Effect of urban morphology on noise propagations for buildings adjacent main roads , case study : El Maadi , Cairo.

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Abstract. Cairo was recorded the second noisiest city in 2018. Noise pollution can affect badly on human health and daily activities. However, Egypt suffered from limitation of controlling noise's research. Planners and designers should be considering how controlling noise propagation at urban planning through determine the relation between urban morphology and noise paths. Here comes the role of this research, it aims to investigate the effect of some urban morphology parameters on noise propagations at selected case study. It was in Maadi, Cairo. The research workflow contained four stages. Firstly, defining urban morphology and its relation with noise propagations. Secondly, researchers visited the site to collate data and observe the traffic flow on weekdays and weekends during rush hour. Then simulate the selected case study on Predictor - LimA software to predict noise levels and create noise maps. Third, analysis noise maps to determine noise propagations characteries. Finally, link urban morphology parameters as buildings factors, road networks, landuses managements and human behaviours with noise separations. The results pointed out the most essential parameters affecting noise propagation and elaborated the direct relation between noise propagations and urban morphology to determine role of planners, governments, and vehicles owners to mitigate noise propagations.

1. Introduction

In 2050, more than half of world's population will reside the cities [1]. They need to increase housing, job opportunities, food supplements, health services and all aspects of urbanization parameters. Consequently, this increase will effect on water, food , air and noise. Consequently, earth can't meet all inhabitant's needs especially with the appearance of climate change phenomena. Several studies were proved the link between climate change and noise pollution. It wasn't a gas. But sources of green gases and carbon dioxide emission were a sources of noise pollution also [2]. Both emitted through transportation and fossil fuels. So, more noise means more suffering from global warming. So, decision makers and planners of cities should increase awareness of designing zero pollution cities or at least, consider the expected percentage of using transportation and noise levels emissions at planning phase to deal with it.

Planners and designers can control noise propagations at urban planning through consider the relation between urban morphology and noise paths. Urban morphology can be defined as a physical form of city and spatial structure by determining its patterns and relations of its components. It depends mainly on human activities and socio-economics forms. It was a result of the accrual of generations which attracted more activities and interests contributed to form urban patterns [3]. Sometimes, this pattern can reinforce sound separation or limit it. This separation can effect badly on human health , their life and daily activities. So, we should investigate the effect of urban morphology on noise propagations through the following.

Urban morphology contains many parameters were divided mainly between buildings and roads including all its properties. Firstly, determining the impact of building factors on noise propagations through building heights, geometry , orientation and facades' design. At 2017 , Zhiyu Zhou consider the relation between building heights and building facades noise level through generate a noise map for four residential neighborhood blocks with different road patterns in China [4]. It determines the negative relationship between high rise buildings with small footprints with facades noise level.

However, Baoxiang Huang and his team were analyze the relation between high rise buildings along expressways at China with acoustics amenity [5] to emphasis the relation between noise reduction and building height. Through creating an neural network to predict noise propagations which based in situ-measurements and factors effecting on propagations. It consider the acoustics amenity at 12 to 24 m (4-8 floor number) and higher than 54 m (floor number 15) was comfortable acoustics comparing with other heights. However, it was recorded a high level of sound level comparing with the acceptance range at quite zone. That defines the importance of building height as a parameter of controlling noise but with considering the surrounding sources of noise and its characteristics.

Most researchers define the distance between sound source and receiver as one of the most important aspects of controlling noise. This relation can control paths of source before reach the receiver. It can happened by orientation of building as an obstacle between source and receiver or geometry of building through limiting facades' length which exposure to noise source. Consequently, Jian Kang at 2017 in Uk, assess the wind turbine noise on building façade by using CadnaA software to consider the reduction of noise through urban morphology [6]. Through building orientation, geometry and differ distance between source and receiver which reduce noise up to 13 dB at the most noise exposure façade. At Turkey, Akdağ evaluated 25 alternative of mass housing with exposing different road types through simulate at Sound-Plan Software. In order to assess the façade noise at different floors levels of building. It consider the efficiency of noise reduction at Linear, C , L and U type of block [7] especially with adding noise barriers at the edge of road.

