PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

The Importance of an Urban Interpretation of Environmental Noise. The case of Mexico City.

Fausto E. RODRÍGUEZ-MANZO[1], Elisa GARAY-VARGAS[1], Laura LANCÓN-RIVERA[1], Dulce PONCE-PATRÓN[1], Silvia GARCÍA-MARTÍNEZ[1]

Universidad Autónoma Metropolitana, Azcapotzalco México

ABSTRACT

Cities are the space where environmental noise finds its most evident manifestation. For this reason, it can be considered that environmental noise is a problem that concerns urbanism and in many cases is also a reflection of poor urban planning. This paper shows a methodology that incorporates urban analysis to find the relationships that exist between urban aspects and environmental noise in public space, in representative areas of the city. The urban environment is analyzed through statistical and cartographic data and noise maps to show the impact of environmental noise with greater definition. The analysis of the sound environment is also incorporated by means of binaural sound registers and acoustic measurements. Some specific examples of the interpretation of data and contributions to the study of environmental noise are shown through the joint analysis of the various urban, social and demographic factors that make it up. The sound environment of cities, perhaps the most important element in the perception and definition of the character and urban image of cities is still absent from the concepts of urbanism and what this study presents is a possible approach to incorporate it.

Keywords: Environmental noise, Urban planning, Soundscape

1. INTRODUCTION

A proposed methodology is presented here to include environmental noise in urban planning projects and studies. It is considered that it should be part not only of environmental impact studies, but also within the normal practice of urban planning. The way this is possible is by incorporating the correlation of urban aspects with the analysis of environmental noise and soundscape.

In this study, a case study is used from a very important urban axis of Mexico City where an analysis is carried which goes from the general to the particular, first considering the axis in its entirety and then disaggregating it into 12 zones, of which three are here presented.

Thus, this methodology considers not only noise maps, but also contrasts urban cartographies with each other as well as integrating the analysis of urban space, a central theme in the reflection of the city as a space for people.

2. URBAN PLANNING AND ENVIRONMENTAL NOISE

2.1 The City and Sustainable Development

According to the report of the Department of Economic and Social Affairs of the United Nations Organization (1) more than half of the world's population lives in cities, and its growth continues to rise. That means an important burden for urban management and sustainable development: "Urbanization will continue and will do faster in low- and middle-income countries," highlights the document.

Large population centers with more than 10 million inhabitants known as Megacities are proliferating throughout the world. The consequences for this are the accumulation of economic,

[1] rfme@correo.azc.uam.mx

social and environmental problems.

The New Urban Agenda (NUA) (2), states that: ". . . governments must undertake policies that improve the quality of life for both urban and rural dwellers, while strengthening the links between them. It is about making the benefits of urbanization inclusive, ensuring that everyone, regardless of their place of residence, has access to decent work, health care, training and a safe environment." This corresponds to the vision of the sustainable development.

The NUA finds that cities can be a source of solutions and not the cause of problems if they are well planned and managed. It considers that urbanization can be a powerful instrument for the achievement of sustainable development at all levels, poor countries and the developed or rich. Its main objectives are:

- Sustainable urban development for social inclusion and the eradication of poverty
- Sustainable and inclusive urban prosperity and opportunities for all
- Resilient and environmentally sustainable urban development.

Thus, at NUA environmental and public health aspects are considered, as well as population mobility, especially transport, air pollution and **noise**. On the other hand, the creation and maintenance of well-connected and distributed networks of quality public spaces, open, safe, inclusive, accessible, green and intended for multiple purposes, is also considered. Promoting cities, human settlements and urban landscapes that are attractive and livable is also a priority.

2.2 Sound, Noise and Urban Environment

Human being has lived surrounded by sound, an element that has generally escaped the consideration of urban development, planning and design, including green movements, and sustainable development, in whose texts the problem of noise is generally not mentioned.

The urban evolution of the world has been in a line of deterioration in the last fifty years. The ideas of urbanism that "modernized" cities have acoustically damaged the human and living being habitat.

These ideas, which generated new urban paradigms, produced also a lot of urban problems, for their focus on the automobile. The excessive growth of the number of cars and in general of vehicles in circulation, as well as the infrastructure to serve them, have turned cities into cities for automobiles.

