The noise pollution perception in the city of Milan: analysis of registered complaints by the population

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ABSTRACT

The present study deals with the analysis of registered complaints of noise pollution reported in the city of Milan by citizen from 1999 to 2015. Such complaints have been organized in a digital database and statistically analysed according to: *1)* the main types of noise source (technical facilities, music, transport infrastructures), *2)* activities (retail and catering businesses, production, tertiary) and *3)* conclusion of the registered complaints. Further evaluations have been carried out by means of a GIS software (*Geographic Information System*) to represent territorial analysis of complaints according to the noise source and disturbing activities. This analysis includes also a geo-statistical representation with density maps. We have therefore identified the most annoying sources for the population and their distribution. Such information could provide a valuable benefit for the city administration.

INTRODUCTION

Noise pollution is one of the key-issues in the evaluation of life quality in urban areas. It does not have only implications on the health and wellness state but it may also have economic and social effects. The World Health Organization (WHO) estimates that in the EU countries more than 80 million people are exposed to outdoor noise levels higher than 65 dB(A). The European Environmental Agency (EEA) remarked the importance of realizing spaces at low noise pollution (Quite Areas) in large built-up areas so to protect the resident population. Epidemiological studies show how the noise exposure not only produces hearing damages (acute or chronic ear system disorder) but is also related to diseases of the cardiovascular system (hypertension, myocardial ischaemia, heart disease), of the digestive system, of the endocrine system including neural (such as insomnia) and behavioral disorders (aggressiveness, depression, etc.). Sleeping disorders represent a common complication to noise exposure having a major impact on the health and quality of life (with effects such as fatigue, cognitive and learning performance deficiency). The who suggests that for a physiologically healthy sleep in all its stages and duration, the background noise level, at 1 m from the bedroom external façade, should not exceed 45 dB(A). This value takes account of the possibility to leave the windows open during the summertime nights.

In large cities noise represents a complex issue both for the levels reached and the variety of sources. Noise propagates both through air and building structures (especially for low frequencies), therefore the annoyance evaluation at the receptor site depends not only on the noise attenuation due to building structures but also on the noise power and immission levels of disturbing sources. To understand the real perception of the noise by the urban population, we present the analysis of registered complains of noise pollution, reported in the city of Milan by the citizens in the years between 1999 and 2015.

EVOLUTION AND MANAGEMENT OF NOISE NUISANCE IN THE CITY OF MILAN

In Italy city administrations and provinces are the reference authorities dealing with complaints reported by the citizens. Local authorities are wholly responsible to establish all the necessary actions to reduce noise; these include the acoustic zoning of the territory in homogeneous zones and the realization of mitigation measures for noise pollution where the law limits are exceeded.

Since early 80's, outdoor noise has represented one of the major source of complaints of the citizens in Milan. The entry into force of the Framework law 447/1995 on acoustic pollution, allowed the local authorities to legally organize and address to the requests filed by the citizenship. The main sources of acoustic pollution in urban areas are: transport infrastructures (roads, railways and airports), public commercial and entertainment establishments (bar, pubs, disco club), tertiary activity with correlated technical installations (air conditioning, ventilation), productive and artisanal activities. The complexity of these activities (as for spatial localization, temporal frequency and mode of noise generation) makes the intervention at polluted areas not an easy task. In the city of Milan a private citizen affected by noise nuisance can take the following actions**:**

- call for MPD (Municipal Police Department) intervention, whenever there is public nuisance;
- report a complaint (individual or collective) to the Municipality, whenever the noise is generated by stationary sources or transport infrastructures.

In the case of problems caused by noise, the citizen can directly report to the MPD. The MPD assesses the intervention request, verifying the noise relevance in relation to maintaining order to the disturbance of neighborhood or to maintaining the urban decency (as referred to the Penal Code). The authority can subsequently carry out on-the-spot inspections to identify the annoying source, ask for the immediate end of it and punish the activities which do not comply with the established opening and closing times.

The Municipal offices can intervene, in the case of ensured exceeding of the limits, when the noise source is generated by installations or equipment used for production, commercial and professional activities. Cases of complaints between individuals, construction sites, roadworks for urgent restoration of public services, street cleaning, collection of urban solid waste do not fall within the competences of the Municipal authorities. Upon receipt of the complaint, the Municipality opens the formal administrative proceeding for the alleged acoustic pollution and requests phono-metric investigation from the Regional Agency for Environmental Protection (ARPA).