Road traffic was the top source of noise pollution at world [8] . There are many aspects attribute this pollution as road patterns, traffics density, vehicles types and speed. Combinations of all the previous elements with noise paths at urban form it led to many reflections, diffusion and scattering of noise paths many times between roads and building facades. That's mean receiving facades the noise pollutions especially with limitation of absorption materials at street, pavements, and facades.

Tang and Wang state the efficiency of narrow roads, complex road networks and higher of intersections at historical areas which lead to reduce noise pollution as the lowest of traffic density [9]. However, they suffered from carbon dioxide concentrations. In addition to verification of the lake of direct correlation between decrease or increase of vehicles' number with the rise or fall of noise level [10]. As behavior of some vehicle's owners, unauthorized parking, and horn usage lead to heterogeneous of traffic flow with lanes and increase noise levels. Consequently, urban planners should avoid design of this road pattern in new cities especially with the increasing of populations and global warming.

Sanchez demonstrated the importance of building shapes, street geometry and availability of street furniture as a method to reduce noise reflections at urban [11]. Through positioning the road and buildings on two levels or changing the geometry of buildings facades and noise barriers to be inclined upwards or concaves as it was having a higher relevance for lower floor buildings and pedestrians. Moreover, using balconies with inclined ceiling or self-shading windows or windows with triangular prominences had a good influence on noise reduction especially at the upper floors. That's mean the role of façade's design on controlling noise propagations. Consequently, urban morphology can deal with noise separation positively.

Moreover, noise was imposed according to landuses. It imposed a level of noise related to human activities. So, any area with special activity has an acceptance range of noise according to the acoustics organization or societies affiliated with it. For example, in Egypt, Ministry of Environment sets regulations for acceptance range of noise according to zone activity, table 1.

Table 1. Regulations of acceptance range of noise at Egypt [12]

Activity of zone	Morning (7 am to 10 pm)	Night (10 pm to 7 am)
Sensitive Area (Schools , hospitals and libraries)	50 dB	40 dB
Suburban with limited activities	55 dB	45 dB
Residential zones with commercial activities	60 dB	50 dB
Residential zones exposed road less than 12 m with some activities or commercials zones	60 dB	50 dB
Zones exposed road more than 12 m or industrial zones and other activities	70 dB	60 dB
Industrial zones with heavy activities	70 dB	70 dB

Sometimes planners exploit landuses around or adjacent the noise source as a buffer zone. They can control or mitigate noise levels through reshape its lands or manage land uses. As, Tammam measure the noise levels at lands around Sphinx International Airport at Egypt [13]. In order to investigate aircrafts noise wasn't affect on the surrounding cities. It determine the safety of the three cities around airport (Sphinx city , Zayed city and 6 th October city). They weren't affected by noise problems. However, the different of their activities (Residential Areas , Agricultural Resorts , Industrial Regions and Agriculture/Reclaimed Land), they subject the acceptance range regarding their activities. That's define the efficiency of manage land uses to mitigate noise.

In addition to human activities or their behavior sometimes be the source of noise. Consequently, Ming Cai measure and calculate noise levels at four regions with different activities and road types at Chancheng District, Foshan, China [14]. It found that acceptance noise level at most area except traffic boundaries area. It increased. Noise level increases at peak-off time more than rush hour. As increasing of traffic speed and traffic volume of traffic flow. So, awareness of noise pollution should increase between vehicles owners and inhabitants of cities to limit their speeds and noise level.

Egypt, Cairo was recorded the second noisiest city in 2018 [15]. However, a limited number of researches were determine the relation the aspects of urban morphology with noise pollution to consider noise contour mapping and predicated the useful. Consequently, it leads to create urban form doesn't respect any guidelines of controlling noise which can effect badly on populations. Here, comes the role of paper which aim to investigate the relation between urban morphology and noise propagations.