In cities such as Mexico and in general in Latin American cities, the vehicular and road growth has been exponential. This situation has had to do with urban disorder, and a lack of road planning and at least in Mexico City, due to the pressures of the automotive industry as well as urban sudden projects. Today in Mexico City, road traffic noise, like many cities in the world, is the main source of noise pollution.

2.3 The Role of Noise in Sustainable Urban Planning

What has been proposed by the NUA (2), concerns also to the world of acoustics and especially the urban environmental noise issue. Environmental noise as a problem in urban environments are an important part of sustainable, inclusive, socially responsible, environmental and resilient development.

The problems of generating environmental noise and its health and social effects have a lot to do with the way cities are planned and managed. It is at the same time a problem of quality of life and wellbeing of population that cannot be ignored when planning the city. That is why it is very important to relate the urban and acoustic aspects of the city with the planning process of the city.

2.4 Mexico City Urban Conditions

The City of Mexico, although named city, is a conglomerate where municipalities and districts of two entities are mixed: 16 mayors of the City of Mexico before delegations of the Federal District and at least 18 municipalities of the State of Mexico. That is, the metropolitan area of Mexico City known as the Metropolitan Zone of the Valley of Mexico (ZMVM).

Its population exceeds 20 million inhabitants and more than 8 million cars circulating daily for its more than 2 thousand kilometers of primary roads (3). It has an inefficient public transport network, and, in many cases, people must cross the metropolis side by side to reach their destinations.

The airport is located inside the city where the landing routes of most of the planes cross the city from west to east, bathing it with its wake of noise.

Urban planning is not carried out jointly by the entities that make up the metropolitan area and generally there is no communication between them. In Mexico City, the land use aspects are planned and executed somewhat anarchically, since the permitted uses are constantly changed by others that are not allowed for the general benefit of real estate businesses or spontaneous urban projects.

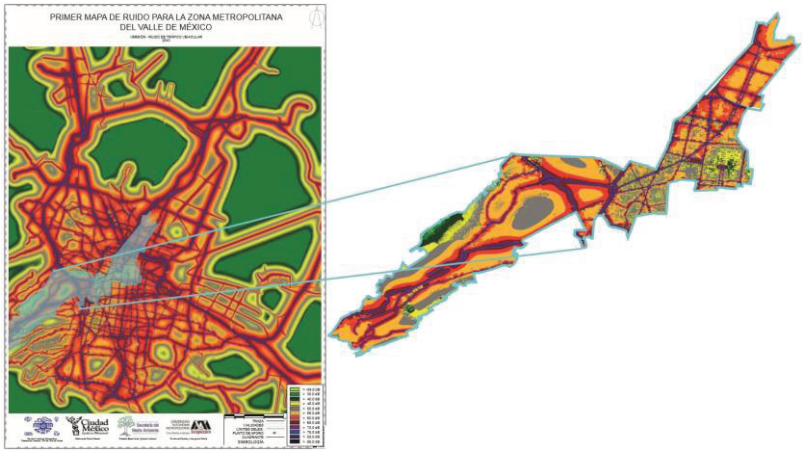
2.5 Mexico City Case Study

The urban situation of Mexico City results in a significant problem of environmental noise, particularly the road traffic noise, which is showed by the First Noise Map of the ZMVM (4). This represents a very important impact in the Metropolis (Figure 1a).

Given the immensity of the ZMVM, for this project a significant urban corridor has been selected, due to its urban, economic, social and cultural characteristics, that represents a clear example of the city's urban and environmental noise problems. (Figure 1b).

The corridor is made up of the main and historic avenue of Paseo de la Reforma (Reforma Corridor), which has been differentiated into three regions: The North Region, the Central Region and the South-West Region (Figure 2).

