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Analysis of Road Noise in Urban Highway in Casablanca Using PCA Method

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Abstract
In order to analyze the road noise from the road traffic in the immediate vicinity of a section of the highway at the level of the urban highway of the Casablanca city, we measured the road traffic noise during two periods "day and night." The road noise perceived by the human is a mixture of several sound waves from the speed of the engine, the bearing, shocks, and of the aerodynamics. The application of suitable materials during the construction of the roadway, and the rejuvenation of the automotive park has led to a net decrease in noise, even with a significant increase in the daily traffic. The results obtained showed that after the renewal of the bituminous coating, and the enlargement of roads, the flow of vehicles per lane, has decreased and has caused the fluidity of movement. This has led to a considerable decrease in the noise level roads in the vicinity of the urban highway. The reduction of the noise experienced by the bordering population has varied according to the daily periods from 9 to 23 db (A), which explains an important reduction of the noise during the noisiest periods in the day [10am-4pm], and a reduction during the night [6pm-8pm] and [6am-7am].

1. Introduction
Given the increase in traffic in the metropolis of Casablanca, the urban highway linking the district of Ain Harrouda to Lissassfa, presents a real problem for a fluid traffic during the day.
Initially the urban highway had 2x2 tracks as profile type, and which has been planned to be expanded in order to facilitate the traffic on this urban axis, who is clearly requested by the population of the Casablanca City.
The European Directive requires performing noise maps to help locate which urban areas are exposed to unacceptable noise levels, and to determine the percentage of the population which is affected by excessive noise levels. In the existing literature there are many relevant studies concerning noise annoyance and its effects on population [1– 7]. These types of reports are meant to give some insight to future action plans builders, since the Noise Law [8] requires that noise pollution action plans are established not only for those areas where noise quality objectives are not fulfilled, but also wherever the population is annoyed with noise even if the noise quality objectives are met.
The purpose of this study is to examine the level of the Noise generated by the traffic of light and heavy vehicles, in two cases of figure, namely before and after the tripling of the urban highway.
The initial hypothesis stipulates that the road noise is mainly generated by the bearing, that is to say the result of the contact between the tires and the road surface. Each vehicle emits a low noise variable during its travel on a flat surface, it is this that defines a point source issuing the noise.
The sources of vehicle noise can be classified in two categories: the first is the sources of noise controlled by the engine speed, and the second is the sources of noise ordered by the speed of movement. It results in a noise composed by several sound sources which combine together (Table 1). The predominance of a source is closely linked to the vehicle speed.

2. Materials and methods
2.1. *Study area*
Our study is interested to measure the noise generated by the whole of the vehicles on a section of the road with a length of 250 m, and during a time range from 6 am until 8 pm.The coordinates of the different points of measures are defined below in Table 2:

Table 1 The main noise sources for vehicles

The Source of the Noise	Type of the Source of the Noise	Comments
Engine noise	The source of the noise linked to the engine speed	The noise from these sources is often referred to as “noise from the power train” or “noise of propulsion.”
Noise of pneumatic contact/shod	The source of the noise related to the speed	The noise from these sources is called “bearing noise.”
Noise radiated by the vibrations and shocks of vehicle components		
Aerodynamic noise		

Table 2: Coordinates of measures points

Site	North	West	Distance from The Central Axis (m)	Elevation from The Road (m)
1	33°33’52.34"N	7°34’50.87"W	15	1.2
2	33°33’48.12"N	7°34’58.60"W	20	0.9
3	33°33’48.62"N	7°34’55.26"W	20	0.7
4	33°33’49.34"N	7°34’54.43"W	6	5.5
5	33°33’49.70"N	7°34’54.59"W	0	6
6	33°33’50.32"N	7°34’53.33"W	0	0
7	33°33’50.46"N	7°34’55.00"W	27	3.5
8	33°33’46.52"N	7°34’55.96"W	60	4
9	33°33’49.81"N	7°34’56.71"W	40	2.5
10	33°33’52.71"N	7°34’53.61"W	64	4.2

This map (Fig 1,2) shows the location of the points of measures in the case of the 2x3 track and in the case of 2x2 tracks:

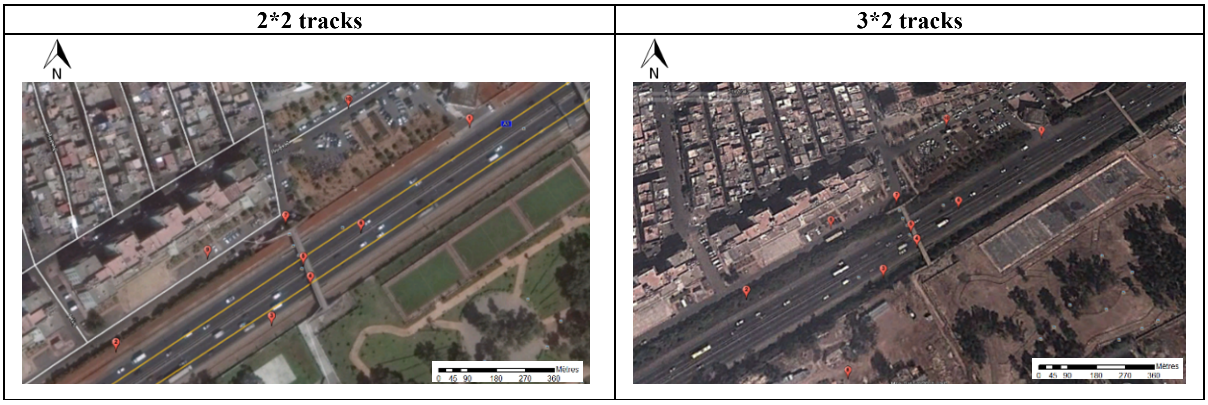

Figure 1: Study Area

The following parameters have been selected for the characterization of the noise in the vicinity of the urban highway:

- The remoteness from the highway central axis
- The elevation of the point of measures on the edges of the highway
- Leq (A) measured in site at one-hour intervals ranging from 6 am until 8 pm (active range of the day).