2. Background

With the development of Cairo and urban sprawl, the government created the Cairo Ring Road. It was the most important freeway in the Greater Cairo metropolitan area in Egypt. Its total length was 100 km which passes through many districts. It has many entrances, excites and road intersections which cause a huge traffic noise throughout the day. It wasn't caused only by the number of cars passing through, but its acceleration, fast travelling, exhaust, sudden stoppage, and vehicle types [16]. However, people start to construct their buildings themselves without considering aspects of design standards of buildings and urban morphology of cities. Most buildings were located adjacent to continuous noise sources from road without masking noise.

Unfortunately, Cairo was recorded the second noisiest city in 2018 [15]. In 2007, Ministry of Environment Resolution No. 223 of 2007 came to establish the Environmental Indicators and Reports Unit including The Noise department. They started a national network for monitoring environmental pollution levels has been implemented since March 2007 to date over the country [17]. However, there wasn't a documented noise map for all Cairo and a limited researches focus on considering traffic flow at Egyptian context [18]. So, The selected case study was located in Cairo, Egypt. Consequently, the research workflow contained four stages. Firstly, defining some urban morphology and its relation with noise propagations. Secondly, researchers visited the site to collate data and observe the traffic flow on weekdays and weekends during rush hour. Then simulate the selected case study on Predictor - LimA software to predict noise levels and create noise maps. Third, analysis noise maps to define the noise propagations. Finally, link the literature with results to define the effect of noise propagations on buildings and define role of planners, governments and vehicles owners to mitigate noise propagations, 'figure 1'.

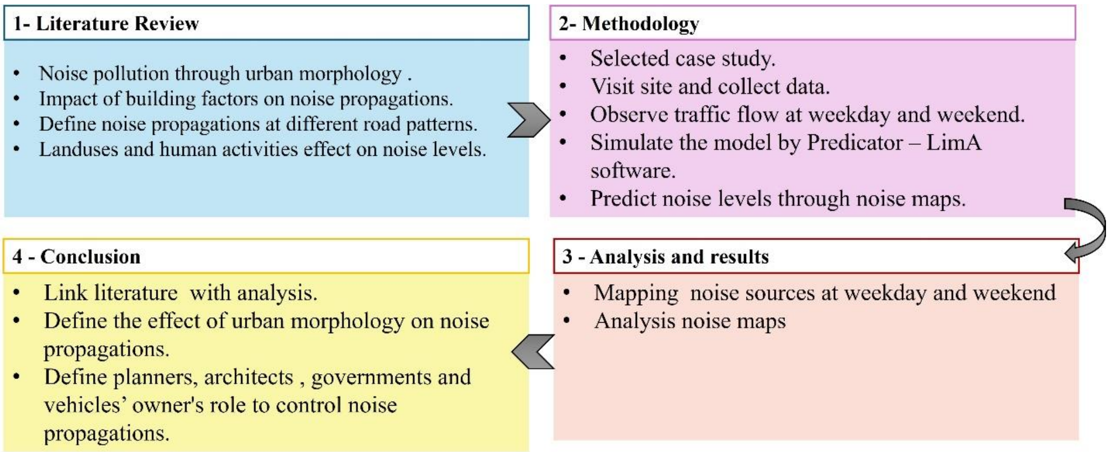

Figure 1. Research structure.

3. Case study :

The selected case study was at Maadi zone , Ring Road, Cairo. It was selected as it contains different building types. Some of them were a special purpose buildings such as Al Ahly Bank hospital , Modern Academy (private university) and Malvern Collage Egypt (international school). In addition to many office buildings such as Sama tower, retails , private clubs and residential buildings, 'figure 2'. All of the previous buildings were adjacent to Ring Road directly.