The South-West Region considers Paseo de la Reforma prolongation avenue, within the Urban Center of Santa Fe, a pole of development of high economic power. The corridor follows through Paseo de la Reforma Lomas, a very exclusive neighborhood of high economic level. The Central Region begins to the west by the Polanco neighborhood, with a mixed use between housing and offices of medium-high and high purchasing level. The corridor continues through the traditional Paseo de la Reforma, designed since the time of Emperor Maximiliano (1867), from the Bosque de Chapultepec to the Alameda Central, this section crosses traditional mixed-use neighborhoods between housing, shops and offices, as well as Government offices, the income level in this area is centered on high and medium-high. It continues to the North Region with contrasting areas of low-income, medium-low and medium-income housing reaching the well-known roundabout of Peralvillo, a low and middle-low class neighborhood. Finally, the Paseo de la Reforma Norte becomes the Calzada de Guadalupe until reaching the sanctuary of the Virgin of Guadalupe, the most important site of veneration and pilgrimage in the country, where each year ends in December receiving several millions of people from across the country.



a b

Figure 1. a) First Mexico City Metropolitan Area Noise Map y b) Case study area

Subsequently, 12 study areas have been selected (Figure 2) within the Reforma Corridor, contrasting the specific urban characteristics of each one and how they impact the different sound environments.

In all cases, various relevant approaches were considered, such as cultural, patrimonial, economic, social, among others. Some areas are adjacent sections that communicate directly with the corridor through main or secondary roads and that are part of it due to its proximity and importance within the city.

It was sought that in these areas there would be diversity of land uses, population densities and socio-economic levels, to be able to contrast them with noise areas and observe the relationship of all these elements with respect to the acoustic environments in them. The analyzed sections are distinguished by their commercial or historical value and represent different types of areas with the various characteristics mentioned above.

Finally, the methodological proposal culminates with an acoustic interpretation of urban space, that is, the minor scale of the urban analysis of this study, where within the corridor a selection of specific urban spaces was made, which were analyzed from the point of view of the urban soundscape,

including a collection of data from measurements and acoustic recordings that were contrasted with physical, social and urban image aspects.

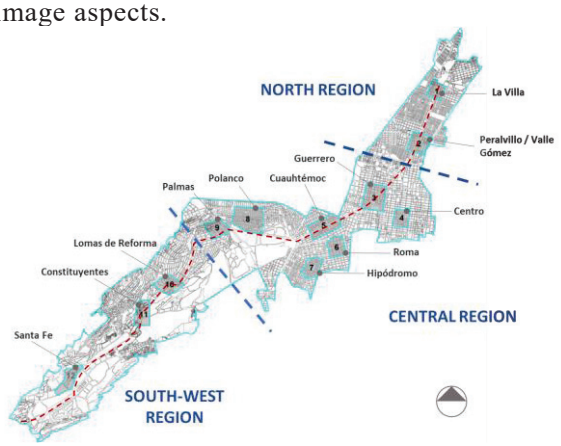


Figure 2. Case study map with region differentiation and zone selection.

3. URBAN ANALYSIS AND ENVIRONMENTAL NOISE

3.1 Urban Aspects and Environmental Noise

To analyze the urban features of this corridor, cartography was generated based on data describing population density, land use, socioeconomic status, roads, and urban infrastructure. For this case study, the first three urban features mentioned were correlated with the vehicular traffic noise map of the corridor. (Figure 3).

There is a close correlation between population density (Figure 3a) and socioeconomic level. The north region of the corridor has high population density and low to medium socioeconomic level, while the southwest region presents low population density and a high socioeconomic level.

There is a great variety of land use in this corridor (Figure 3b). There is primarily residential use with different configurations (commercial-residential, mixed-use, and office space). Neighborhood squares, urban infrastructure, industrial areas, and green space are also present. The historic downtown area has the greatest variety of urban infrastructure (Figure 2 – zone 4). Industrial use is mostly present in the north, while green space is most common in the south-center and southwest region.

The socioeconomic level map (Figure 3c) shows low and middle levels residing north of the city and middle to high levels living in the center and the southwest zones. There are also some low-level regions in the southwest region that correspond to older urban settlements.

The noise map of the corridor (Figure 3d) shows that sound levels are higher in the north of the corridor, due to the low building heights. In the central region, although noise levels are high at main avenues, noise does not permeate through the city because building heights act as a barrier to the surrounding areas. However, the noise level in these urban canyons increases due to reflective materials and the successive reflection effect. In the southwest region, noise spreads through large areas adjacent to roads, which is caused by the high speeds and the lack of noise barriers and tall buildings.