For each parameter, the equipment and the analysis method implemented have been described below:

Distance from the central axis:

The distance from the central axis has been calculated using a rangefinder “bush” to laser beams.

The elevation of the measuring point:

The elevation of the measuring points has been calculated using the GPS Garmin Map 62.

Leq db(A):

The noise has been measured using the Kimo Sound Level Meter DB 300 and Chauvin Arnoux CA 832. The measures were made during a time range from 6 am until 8 pm, with intervals of measures of an hour.

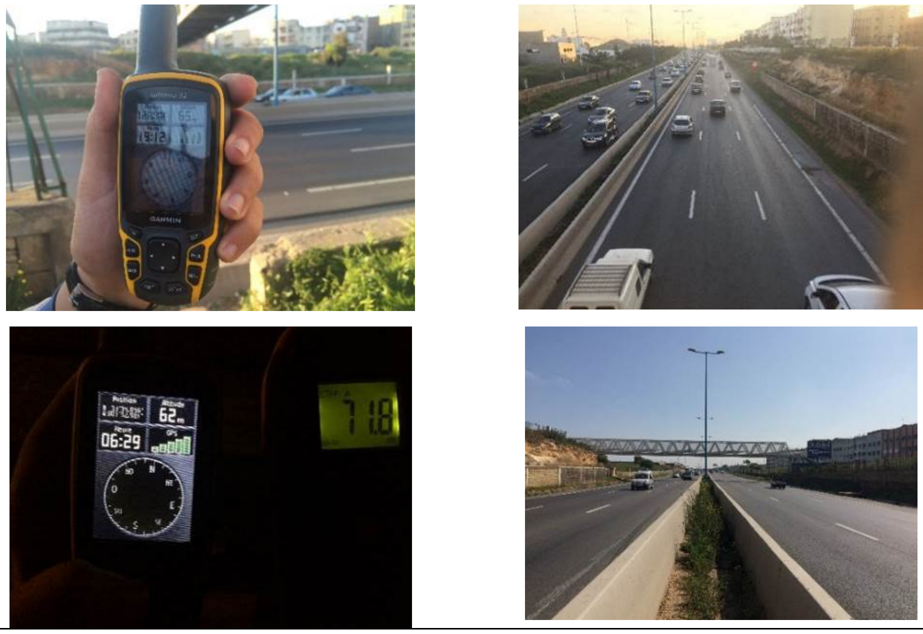

Figure 2: Field work

2.2. Statistical analysis

The Principal Components Analysis (PCA) is a statistical tool used to analyze large amounts of data by creating artificial variables (principal components PC or factors) which synthesize the information or reduce the number of original variables with minimum information loss. To create the PC it is necessary to identify the most relevant sources of data variability and then combine original variables into the new artificial PC. These PC can be used to easily display the individuals cloud and clusters and quickly visualize relations between them as well as to represent the highly complex structure of correlations between variables. The PCA also simplifies the latter cluster characterization.[9].

The method of principal component analysis (PCA) is one of Data Mining's most used and known methods. It belongs to the descriptive methods, family of geometrical models and sub-family of factorial analysis. When p variables describing n individuals of a population are all numeric, each individual can be represented by a point in a p-dimensional space. The set of individuals is therefore a cloud of points in the p-dimension space. When $p \leq 2$, the distance between individuals can be visualized, in the case of p=3, it still can be visualized but with difficulty, as for $p > 3$, this visualization is impossible. PCA intervenes when we desire to realize a reduction of the dimension of the space while conserving a maximum of represented information, it's a geometrical and statistical approach where we search for a new space where independent axes explain the variability of data [10]. The whole of the variables are quantitative, this is why we used of the PCA (principal component analysis). The whole of the statistical analysis has been made using the XLSTAT 2014.5.03.

2.3 Spatial Analysis

The calculations are made according to a simplified procedure for the French regulatory method [18], and can take into account noise sources from road transportation (light vehicles, heavy vehicles) and rail (tram only).

The calculation method is based on a 2D simplification of the regulatory French method “NMPB 2008,” adopted in the framework of the European Directive 2002/49/EC relating to the assessment and management of environmental noise. [14-18]

The interpolation of the results was made using the software OrbisGIS, after the digitalization of the residential areas and roads. OrbisGIS is a Geographic Information System oriented to scientific modeling. He wants a unified platform to create, process, edit, and share geographic vector data.

Acoustic measurements are made at the measurement points (for noise exposure calculations), or on a network of points obtained by a Delaunay triangulation mesh in the study area, with a refinement close to the traffic lanes and of the frame.

The OrbisGIS geographic information system fits into the broader context of the implementation of a Spatial Data Infrastructure Urban. It is one of the essential components for handling space data (create, update, processing, modeling).

Built on the basis of proven open-source technologies such as the library of operators and spatial predicates Java Topology Suite or the bookstore ImageJ, OrbisGIS allows crossing and visualizing 2D as well as vector data from databases or flat files as raster images

3. Results and discussion

3.1. *Before the tripling of track*

The table (Tab 3) below presents the results of the noise measurements for each site in the case 2x2 tracks.