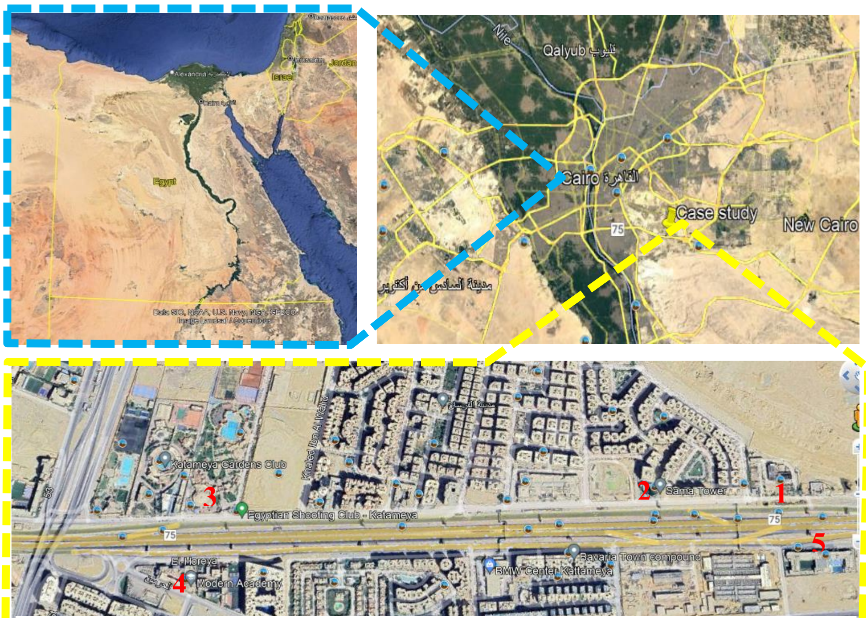

Figure 2 . The selected case study at Egypt, Cairo . 1) El Ahly Bank Hospital, 2) Sama Tower – office building , 3) Shooting Club , 4) Modern Academy and 5) Malvern Collage Egypt.

Firstly, the researcher visited the selected site twice on the weekend Saturday 9th of November 2023 and weekday Sunday 10th November 2023. The visit is at rush hour from 12 pm to 2 pm. Observed the building heights at two sides of road and counted the traffic flow through category them into light vehicles , motorcycles, Light trucks and heavy trucks. They counted all the lanes of road in two direction. Roads were divided into three categories of lanes with different speeds. First lane , the slowest lane adjacent to buildings , maximum speed should be 40 km/hour. The second lane should be 60 km/h and third lane were be 100 km/h for light vehicles, 'figure 3'. Measured L eq, L min and L max through mobile application to be as an indicator to calibrate with software.

Then simulate the case study to create the noise map by using Predictior- limA software. It was a simulation software tool used to predict noise maps on a vertical grid and horizontal grid. It allows the sound at different heights of buildings by locating receivers at facades of buildings. Sound power levels of software were based on several measurement methods, including ISO 3744, ISO 3746, and ISO 8297 [19].

4. Data processing:

Counting the number of cars was used as input data for roads. To calculate the emission noise from roads then record on receivers of facades. Receivers 1,2,3 & 4 located on façade on selected buildings at the Right side and 5,6 & 7 located on selected buildings at the Left side. They were located on 1.5 m , 5 , 10, 15 , 20 , 25 and 30 m levels on selected façade which faced the continuous noise (Ring Road) . They were fitted with different buildings height. It ranged between 6 m to 33 m, table 1. For roads , there are a different level between right side and parts of left one, 'figure 3'. The selected buildings were mainly at the first line of buildings adjacent to ring road.