Despite road traffic represents the main noise source in urban areas, most of the complaints are concerned with technical installations, productive activities, music and noise of anthropic nature (screaming and shouting). In fact, road traffic noise (with its characteristic lower frequencies) is perceived from the population less annoying than unsteady sources such as the music or sources that emit impulsive or strong tonal noises such as technical installations in productive activities. As for the transport infrastructures, the Municipality is in charge of all

the complaints regarding only the surface public transport (including the tramway lines). On the contrary, whatever noise source placed below the ground level (e.g. underground section of metro lines) falls within the competence of the service provider; there are specific procedures to evaluate the annoying areas and the corresponding remediation.

In this work, we deal just with complaints addressed to the Municipality, excluding those related to transport infrastructure. Complainants can file a report according to two different modes: individual (single person or family unit) and collective (apartment building or citizens' committee). In Figure 1 the administrative process for the management of complaints (since 2014) is illustrated.

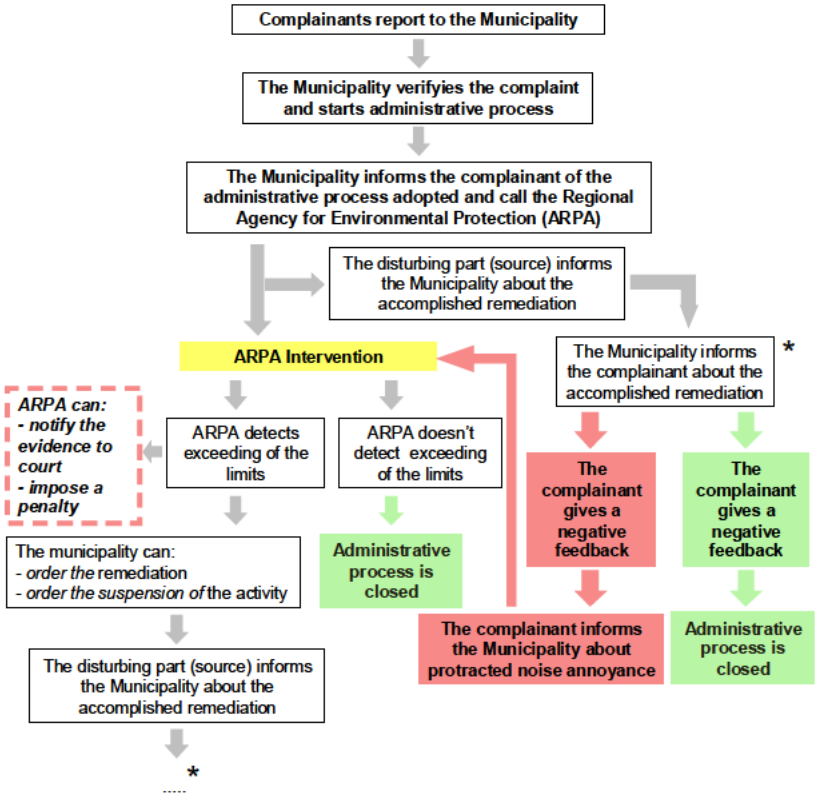

Figure 1: The administrative process adopted for the management of complaints (since 2014)

Organization of the digital database and analysis of noise pollution complaints

Data obtainded from the archives of the Municipality of Milan have been organized in a digital database separating years between 1999-2013 and years between 2014-2015 with different degree of detail. The statistical analysis dealt with:

- the yearly trend of the number of complaints;
- the type of sources and activities reported;
- the type of resolution action (e.g. adopted mitigation intervention);
- the average duration of the procedure.

The database was organized with specific table fields (receptor and disturbing source location, specifications of the disturbing source, status of the application, mitigation intervention). Each complaint has been associated with an identifying code which refers to the starting date of the application; the indexing allows also a quicker search in the database, therefore, easing the GIS post-processing. The collected data have been further spatially analyzed with the help of a GIS (Geographic information system) program. The geo-statistical analysis (density maps) focused on the distribution of the complaints according to the type of disturbing source and activity.

Time evolution of reported complaints

The database analysis and the analysis sent from the Municipality to the Central Government (ISTAT), allowed the time evolution of the reported complaints as represented in Figure 2.