TABLE 3: The measured noise (2x2 tracks)

2x2 tracks	**Distance from the central axis (m)**	**Elevation from the road (m)**	**Noise at 6 am, db(A)**	**Noise at 7 am, db(A)**	**Noise at 8 am, db(A)**	**Noise at 9 am, db(A)**	**Noise at 10 am, db(A)**	**Noise at 11 am, db(A)**	**Noise at 12 am, db(A)**	**Noise at 1 pm, db(A)**	**Noise at 2 pm, db(A)**	**Noise at 3 pm, db(A)**	**Noise at 4 pm, db(A)**	**Noise at 5 pm, db(A)**	**Noise at 6 pm, db(A)**	**Noise at 7 pm, db(A)**	**Noise at 8 pm, db(A)**
Site 1	17	2.1	71	69	75	74	82	85	87	85	86	82	82	83	83	77	78
Site 2	32	1.3	73	72	74	75	79	84	85	82	85	79	84	80	81	78	75
Site 3	15	0.7	73	75	78	78	82	85	87	83	84	83	86	82	78	79	78
Site 4	11	1	70	73	74	76	79	76	83	78	81	78	78	79	78	76	74
Site 5	2	5	69	74	79	82	81	80	82	80	83	81	82	79	81	78	79
Site 6	2	0	71	75	80	84	89	92	87	85	90	89	84	86	90	88	85
Site 7	21	3.5	68	71	75	72	68	78	80	79	81	80	79	82	81	78	75
Site 8	48	4	65	68	75	75	74	75	77	74	78	76	77	78	80	75	73
Site 9	40	3.8	67	69	76	72	73	74	75	76	77	74	80	82	84	78	75
Site 10	42	4.2	65	66	72	70	69	72	75	72	75	70	77	79	80	74	72

The analysis of normality test (Lilliefors), affirms that the whole of the variables follow a normal law.
The hypothesis H0 being the variable from which the sample follows a normal law, and the hypothesis H1 being the variable from which the sample is not following a normal law.
The p-value is greater than 0.05, since the p-value is large, we accept the null hypothesis H0, that the data are from a normal distribution.
For knowing the correlation between the different variables, we have conducted a principal component analysis in order to know the behavior of the different quantitative variables.
According to the Pearson (n) correlation matrix (Tab 4), we find that some variables are highly correlated between them with a correlation coefficient higher than 0.900 and which represent a period from 11am to 3pm, they coincide with the moment when the traffic is important, which means a rise in the level of the noise.
The factors F1 and F2 are only for themselves more than 82% of the information (Tab 5, Fig 3), which helps us to shrink the fields of analysis that on these two factors.
In the graph (Fig 4) below we conclude that the Sub variables of the noise are positively correlated to the factor F1, by against the other two variables are negatively correlated to the same factor.
From the present results, we conclude that the sites 8.9 and 10 have the same characteristics of position and elevation from the road, These sites have physical barriers to the spread of the sound wave. The perceived noise at the level of these sites is similar between them and mainly characterized by the two variables “distance from the central axis of the road, and the elevation from the floor.”
The sites 1, 2, 3 have the same characteristics of position. They are near to the floor with a low elevation.
Adding to this, the dendrogram below (Fig 5) allows us to individualize the two large groups, the first being the sites 8.9 and 10 and the second divided into two sub groups, the first (sites 5,6,1,3 and 4) and the second (site 2.7).

Table 4: The Pearson (n) correlation matrix

Variables	Distance from Central axis	Elevation from the road	Noise at 6am	Noise at 7am	Noise at 8am	Noise at 9H	Noise at 10am	Noise at 11am	Noise at 12am	Noise at 1pm	Noise at 2pm	Noise at 3pm	Noise at 4pm	Noise at 5pm	Noise at 6pm	Noise at 7pm	Noise at 8pm
Distance from Central axis	**1.000**																
Elevation from the road	0.157	**1.000**															
Noise at 6am	-0.525	-0.490	**1.000**														
Noise at 7am	-0.520	-0.603	0.850	**1.000**													
Noise at 8am	-0.700	-0.543	0.764	**0.912**	**1.000**												
Noise at 9am	-0.640	-0.625	0.651	0.808	0.888	**1.000**											
Noise at 10am	-0.750	-0.487	0.752	0.821	**0.947**	**0.918**	**1.000**										
Noise at 11am	-0.792	-0.337	0.829	0.853	**0.937**	0.829	**0.952**	**1.000**									
Noise at 12am	-0.867	-0.354	0.724	0.726	0.818	0.760	0.895	**0.912**	**1.000**								
Noise at 1pm	-0.822	-0.460	0.720	0.723	0.810	0.813	0.880	0.881	**0.973**	**1.000**							
Noise at 2pm	-0.827	-0.449	0.648	0.659	0.755	0.790	0.856	0.838	**0.963**	**0.979**	**1.000**						
Noise at 3pm	-0.804	-0.422	0.680	0.619	0.683	0.679	0.802	0.794	**0.960**	**0.947**	**0.971**	**1.000**					
Noise at 4pm	-0.736	-0.501	0.707	0.616	0.666	0.785	0.773	0.767	0.859	**0.929**	**0.936**	0.895	**1.000**				
Noise at 5pm	-0.784	-0.628	0.739	0.751	0.803	0.811	0.819	0.816	0.900	**0.959**	**0.934**	0.897	**0.931**	**1.000**			
Noise at 6pm	-0.812	-0.544	0.724	0.727	0.779	0.761	0.788	0.812	0.911	**0.962**	**0.926**	0.897	**0.913**	**0.991**	**1.000**		
Noise at 7Pm	-0.843	-0.432	0.702	0.714	0.784	0.792	0.816	0.843	0.930	**0.973**	**0.926**	0.884	**0.907**	**0.960**	**0.979**	**1.000**	
Noise at 8pm	-0.773	-0.596	0.733	0.778	0.811	0.828	0.809	0.808	0.880	**0.940**	0.883	0.843	0.881	**0.973**	**0.977**	**0.976**	**1.000**

