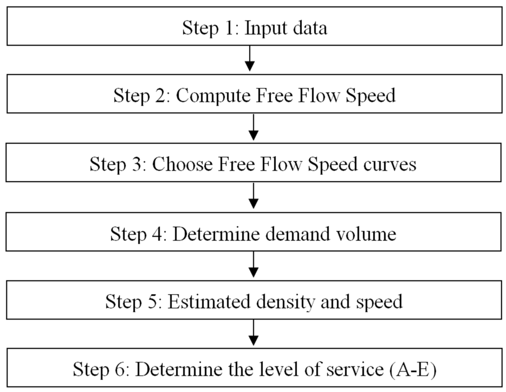

Figure 1. *Road segment methodology.*

Figure 2. *Location for the studied road.*

4. Result Analysis and Discussion

This section presents in the first part the level of service, the results, and the analyses got from the measured data and determine the statistics of the traffic noise level.

4.1. Level of Service

As an experimental support, the traffic flow has been performed in the study area at peak periods. However, the service level during the study period is established from Figure 1. The LOS obtained for the each peak hour during study week are summarized in Table 1. It is found that the LOS during the study period are A and B. In the following, a discussion will be evoked concerning the demand volume of the LOS:

i. The lowest service level (level B) is observed during the peak hour 11.30 am - 12.30 pm.
ii. The service level is low on Saturday. Consequently, the traffic volume is most important on Saturdays, especially the peak hours 11.30 am - 12.30 pm and 17 pm - 18 pm.
iii. The least traffic volume is on Sunday.

From this analysis The LOS in our situation is A and B this indicates that is a free flow. Traffic flows overhead the speed limit and motorists have between lanes complete mobility. Motorists have a high-level comfort and LOS A speeds are maintained.

4.2. Equivalent Sound Level

Traffic noise measurements have performed on the studied road. Figure 3 shows the equivalent sound level signal of study area for the three peak hour at Friday. As can be noticed, the sound levels are higher during the hour 7.30 am - 8.30 am and lower during the two peak hours. As attempt of explanation, the most people go to work at this hour. It can be seen that the equivalent sound level increases with the heavy vehicle percent. It is noticing that the heavy vehicle percent is not excessively high. For the equivalent sound levels, however, it is found to be 12.3% and 12.2% from 7.30 am – 8.30 am and 11.30 am – 12.30 pm higher than that 8.8% from 17 pm – 18 pm respectively. More especially, a higher equivalent sound level is attained for higher heavy vehicle percent, see Table 2. However, the equivalent noise level is lowest during the weekend. It should be noted that the equivalent sound levels depends of flow traffic and more significantly with heavy vehicle percentage. It can be seen that the noise levels in the city of Sousse are considered lower compared to other cities such as Istanbul, Cairo and Monastir [9, 10, 21, 22]. The equivalent sound levels, however, are generally higher than the limits set by the World Health Organization (WHO) [23] and the Tunisian environmental standards [24].