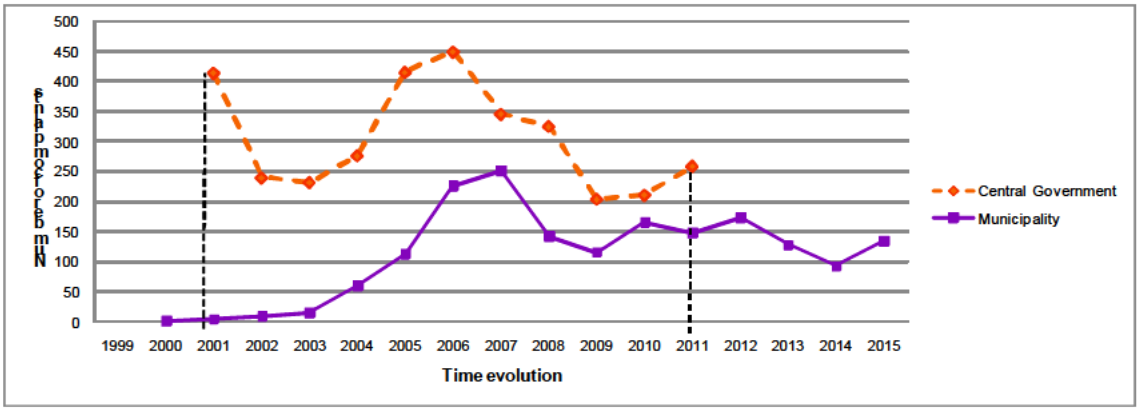

Figure 2: Time evolution of reported complaints by the citizens to the Municipality (years 1999-2015)

Figure 2 shows that the number of complaints reported over the years 1999-2003 is lower than that in more recent years (2005-2015). The difference between the number of complaints present in the database and those sent to the Central Government is correlated to those cases in which the parties involved solve independently.

Figure 2 shows an increasing trend of the number of complaints up to the year 2007 and a progressively reduction in the following years (150 - 200 complaints per year). This is mainly due to three factors: primarily a greater awareness of the citizens about the Municipality competence in noise-related issues, afterwards the entry into force of regulations and administrative acts that protect the population from the noises generated by technical plants, last production machineries and the recent installation of facilities technologically more silent and advanced.

Trend of complains according to the type of annoying source and activity

In Figure 3 the trend of complains according to the type of annoying source is shown.

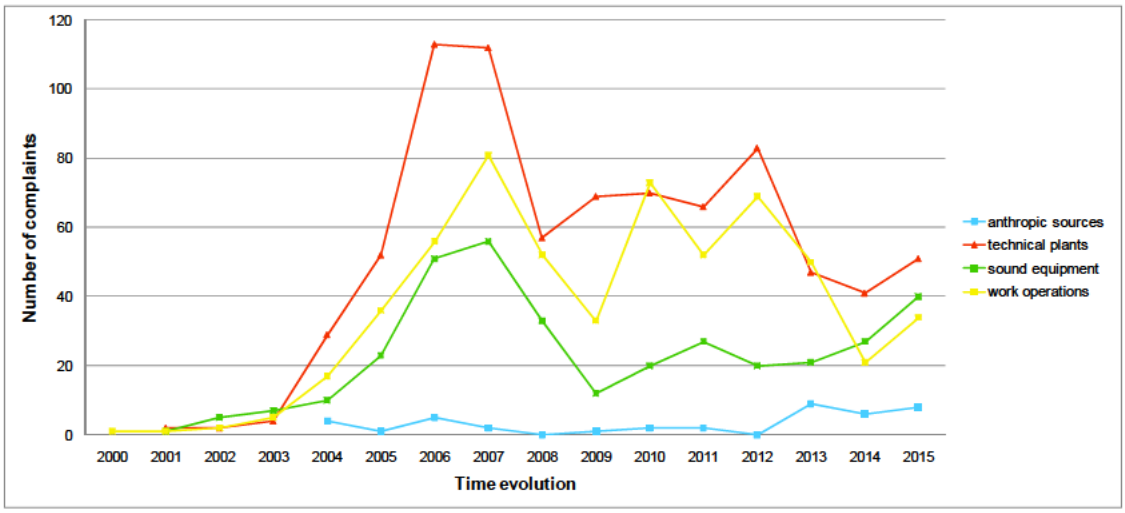

Figure 3: Trend of complains according to the type of annoying source (years 1999-2015)

Here we can observe how most of complains are due to noise emissions generated by technical plants (air conditioning system, refrigeration system, industrial machines, etc.), sound equipment, activities linked to work operations (bays, handling of vehicles etc.). The number of complaints due to anthropic sources is low. Figure 3 also remarks that the noise related to the source “music” and “anthropic noise” has increased during the last years. This is mainly due to the increase of public commercial establishments (pubs, restaurant) with music entertainment in the city of Milan.