Table 5 The statistics of the main factors

	F1	F2
Eigenvalue	12.0674	1.9012
Variability (%)	70.9849	11.1838
Cumulative %	70.9849	82.1687

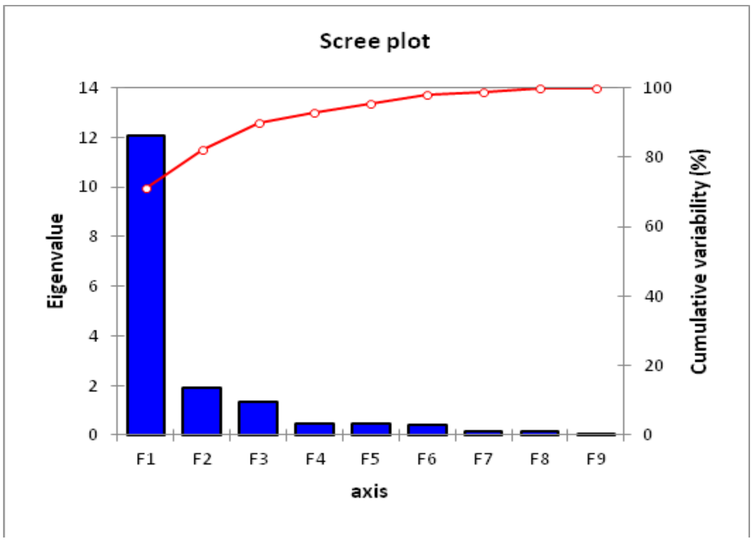

Figure 3: plot of Eigenvalue and cumulative variability

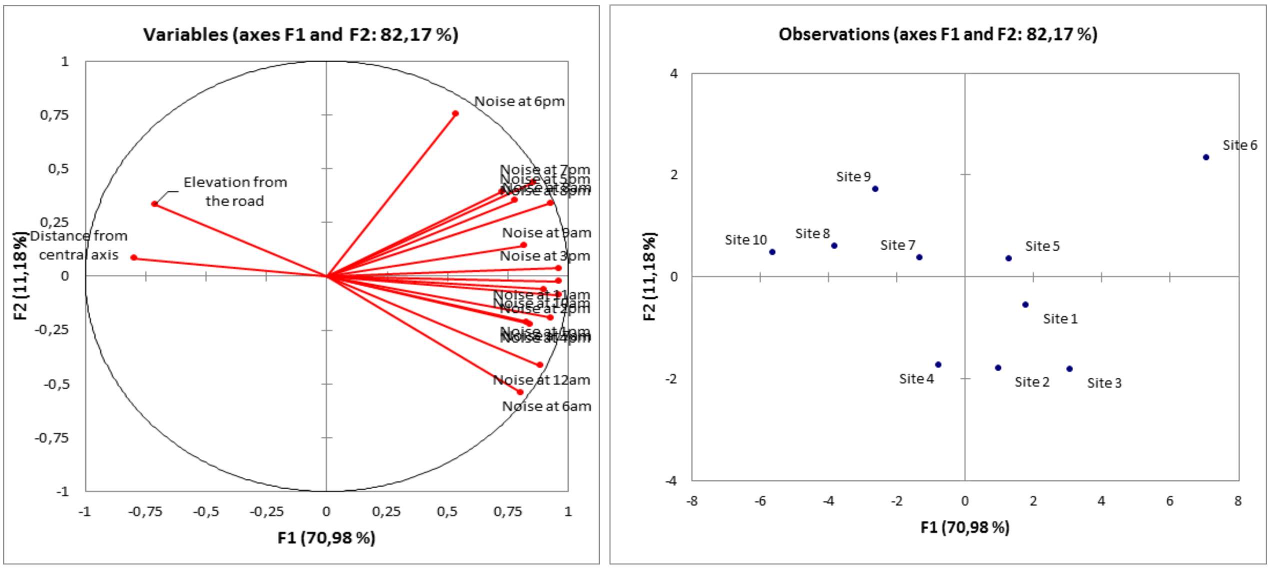

Figure 4: plot of variables and Observations

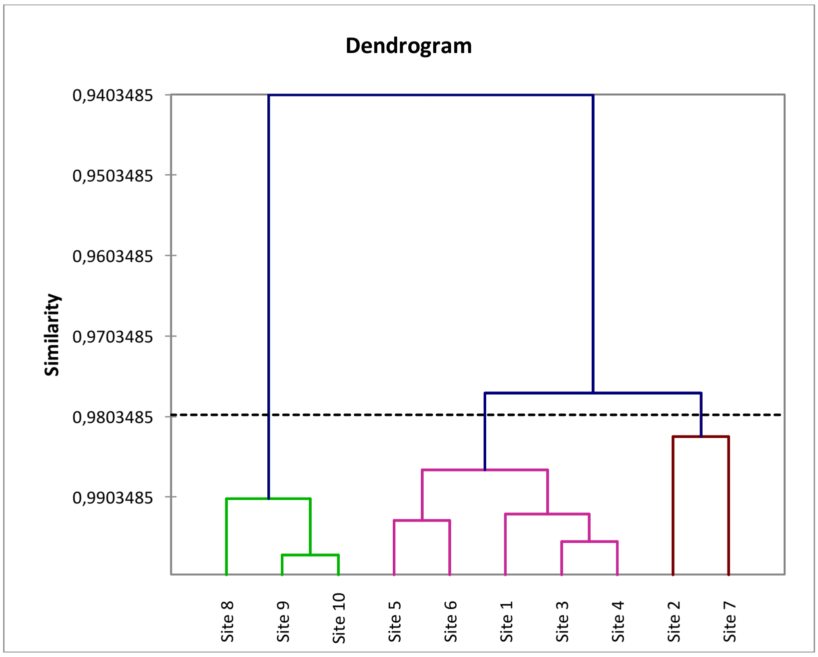

Figure 5: Dendrogram of PCA method (2x2 tracks)

According to the distributions of variables and the observations, we noted that two sections of times are individualized during the day, the first one is between [11am—4pm [and the second is between [5pm—7pm[. The Hours 06 am, 09 am, 12 am and 6 pm have the maximum and minimum values of the noise, which means that it is the period when the traffic is important or not.

3.2. *After the tripling of track*

The analysis of normality test (Lilliefors), affirms that the whole of the variables follow a normal law.

The hypothesis H0 being the variable from which the sample follows a normal law, and the hypothesis H1 being the variable from which the sample is not following a normal law.

The p-value is greater than 0.05, since the p-value is large, we accept the null hypothesis H0, that the data are from a normal distribution.

For knowing the correlation between the different variables, we have conducted a principal component analysis in order to know the behavior of the different quantitative variables.

The table (Tab 6) below presents the results of the noise measurements for each site in the case 2x3 tracks.

TABLE 6 The Measured Noise (2x3 tracks)

2x3 tracks	Distance from the central axis (m)	Elevation from the road (m)	Noise at 6 am	Noise at 7 am	Noise at 8 am	Noise at 9 am	Noise at 10 am	Noise at 11 am	Noise at 12 am	Noise at 1 pm	Noise at 2 pm	Noise at 3 pm	Noise at 4 pm	Noise at 5 pm	Noise at 6 pm	Noise at 7 pm	Noise at 8 pm
Site 1	15	1.2	62	64	70	71	68	69	70	71	70	65	68	72	73	72	70
Site 2	20	0.9	61	62	67	70	69	67	71	70	72	70	68	69	69	67	65
Site 3	20	0.7	63	64	68	65	66	68	72	71	72	71	67	72	73	69	67
Site 4	6	5.5	60	61	64	63	62	65	68	65	66	64	63	65	67	65	62