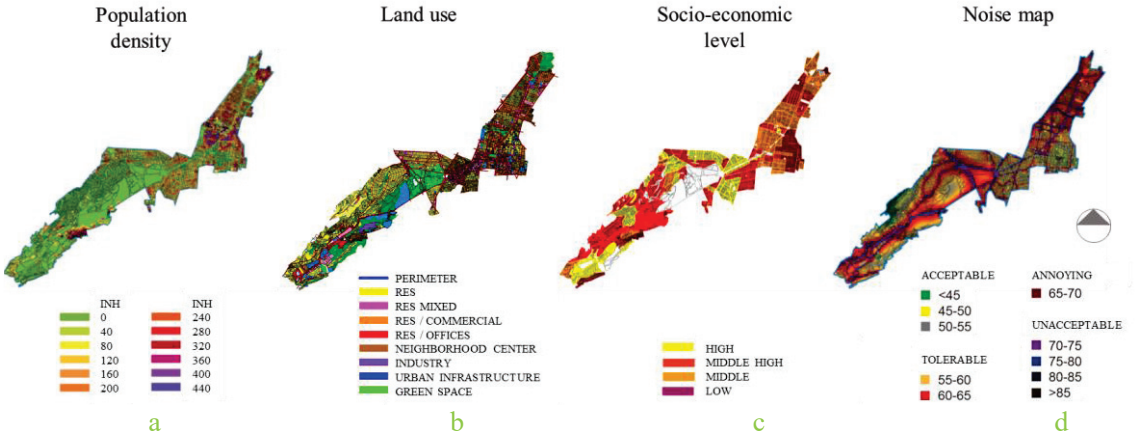
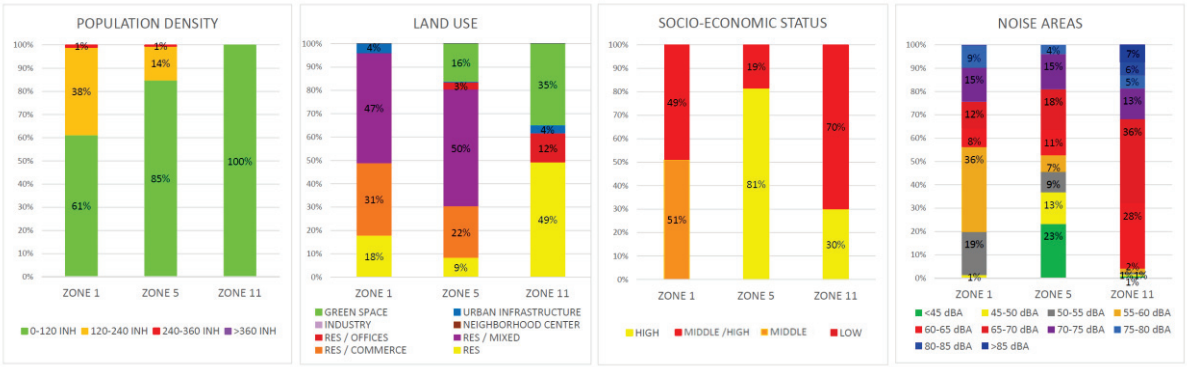


Figure 3. Urban aspects of the corridor.

3.2 Analysis of Three Specific Zones

The urban features of the 12 selected zones were analyzed. For this study, three different zones were selected to show the correlation between urban features and the sound environment. Zones 1, 5, and 11 were selected, corresponding to the zones of La Villa, Cuauhtémoc, and Constituyentes, respectively (Figure 2).