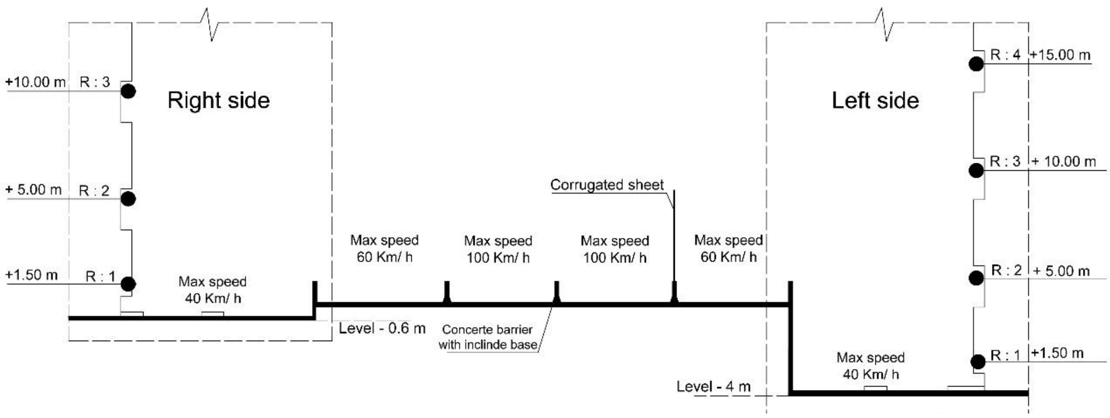

Figure 3 . Cross section at road showing left and right side of main road and receivers height.

Once simulate the model start to analysis the noise maps horizontally on roads and vertically on facades. Horizontal maps show the effect of traffic flow on main roads and secondary ones. Vertical maps show noise level at facades. To estimate the sound levels received at facades of building which effects on inhabitants at buildings adjacent to Ring Road.

5. Analysis and Results:

The selected case study was defined as a mixed-use area. The acceptance range of sound level for residential buildings shouldn't exceed 55 dB during the day and 45 dB at night [20]. To reach this acceptance range of sound level surrounding roads should achieve the acceptance range of sound at outdoor at least. It shouldn't exceed 60 dB during the day and 50 dB at night externally [12]. So, simulation of the model will be helpful to estimate the range of noise levels at weekends and weekdays.

On weekdays the noise level ranged between 78 dB to 85 dB , 'figure 4'. It was a huge difference between the required level and the real level. The noise map showed the highest level of noise at the middle of road which was recorded at 85 dB. That mainly happened at lane three in two directions then decreased gradually to the first lane. It was recorded between 80-83 dB. Unfortunately, the first lane was still out of the acceptance range of the required noise level. It was the nearest lane to the building. Consequently, receivers at facades will expect to record a high level of sound. It was located on mix-function facades at two sides of the road which means different acceptance ranges of noise levels internally.

On the right side , a receiver was located at 78-80 dB zone. On the left side, it was the lowest which was recorded at 77-78 dB. Although they exposed the same noise level, 'figure 4'. This difference happened as the left side has a contour lines different start from zero level to -4 m lower than the Ring Road level. It is defined as different in sound levels between two sides.