Site 5	0	6	58	60	67	65	67	68	72	70	71	68	64	67	69	68	63
Site 6	0	0	59	64	70	70	68	67	72	71	72	69	65	72	73	71	70
Site 7	27	3.5	57	58	60	62	59	60	68	68	69	67	66	68	70	68	65
Site 8	60	4	55	59	61	62	58	59	62	60	62	57	59	60	61	57	55
Site 9	40	2.5	56	57	61	60	58	58	62	60	61	58	59	62	63	58	57
Site 10	64	4.2	58	60	62	60	59	60	63	60	59	57	56	59	61	58	57

TABLE 7 The Pearson (n) Correlation Matrix

Variables	Distance from Central axis	Elevation from the road	Noise at 6am	Noise at 7am	Noise at 8am	Noise at 9H	Noise at 10am	Noise at 11am	Noise at 12am	Noise at 1pm	Noise at 2pm	Noise at 3pm	Noise at 4pm	Noise at 5pm	Noise at 6pm	Noise at 7pm	Noise at 8pm
Distance from Central axis	**1**																
Elevation from the road	0.4365	**1**															
Noise at 6am	-0.6147	-0.7770	**1**														
Noise at 7am	-0.8272	-0.5884	0.7471	**1**													
Noise at 8am	-0.6724	-0.2430	0.3867	0.7508	**1**												
Noise at 9am	-0.7615	-0.3926	0.4804	0.8210	0.8715	**1**											
Noise at 10am	-0.7048	-0.6731	0.7168	0.7182	0.6991	0.8504	**1**										
Noise at 11am	-0.6526	-0.7178	0.7942	0.6851	0.6564	0.7058	0.8512	**1**									
Noise at 12am	-0.7349	-0.7748	0.9162	0.7301	0.4757	0.6170	0.8282	0.8948	**1**								
Noise at 1pm	-0.7242	-0.6792	0.8807	0.6937	0.5871	0.5967	0.7997	**0.9351**	**0.9407**	**1**							
Noise at 2pm	-0.7441	-0.7034	0.8157	0.7286	0.6293	0.7318	0.8639	**0.9730**	**0.9275**	**0.9554**	**1**						
Noise at 3pm	-0.7973	-0.6380	0.7070	0.8018	0.7822	0.8015	0.8195	**0.9274**	0.8571	0.8989	**0.9451**	**1**					
Noise at 4pm	-0.5385	-0.5921	0.8716	0.7195	0.6442	0.5887	0.7308	0.8468	0.7917	0.8465	0.7844	0.7308	**1**				
Noise at 5pm	-0.4531	-0.5591	0.4480	0.3780	0.5475	0.3472	0.5067	0.7368	0.5145	0.6991	0.6685	0.7034	0.5709	**1**			
Noise at 6pm	-0.2558	-0.2375	0.0843	0.1505	0.5131	0.4156	0.4485	0.5527	0.1910	0.4081	0.5094	0.5028	0.2855	0.7771	**1**		
Noise at 7Pm	-0.5943	-0.5806	0.4743	0.6612	0.7760	0.7293	0.6972	0.8115	0.5480	0.6677	0.7691	0.8243	0.6243	0.8326	0.8102	**1**	
Noise at 8pm	-0.7629	-0.4897	0.5430	0.6996	0.8734	0.8397	0.8354	0.8741	0.6843	0.7911	0.8542	**0.9021**	0.7072	0.7806	0.7274	**0.9148**	**1**