Figure 4 shows the comparative percentages of four urban features analyzed: population density (Figure 4a), land use (Figure 4b), socioeconomic level (Figure 4c) and noise level (Figure 4d). The population density of zones 1 and 5 are greater than zone 11, due to their respective land use. In these zones varied residential use dominates, while zone 11 has more than 50% of green spaces and offices. Socioeconomic level has a strong correlation with land use and population density. For example, socioeconomic level tends to be higher in areas with more green spaces and less population density. Noise levels are contrasting across different areas ranging from acceptable to unacceptable depending on the type of road that connects them.



a b c d

Figure 4. Percentage analysis of urban aspects

Figure 5 shows the noise levels of the selected areas generated by vehicular road traffic exclusively. These do not include other sound sources such as noise generated by formal and informal commerce, or occasional events, political manifestations, and blockades, which are specific to zone 5.

The more complex and busier the streets get, noise levels increase. For example, in zone 1 the main noise-generating roads are the ones connected to the Basilica of Guadalupe (north-south roads) where the low height of buildings allows noise to diffuse more easily within streets. In zone 5, noise-generating roads are main roads with high traffic rates. However, noise penetration to adjacent areas is lower due to building heights. In zone 11, noise is generated by two main roads that connect the city with the southwest zone of Santa Fe, producing a high volume of vehicular traffic.

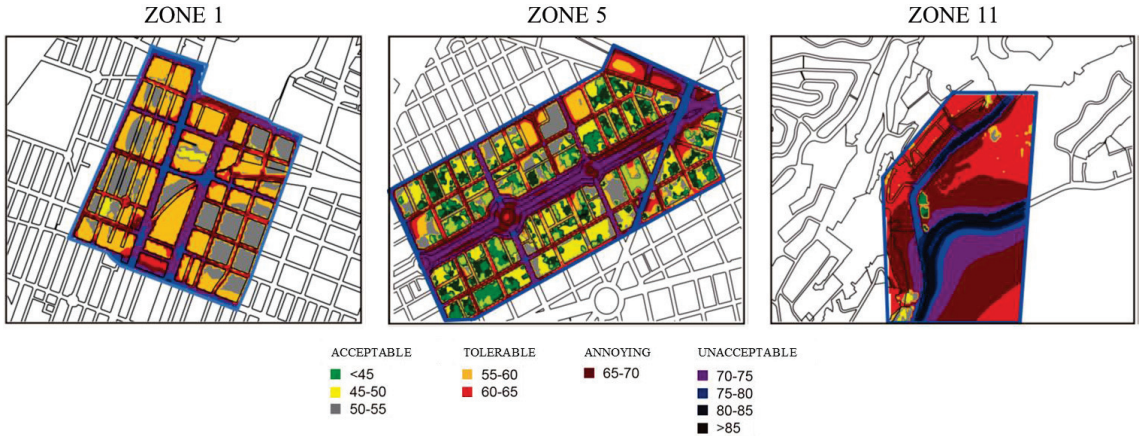


Figure 5. Noise map comparison.

4. THE ACOUSTIC INTERPRETATION OF URBAN SPACE

The public space is a place where a dialogue between pedestrians is conceived (their steps, talks, laughter, singing and movements) and the sound that in the environment exists. According to this, the city in its acoustic dimension takes the public space as a setting for life and urban customs.

The public space is a continuum of structures that order different activities and space usage (5), and each one will have different acoustic expressions. For this study, seven elementary urban structures were classified according to the user's experience:

- those related to pedestrians, as; squares, parks and pedestrian streets; with uses such as transit, sightseeing, permanence, contemplation or to enable social activities.
- those related to motor vehicles, roundabouts, primary, secondary and tertiary roads; spaces that promote mobility and connection.

According to these seven typologies, 31 urban spaces were selected within the twelve zones of study, physical configuration and urban characteristics, 45 sound records were registered (Figure 6).

Figure 6 –Location of selected urban spaces

The urban characteristics considered are physical and formal criteria, organizational criteria, functional criteria and qualities of the place.

4.1 Analysis of Urban Structures

The analysis process carried out in each of the urban spaces consisted of

- **Physical analysis**: Physical description of the space: location, dimensions, spatial limits, facades, proportions and urban components.
- **Activity / social analysis**: people activities and functions within the study area, pedestrian / vehicular / space usage
- **Analysis of the sound environment**
  a. Selection of measuring points
  b. Acoustic measurement, binaural recording, photographic record
  c. Analysis of acoustic index
- **Results**. Correlation of analyzed aspects.