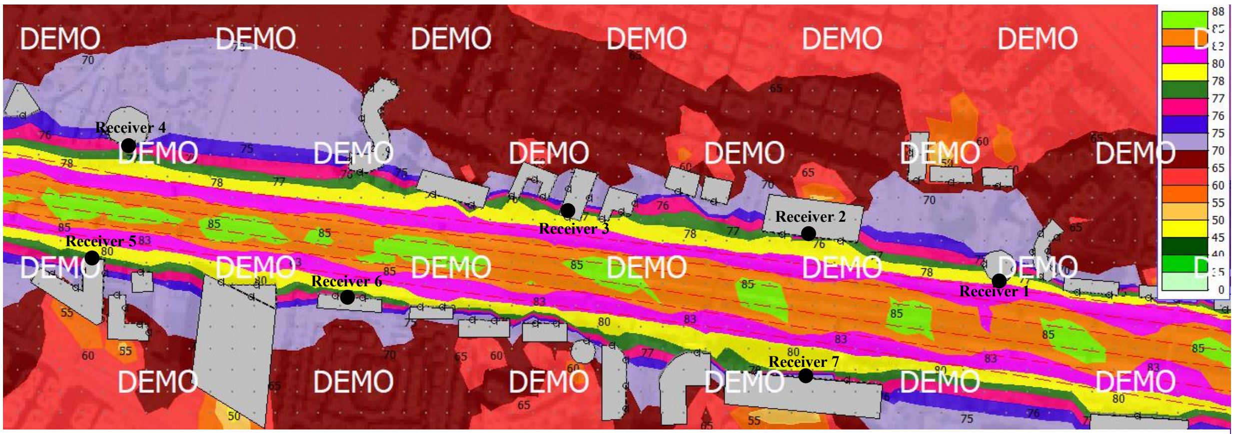

Figure 4. Noise map for selected case study at weekday.

Numerical values of (Leq) equivalent sound pressure level at different levels of facades were counted down gradually. The highest results were recoreded on the lowest floors and the lowest results were recoreded on the upper floors. The difference between the highest results and the lowest ones ranged between 1-2 dB only difference, table 2. On the right side, the receiver recorded a range between 81.9 to 78.8 dB. On the left side, the receiver recorded a range between 79.2 to 75.2 dB, 'figure 5'. There was still a huge difference between the required level at indoor spaces and the real sound at facades.

Table 2 . Receivers on buildings at different levels on weekday.

Building Functions	Right side				Left side		
	Office Building	Residential building	Residential building	Shooting club	Modern Academy	Residential building	Residential building
Building Height (m)	33	12	33	6	12	10	33
Receiver level (m)	Receiver 1 Leq	Receiver 2 Leq	Receiver 3 Leq	Receiver 4 Leq	Receiver 5 Leq	Receiver 6 Leq	Receiver 7 Leq
1.5	81.9	80.4	81.4	79	76.9	76	79.2
5	81.3	79.5	80.6	78.8	75.6	75.6	78.8
10	81	79.1	80.3	-	75.4	75.2	78.5
15	80.7	-	80.2	-	-	-	78.4
20	80.5	-	80	-	-	-	78.3
25	80.2	-	79.9	-	-	-	78.2
30	79.8	-	79.7	-	-	-	78.1

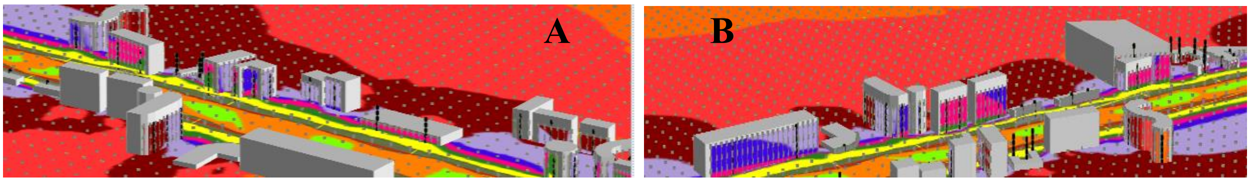

Figure 5. vertical grid showing façade noise map at weekday , A : Right side & B : Left side.

At weekend it was similar to weekdays , the highest results were recorded in the middle of the road and down gradually to the first lane on two sides of the road, 'figure 6'. Although, there are different sound levels. As the difference between number of vehicles between weekday and weekend. The highest level in the middle was recorded at 83 dB. Then down gradually to first lane to be ranged between 78 – 80 dB. That define the decrease of sound level between weekdays and weekends ranged between 2 to 3 dB on the noise map. Although, it was still out of scale of acceptance range of noise level outdoor.

Receivers on the right side were located at 75-76 dB range. On the left side, they were located at 70-75 dB range, figure 4. It shows the great difference between as contour different at the left side. Similar to results on weekdays.