According to the Pearson (n) correlation matrix (Tab 7), we find that some variables are strongly correlated between them and they are specific to the period from 12am to 8pm, who doesn't give an important variation of the noise level.

The factors F1 and F2 give more than 88% of the total information (Tab 8, fig 6)), which helps us to shrink the fields of analysis that only on these two factors.

TABLE 8: The Statistics of the Main Factors

	F1	F2
Eigenvalue	13.7040	1.2580
Variability (%)	80.6120	7.4001
Cumulative %	80.6120	88.0121

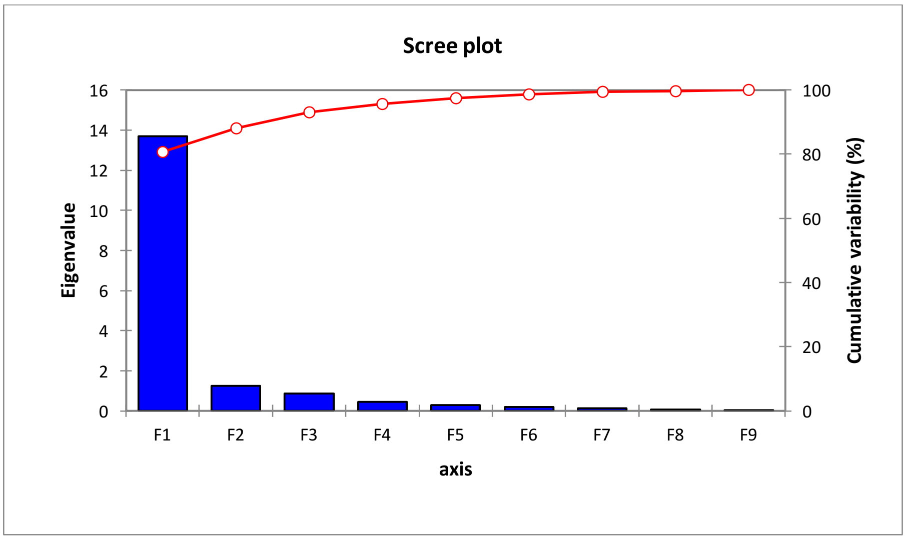

Figure 6: Plot of Eigenvalue and Cumulative Variability

In the graph below (Fig 7), we conclude that the Sub variables of the noise are positively correlated to the factor F1, by against the two other variables are negatively correlated to the same factor.

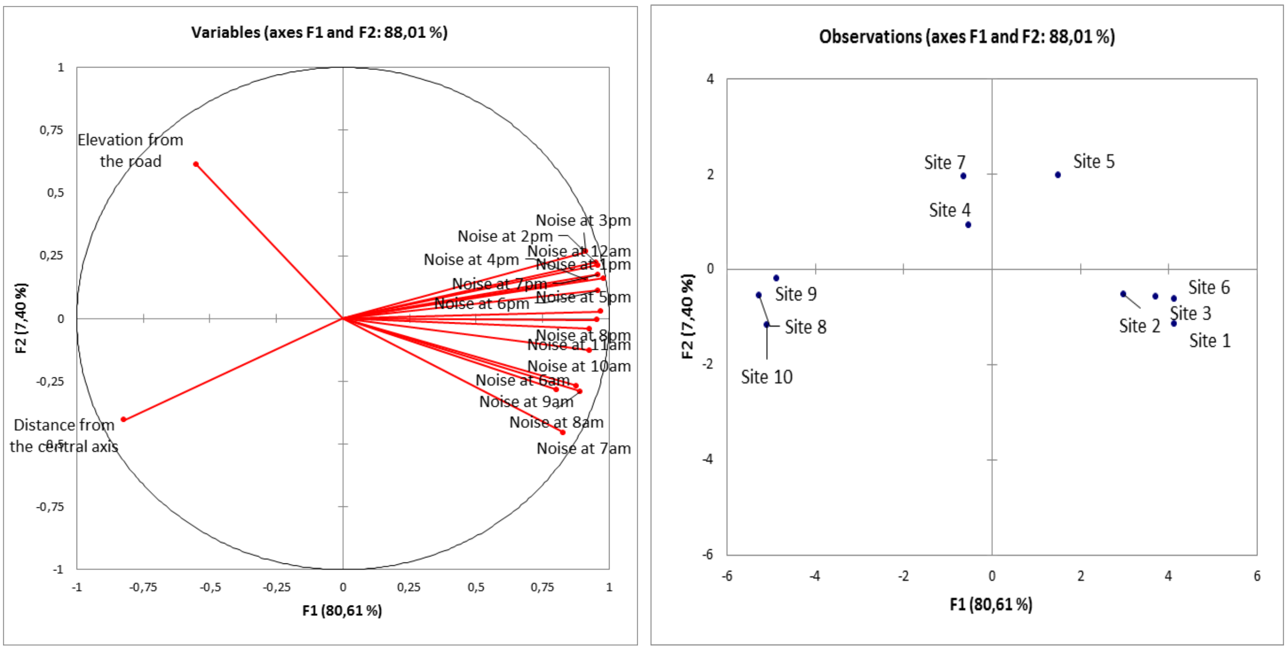

Figure7: Plot of Variables and Observations

From these results, we conclude that the sites 8.9 and 10 have the same position and elevation; these sites have some physical barriers to the spread of the sound wave. The perceived noise at the level of these sites is similar between them and mainly characterized by two variables "distance from the central axis of the road, and the elevation from the floor."