4.2 Analysis of the sound environment of urban space

In order to show the methodology carried out in the different observation sites, the square "Plaza Rio de Janeiro" was selected as an example (Figure 7), which is located in zone 6, notable for its physical and social characteristics, its particular sound environment and variety of activities and sound sources that converge there (Figure 8).

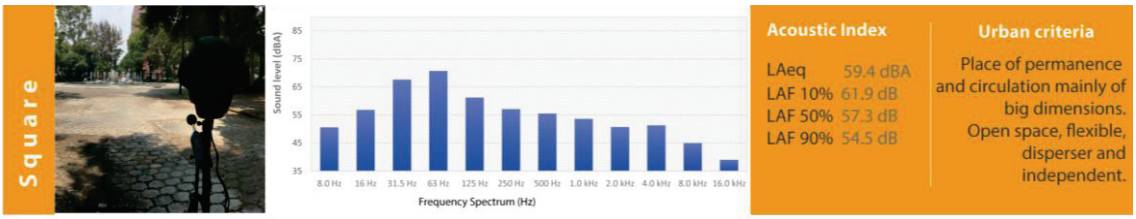


Figure 7 – Technical details of the urban-acoustic characterization "Plaza Rio de Janeiro", Mexico City

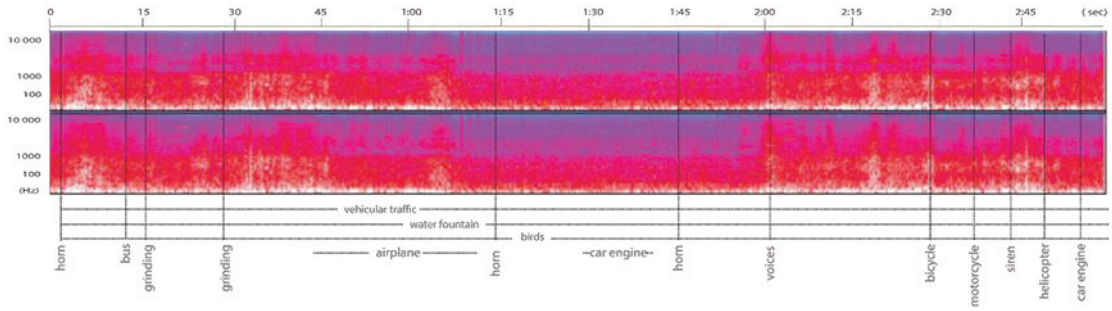


Figure 8 – Spectrum of binaural recording and of sound sources of the Plaza Rio de Janeiro, CDMX.

The square has a symmetrical arrangement, flanked by secondary roads with medium flow and four to six levels buildings, which is why it is formally considered cloistered.

On the inside, the square has a water fountain in the center that functions as a visual and sound landmark; by structure and form it is conceived as a population concentrating space that allows flexibility in everyday use, beyond permanence or transit, the previous is reflected in a diverse sonorous environment that is a function of the temporary use that is given to the space as: the grouping, the exchange or trade, the game, the stay, the walk, among others.

From the acoustic perspective it is considered a quiet space with low sound levels fluctuation, between 3 dBA (barely perceptible) and 5 dBA, with stable sound sources that compose the background noise such as: the low-medium vehicular traffic, the water source and the various birds that converge there, this is observed in the spectrogram of Figure 8, between minute 1:15-1:45 when the possible sound sources (derived from road traffic noise) are not found, the sound level and its spectrum are stable. On the other hand, the background noise is complemented by sounds derived from specific activities such as people usage (voices), transit (steps or bicycle) or playground (creaking) depending on the use of space, its flexibility and the temporal routine.

Finally, it was determined that this public space, despite being immersed in an area with great commercial activity, heavy traffic capacity and high population density, presents a stable or continuous background noise that includes the sound of the water source, the medium-low vehicular traffic and natural sounds such as birds or pets, and occasional sound marks that vary according to the activities. From the data obtained from four squares studied, it was concluded that the relationship of social activities together with the physical characteristics and the sound environment determine the acoustic congruence of the proposed urban structures (Figure 9).