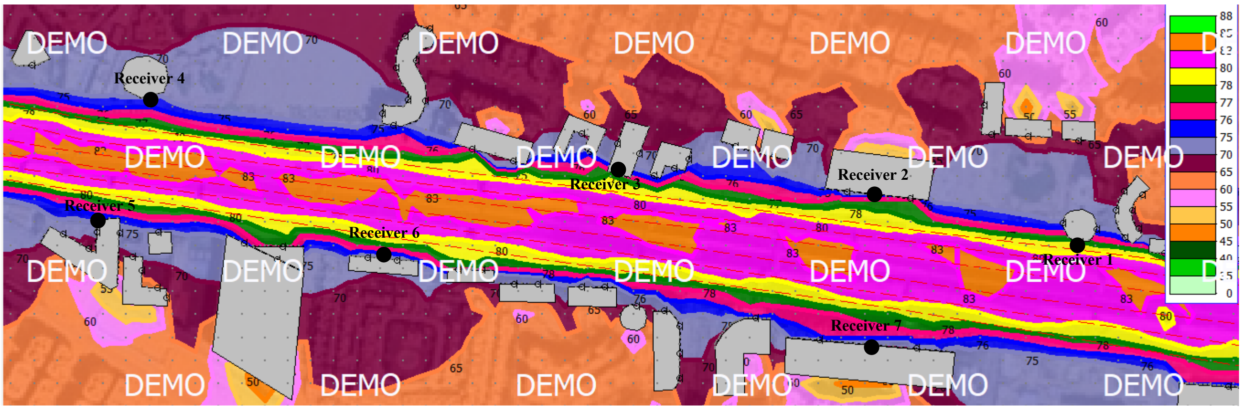

Figure 6 . Noise map for selected case study at weekend.

For numerical values of the receiver's facades, Leq was counting down gradually similar to weekdays. The highest results at lower level and the lowest levels on the upper floors, table 3. On the right side, it ranged between 80.5 to 77.2 dB, 'figure 7'. The difference in facades levels and comparison between receivers at the same level were recorded range between 2 to 3 dB difference. On the left side, it ranged between 78.5 to 73.2 dB. For comparing at vertical level between the first and the last receiver a 2 to 3 dB difference. However, when calculating the difference at the same level of receivers' the difference can reach 5 dB difference. It happened as contour line -4 m was located exactly at receiver 6 . It was the lowest results at all levels at two sides. Although, It was still over than the acceptance range of noise should be outdoor.

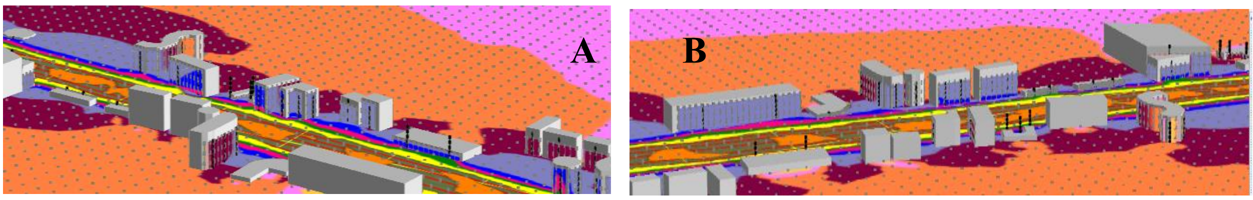

Figure 7 . vertical grid showing façade noise map at weekend , A : Right side & B : Left side.

Table 3. Receivers on buildings at different levels on weekend.

Building Functions	Right side				Left side		
	Office Building	Residential building	Residential building	Shooting club	Modern Academy	Residential building	Residential building
Building Height (m)	33	12	33	6	12	10	33
Receiver level (m)	Receiver1 Leq	Receiver 2 Leq	Receiver 3 Leq	Receiver 4 Leq	Receiver 5 Leq	Receiver 6 Leq	Receiver 7 Leq
1.5	80.5	78.9	79.8	77.6	78.5	73.8	77.3
5	79.9	78	79.1	77.2	77.5	73.4	77
10	79.6	77.7	78.8	-	77.3	73.2	76.6
15	79.4	-	78.7	-	-	-	76.5
20	79.1	-	78.5	-	-	-	76.4
25	78.9	-	78.4	-	-	-	76.3
30	78.7	-	78.3	-	-	-	76.2

6. Discussion :

Analyzing the results showed a high percentage of sound levels at middle-of-road lanes and decrease gradually to the edge of roads. However, the sound level was still above the acceptance range as the worst of noise propagation. So, according to literature review we should determine the relation between urban morphology parameters and noise propagation to understand the reasons for bad propagations as the following :

Urban Morphology parameters

1- Building Factors

- **Building height :**

Upper floors were less suffering of noise level than lower ones.