The yearly trend shows a gradual reduction of the complaints (up to 30-60 complains/year/source) caused by a better use of technical solutions, the displacement of most of annoying activities (such as production activities) from the town center to the suburbs and the entry into force of restrictive measures and laws.

In Figure 4 the trend of complains according to the type of reported annoying activity is shown.

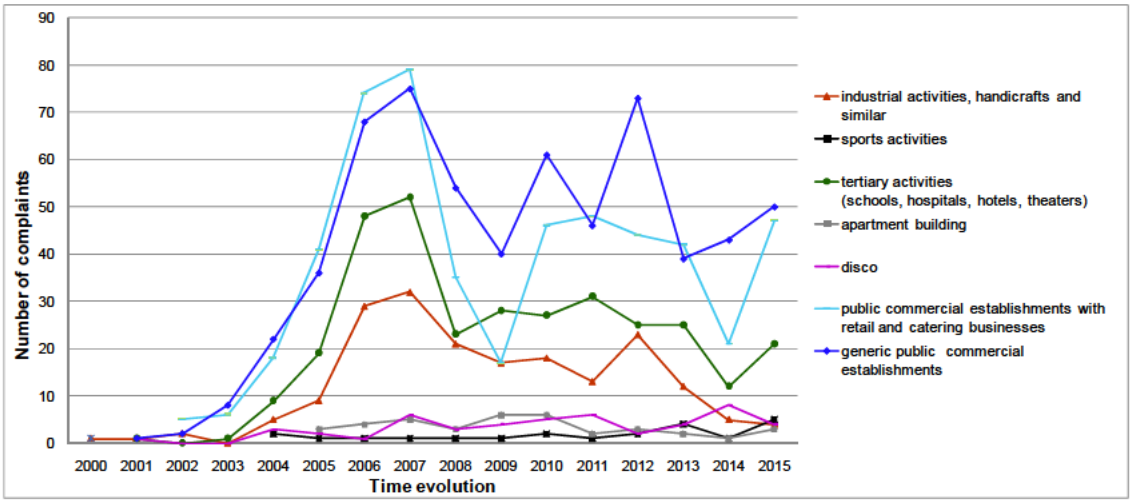

Figure 4: Trend of complains according to the type of annoying activity (years 1999-2015)

Here we can observe how most of complains refer to public commercial establishments both generic (restaurant, supermarket, theatre, cinema, shop, etc.) and retail and catering businesses (lounge bar, pubs, clubhouse, etc.). The industrial activities, handicrafts and similar, though important, do not substantially contribute as the public commercial establishments do. This is why Milan, nonetheless a productive area, has encouraged in the years the displacement of high impact activities from the town center to the suburbs. The number of activities related to “leisure time” presents a slightly increasing trend as a result of a greater interest of young people in such meeting places.

In general, we can conclude that the yearly trend profile shows three stages: an initial stage characterized by a limited number of complaints/year in which citizens started officially addressing the municipal competent offices, an intermediate stage with a growing number of complaints/year, and a more recent one with a quite constant rate.

Analysis of complaints: annoying sources and activities

Below, a summary of the analysis results on the different types of annoying sources and activities reported by the citizens during the period (1999-2013) is presented.

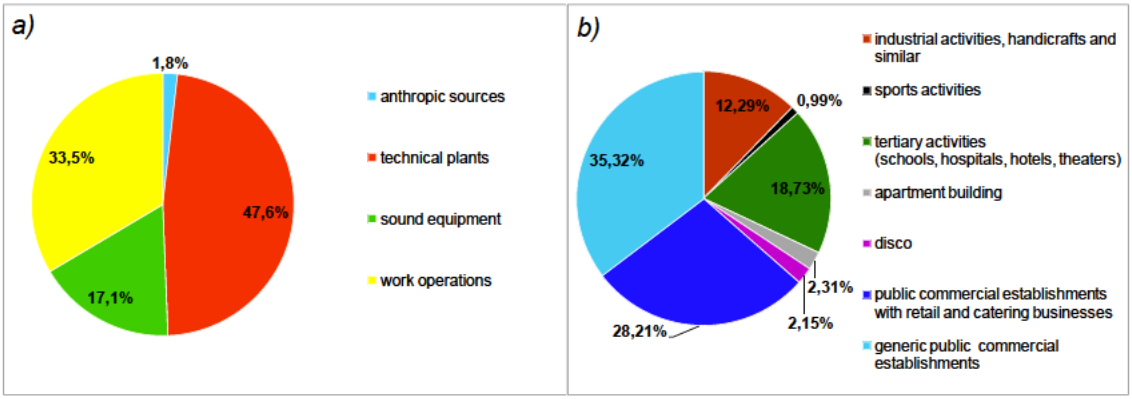

Figure 5: *a)* types of annoying sources and *b)* activities reported by the citizenship during the period (1999-2013)