The sites 1, 2, 3 have the same characteristics of position. They are near to the floor surface.

Adding to this, the dendrogram below (Fig 8) allows us to individualize two large groups, the first is divided into two sub groups (site 9), and (site 8 and 10) and the second divided into two sub groups, (sites 5, 4, and 6) and (Site 7, 1, 2 and 3). According to the distributions of variables, we conclude that during the day just one period is individualized, it's between [10am—8pm[. It means that the perceived noise in the different sites is homogeneous.

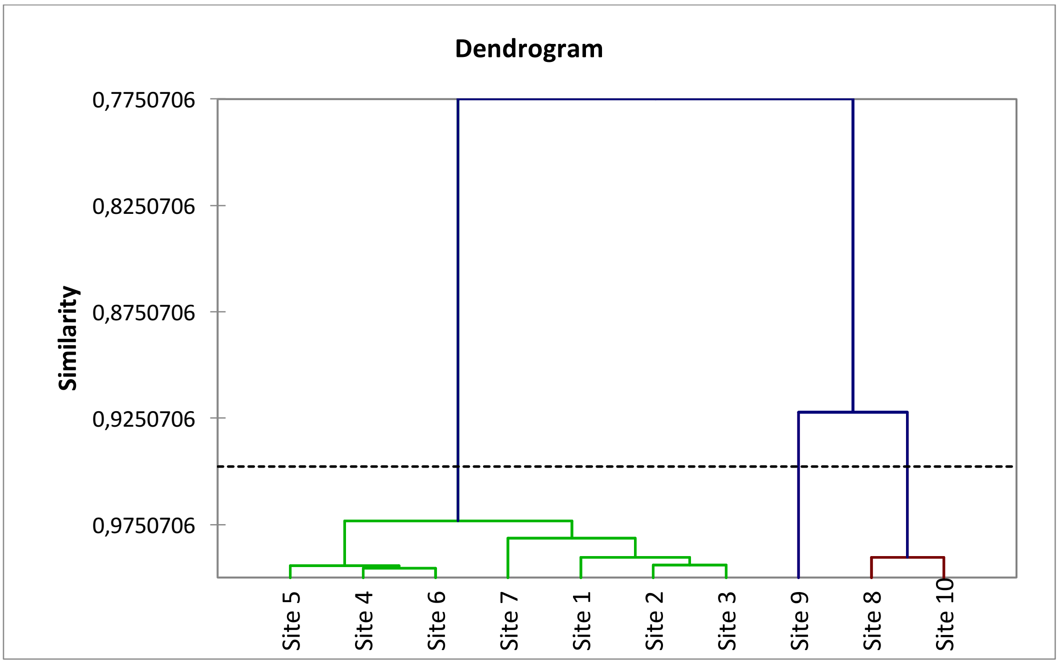

Figure 8: Dendrogram of PCA method (2x3 tracks)

3.3. *Analysis of the percentiles*

In the case of an important road traffic, the minimum distance between two vehicles in the same track is very reduced. This has a direct impact on the level of the noise levied in the vicinity of roads. It can be seen that the noise has been increased from 3 to 5 dB(A) on average. This is due to the addition of the sound waves.

When the sources are independent, we must make the sum of their powers. When we have two levels L1 and L2 of signals, the resulting level from mixing the two signals is estimated by:

$$L = 10\log(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}})$$

In this case two emitting sources of noise are perceived as a single source with a sound level much more important.

The coating on the floor which has been applied is the thinner bituminous concrete. This coating allows minimizing the noise of the bearing generated by the tire contact with the pavement. All these parameters lead us to conclude that the enlargement of the track doesn't have a negative impact on the soundscape, but it has been possible to reduce the level of the noise experienced by the surrounding population, and to decrease the risk of the creation of the traffic jams (Table 9,10).

TABLE 9 The main noise level (2x2 tracks)

Percentiles 2x2 Tracks	Noise at 6 am	Noise at 7 am	Noise at 8 am	Noise at 9 am	Noise at 10 am	Noise at 11 am	Noise at 12 am	Noise at 1 pm	Noise at 2 pm	Noise at 3 pm	Noise at 4 pm	Noise at 5 pm	Noise at 6 pm	Noise at 7 pm	Noise at 8 pm
Maximum 100%	73	75	80	84	89	92	87	85	90	89	86	86	90	88	85
99%	73	75	80	84	88	91	87	85	90	88	86	86	89	87	84
95%	73	75	80	83	86	89	87	85	88	86	85	85	87	84	82
90%	73	75	79	82	82	85	87	85	86	83	84	83	84	79	79
3rd quartiles	71	74	77	77	82	85	86	83	85	82	83	82	82	78	78

TABLE 10: The main noise level (2x3 tracks)