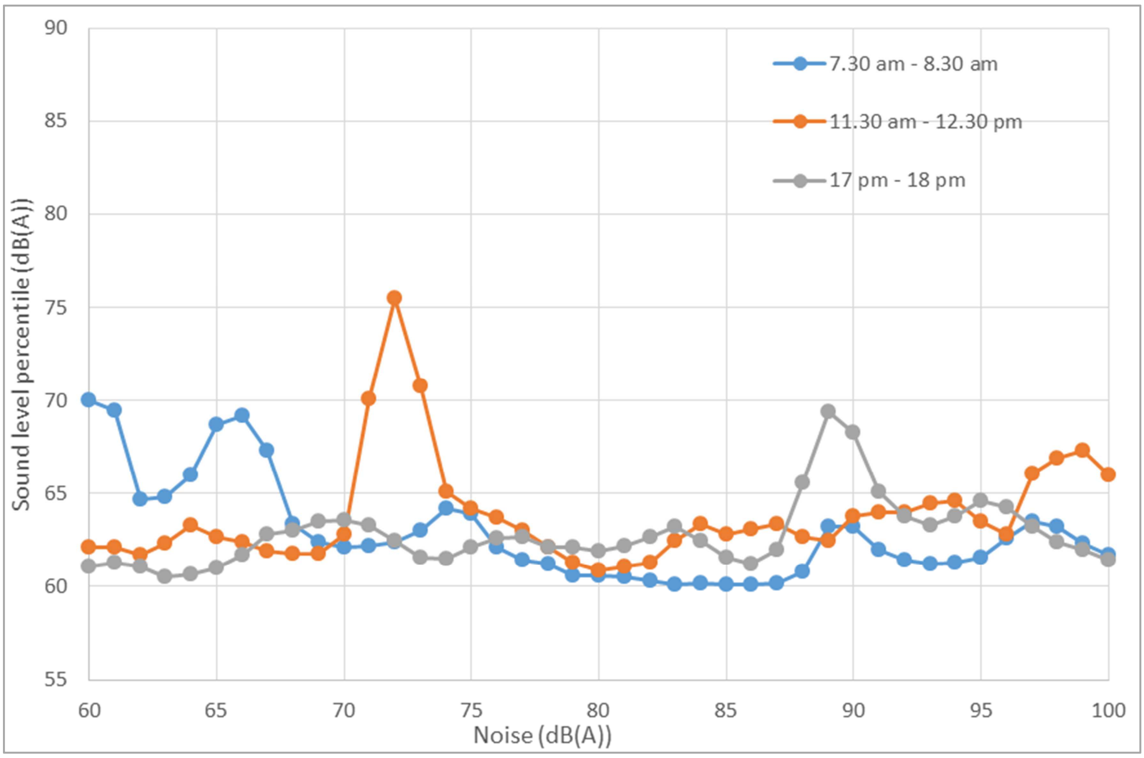

Figure 3. *Sound level signal of study area for the three peak hour.*

Statistical noise levels were also derived for the three hours using traffic noise measurements. From the equivalent sound levels, we have deduced the statistical noise levels L_{10}, L_{50} and L_{90}. The relevant values are listed in Table 3. As can be seen, the highest values are recorded at Monday especially in the 11.30 am – 12.30 pm hour and the noise levels exceed 79.62 dB(A), 72.12 dB(A) and 65.68 dB(A) for 10%, 50% and 90% of the time respectively. This increase is assigned to higher traffic density with vehicles exceeding an average speed of 40 km/h in area study and it is the first day of the week. An attempt to improve the environmental conditions is the banning hours and trucks and lowering the speed limit.

4.3. Performance of Three Road Noise Models

To determine the adequate road noise model for our study area, we have compared the performance of three road noise models discussed in Section 2. A best model of the road noise models is achieved for the minimum Root Mean Squared Error (RMSE). The RMSE can be expressed as [25]:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(L_{eq} - \hat{L}_{eq})^2} \quad (5)$$

where n is the measurements number L_{eq} and $\hat{L}_{eq}$ are the measured and estimated road traffic noise levels respectively. In calculating the RMSE, the traffic volume, heavy vehicle percent and the measured road traffic noise levels measurements have been taken from road traffic and noise data, see Table 2. Measurements are determined at a 5 m distance from the road center for study period. The RMSE for each model is determined from Eqs. (1) – (4). The RMSE values are summarized in Table 4. It can be noticed that the Burgess model outperforms the other two models. This clearly shows that the use of Burgess model is more efficient to estimated road noise levels based on the available traffic data in study area. An attempt to analyze the noisy area has also been made in order to find solutions to reduce the impact of road traffic noise.

Table 1. *LOS in the study period.*

Days/Time	7.30 am - 8.30 am	11.30 am - 12.30 pm	17 pm - 18 pm
Monday	A	A	A
Tuesday	A	B	A
Wednesday	A	A	B
Thursday	A	B	A
Friday	B	A	A
Saturday	A	B	B
Sunday	A	A	A

Table 2. *Measured values of Q, P and Leq.*

Days/Time	7.30 am - 8.30 am			11.30 am - 12.30 pm			17 pm - 18 pm		
	Q(veh/h)	P(%)	L_{eq}(dB(A))	Q(veh/h)	P(%)	L_{eq}(dB(A))	Q(veh/h)	P(%)	L_{eq}(dB(A))
Monday	1202	10.9	74	1286	10.7	81	1096	7.7	69.2
Tuesday	1199	10.0	73.2	1297	13.1	81.9	1168	8.0	72.2
Wednesday	1193	10.1	72.4	1144	8.7	79.6	1289	11.4	77.3
Thursday	1187	10.8	65.4	1316	12.9	70.8	1187	9.7	69.3
Friday	1235	12.3	71.1	1423	12.2	66.2	1252	8.8	66.9
Saturday	1137	9.1	64.5	1493	9.8	67.5	1255	5.7	66.2
Sunday	715	5.9	63.1	1082	3.3	64.6	1189	3.4	64.7

Table 3. *Statistical noise levels.*

Days/Time	7.30 am - 8.30 am			11.30 am - 12.30 pm			17 pm - 18 pm		
	L_{10}	L_{50}	L_{90}	L_{10}	L_{50}	L_{90}	L_{10}	L_{50}	L_{90}
Monday	79.37	71.80	65.37	79.62	72.12	65.68	79.03	71.37	64.95
Tuesday	78.36	70.96	64.55	78.65	71.33	64.91	78.26	70.83	64.43
Wednesday	77.51	70.24	63.85	77.35	70.04	63.66	77.79	70.60	64.20
Thursday	76.78	69.62	63.25	77.16	70.10	63.72	76.78	69.61	63.25
Friday	76.30	69.28	62.93	76.82	69.95	63.57	76.34	69.34	62.99
Saturday	75.44	68.43	62.10	76.43	69.70	63.34	75.79	68.89	62.55
Sunday	73.24	65.83	59.58	74.75	67.77	61.46	75.09	68.21	61.89

Table 4. *RMSE results for the three traffic noise models.*

Models RMSE	Burgess	Griffith & Langdon	CSTB
7.30 am – 8.30 am	0.63	0.76	0.92
11.30 am – 12.30 pm	0.78	0.85	0.92
5 pm – 6 pm	0.75	0.77	0.8

5. Summary

In the present work, we have investigated the road traffic noise levels in the city of Sousse. As has been shown, level of service is a free flow. This has led to sound levels are higher than the limits set by the Tunisian environmental standards. In addition, banning horns and speed lowering are recommended to reduce road traffic noise. The equivalent sound level, statistical noise levels and RMSE allows determine the adequate road noise model for our study area. As a consequence, the Burgess model is used to estimate road noise levels in the city.

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