- **Building Geometry :**

Most building were rectangular from (a) , (b).

- **Building position :**

Locating the long edge of building parallel with road. As, most sellers increase department price for view (a) .

- **Facades design :**

Mixed between windows , balconies and curtain walls according to different design , function and owners of building (a) , (b).

2- Road Network

- **Road Type :**

Using concrete asphalt without any absorption materials.

- **Road Width**

Eight lanes of road with different directions which decrease the reflection between building facades but increase diffusion and diffraction.

- **Noise Barriers:**

Using flat with inclined base concrete barrier 90 cm between lanes at most road and adding at limited parts corrugated sheets with metal supports as a noise barrier height 3.00 m (C).

- **Road Levels :**

  - Main road almost have a same level at all directions.
  - Most areas of two road's side are almost at same level except part on right side lower – 0.6 m lower than the main road but without any effect on lower floors.
  - Part of left side only lower than main road -4 m which decrease the noise level at lower floors (d) .

3 - Landuses

Less efficiency of landuses management as evidence of availability special buildings purpose as school , hospital and collage adjacent road without any special noise barrier. However, there are a perfect selection of locating club and retails adjacent road at first row. As it can work as a buffer zone for second row of building which adjacent Ring Road.

4 - Human behaviors

Although the rules of limiting the speed to control noise and avoid accidents. There are some vehicle's owner break the rules and acceptance range of speed in addition to use car's horn without any limitations.

According to analysis of selected case study, we can determine the weakness at urban morphology which affects badly on noise propagation and human health . Firstly, building factors, however the lower level of noise at upper floors it was still suffering from noise pollution. That's mean the needs of using passive acoustics designs at design phase as change the geometry of buildings and position or shortness the edge buildings facing noise source or using absorption materials at facades or balconies or increase the distance between facades of buildings (receivers) and roads (source of noise) as possible. Subsequently, external noise level at facades of buildings and percentage of sound penetration were limited and designers can mask external noise significantly.

Secondly, road networks, with growth of population and urban expansion required of highways with special characteristics were increased to mitigate noise propagation. Consequently, roads should be an efficient acoustics road through using an absorption asphalt or locate barriers with special requirements along road according to expected noise level or change the level between road and buildings levels. To mitigate noise propagations.

Third, landuses management can control by coordinating between planners and government. The first one can plan efficient roads and side roads to limit noise propagation. For second one they should be aware with the acceptance type of buildings can be located adjacent to highways and refuse giving a construction permission to any building except limited types. To control the bad effect of noise on users' of special type of buildings and its inhabitants.

Finally, human behaviors, vehicle's owner should be aware about harmful effect of noise propagations on their life and inhabitants of their cities. They should control their speed according to traffic rules and limit usage of car's horn. To mitigate noise pollution.

7. Conclusion :

Results elaborated the direct relation between noise propagation and some urban morphology parameters as building factors, road network, land uses management and human behaviors. So, we should increase the awareness between government, planners, architects, and populations to control noise propagation. Government should set limitations on constructing a special purpose building adjacent highway. Urban planners should be aware about urban planning and fabric patterns through using barriers, contours, absorption materials or do any other treatments to control sound directions. Designers should treat facades and care about locating sensitive spaces or opening adjacent a continuous outdoor noise as road. Separating the awareness between vehicle users for using horns or high their car speeds. In addition to the importance of repairing their vehicles. Consequently, treating this weakness was a high cost to solve the problem but, priceless for human health.

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