Percentiles 2x3 tracks	Noise at 6 am	Noise at 7 am	Noise at 8 am	Noise at 9 am	Noise at 10 am	Noise at 11 am	Noise at 12 am	Noise at 1 pm	Noise at 2 pm	Noise at 3 pm	Noise at 4 pm	Noise at 5 pm	Noise at 6 pm	Noise at 7 pm	Noise at 8 pm
Maximum 100%	63	64	70	71	69	69	72	71	72	71	68	72	73	72	70
99%	63	64	70	71	69	69	72	71	72	71	68	72	73	72	70
95%	63	64	70	71	69	69	72	71	72	71	68	72	73	72	70
90%	62	64	70	70	68	68	72	71	72	70	68	72	73	71	70
3rd quartiles	61	63	68	68	68	68	72	71	72	69	67	71	72	69	66

3.4. *Spatial Analysis*

In order to simulate the noise in the immediate vicinity of the study area, we used the Software Orbis GIS with the plugin noise map (open source) [11]. We have simulated just the impact of the main axis of the highway. The necessary inputs for the simulation are described in the following table (Tab 11):

TABLE 11: The indicators of speed and vehicles count

	Average Speed (km/h)	Junction Speed (km/h)	Max speed (km/h)	light vehicles count (unit/h)	heavy vehicles count (unit/h)
section of urban highway	75	10	80	2550	450

Using the tool of Noise simulation noise map with the software OrbisGis, we obtained the following map (Fig 9):

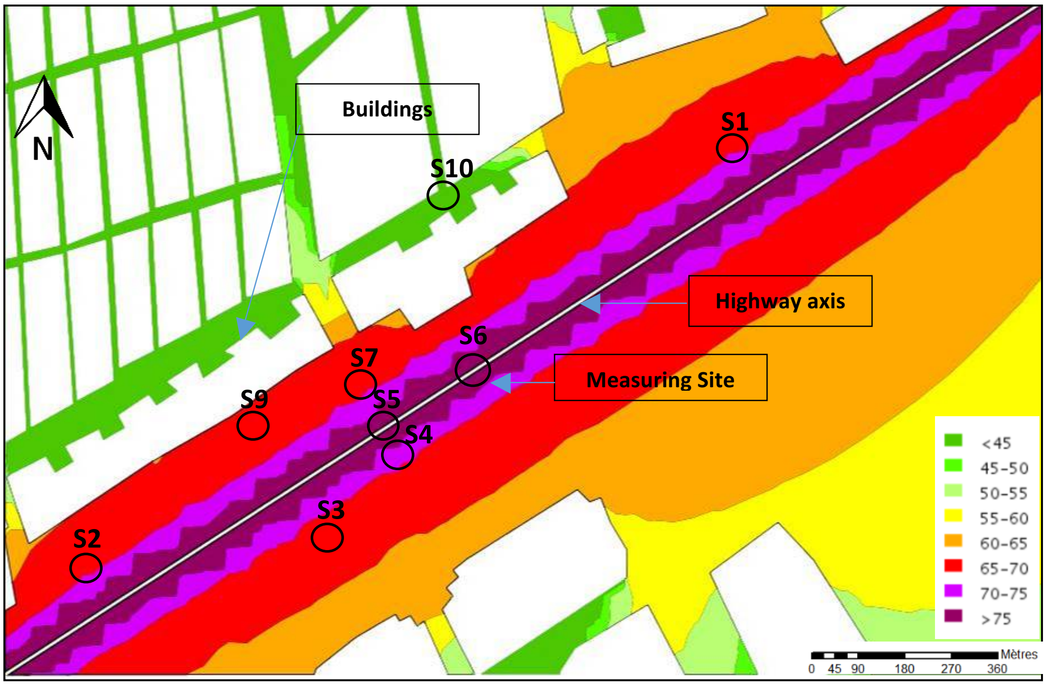

Figure 9:. Maps of simulated traffic noise in study area

The results obtained showed (Tab 12) that after the renewal of the bituminous coating, and the enlargement of roads, the flow of vehicles per lane, has decreased and has caused the fluidity of movement. This has led to a considerable decrease in the noise level roads at the vicinity of the urban highway.

TABLE 12 the percentiles of deviation of the noise experienced

The percentiles of deviation of the noise experienced	Noise at 6 am	Noise at 7 am	Noise at 8 am	Noise at 9 am	Noise at 10 am	Noise at 11 am	Noise at 12 am	Noise at 1 pm	Noise at 2 pm	Noise at 3 pm	Noise at 4 pm	Noise at 5 pm	Noise at 6 pm	Noise at 7 pm	Noise at 8 pm
Maximum 100%	10	11	10	13	20	23	15	14	18	18	18	14	17	16	15
99%	10	11	10	13	19	22	15	14	18	17	18	14	16	15	14
95%	10	11	10	12	17	20	15	14	16	15	17	13	14	12	12
90%	11	11	9	12	14	17	15	14	14	13	16	11	11	8	9
3rd quartiles	10	11	9	9	14	17	14	12	13	13	16	11	10	9	12

Conclusion

The perceived noise in the vicinity of the urban highway is a function of several factors. The new car manufacturers have helped to reduce the two main factors: the aerodynamic noise linked to the speed, and the engine noise. This explains that the noise frequently generated by the traffic is mainly linked to the noise of the bearing and the shocks of the bodywork of the heavy vehicles.

The reduction of the noise experienced by the bordering population has varied according to the daily periods from 9 to 23 db (A), which explains an important reduction of the noise during the noisiest periods in the day [10am-4pm], and a reduction during the night [6pm-8pm] and [6am-7am].

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