		Formal Physical Criteria		Organization criteria		Space qualities				Function criteria								
Direct Indirect Null		Simetric	Enclosed	Landmark	Walking trails	Open space	Flexibility in interior activities	Concentrator	Confort	Permanence	Pedestrian circulation	Social gathering	Coexistence	Commercial Activities	Wander	Exhibition	Exchange	Amusement
Sound Level	LAeq																	
	LA10																	
	LA90																	
Spectrum	Fundamental Frequency																	
Sound source	Voices																	
	Bicycle																	
	Light transit																	
	Heavy transit																	
	Air transit																	
	Vehicle horn																	
	Birds/pets																	
	Water fountain																	
	Other																	

Figure 9 – Matrix of relation of the sound environment of the public space: Plaza Río de Janeiro.

The matrix (Figure 9) shows how the design of public space has an impact on the intangible

environment such as sound, which is affected by the physical configuration of the land, social activities and therefore the variations of sound sources that are present. For example, a space that is formally and functionally flexible will present more alterations in its use and sound environment will be versatile and temporary, on the contrary, rigid spaces will not present significant variations in its primordial function and the sound environment will be stable. Or taking technical considerations as an enclosed space like an urban canyon, it will have DIRECT repercussion in the sound level (LAeq) of a given sound environment (6) or the presence of a landmark (visual or sonic) will generate people concentration, so indirectly the sounds and the sound level will be affected.

This matrix directly or indirectly relates physical, organizational and functional criteria, as well as sound environment criteria in a qualitative evaluation system, which shows the importance of considering in urban planning and design, the social activities and how these affect the sound environment. This group of indicators (activities, sounds, background noise and space configuration) generate a sound identity of the different urban structures, however, despite having similar qualities each case of study will present significant particularities

5. SUMMARY

A methodology for the integration of environmental noise into urban analysis has been proposed for the benefit of urban planning, in this case, of Mexico City.

This proposal considers both the urban and the acoustic aspects with the idea of an integral planning of cities since the control of the environmental noise and the development of the soundscape should be part of a sustainable development of any city.

This study is only the beginning of a transformation towards an urban thought that seeks an acoustic affinity towards the creation and innovation of the contemporary city.

ACKNOWLEDGEMENTS

The authors wish to thank the support of the Consejo Nacional de Ciencia y Tecnologia (National Council of Science and Technology) (CONACyT) to the project *El ruido ambiental en el espacio urbano de la Ciudad de México. Problemas y modelos de solución* (Environmental noise in the urban space of Mexico City, problems and solution models) by the SEP-CONACyT Fund, of which this article is one of its results. We also wish to thank to the Universidad Autónoma Metropolitana for supporting our scientific research.

REFERENCES

1. United Nations Department of Economic and Social Affairs. Cities will continue to grow, especially in developing countries. Available in Spanish at: https://www.un.org/development/desa/es/news/population/2018-world-urbanization-prospects.html. 2018
2. United Nations. *The New Urban Agenda*. Habitat III Secretariat. Ecuador, 2017. Available at: http://habitat3.org/the-new-urban-agenda
3. Instituto Nacional de Estadística, Geografía e Informática. Vehículos de motor registrados en circulación. INEGI, 2017. Available at: https://www.inegi.org. https://www.inegi.org.mx/sistemas/olap/consulta/general_ver4/MDXQueryDatos.asp?#Regreso&c=13158mx/sistemas/olap/consulta/general_ver4/MDXQueryDatos.asp?#Regreso&c=13158
4. SMA-UAM Azc. Elaboración del Primer Mapa de Ruido para la Zona Metropolitana del Valle de México. UAM-A, 2011. Available at: https://www.azc.uam.mx/privado/difusion/adjuntos/MAPA%20DE%20 RUIDO%20ANEXO1.pdf
5. Pérez H., Edmundo &Palomares, Jesús. Percepción del espacio público. Revista Bitácora Urbano Territorial, 1. Enero-diciembre 2011.
6. Migneron, Jean-Gabriel. *Acoustique urbaine*. Masson, Presses de l'Université Laval, Quebec, 1980.