The pie charts shown allow to identify the annoying sources (Figure 5a) and activities (Figure 5b) to be quantified and to compare their relative weight with respect to the overall number of reported complains for the period (1999-2013). The prevailing of technical installations is mainly due to the widespread abundance of air conditioning system, refrigeration system, electrical generators installed in shops, apartment buildings, supermarkets, offices, small and medium-sized enterprises.

As for the high impact activities, we can observe that the public commercial establishments represent 2/3 of the overall reported complains, followed by tertiary and industrial activities. In the years to follow, the number of reported complains related to production activities has significantly diminished, whereas those connected to leisure-time and sports centers show an opposite trend.

A more in depth analysis allowed each reported activity to be associated with the corresponding type of annoying source as illustrated in Figure 6.

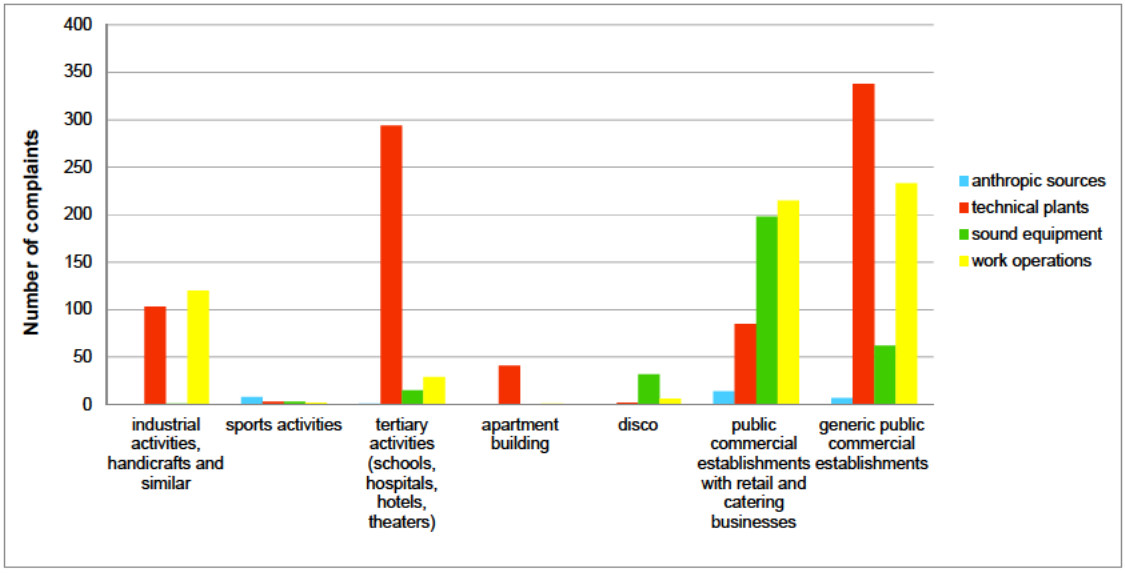

Figure 6: Summary of the reported activity as a function of the type of annoying source during the period (1999-2013)

Here the source denoted as “technical installations” and “music” are referred to as the most annoying.

As for the comparison between generic public commercial establishments (restaurant, supermarket, theatre, cinema, pastry shop, boutique, bakery, etc.) and retail and catering businesses (bar, pubs, disco, clubhouse, etc.), we can observe that, for the generic ones, the technical installations prevail, whereas, for those retail and catering, the music prevails.

The anthropic source gives a minor contribution to public commercial establishments, owing to the overlapping with the field "performance of activities"; in public commercial establishments with retail and catering a higher number of complaints due to anthropic source is found, though.

The most annoying sources linked to industrial activities are technical installations and work operations (bays, cranes, lifting devices, etc.). Figure 6 also shows a marked predominance of technical installations in tertiary activities and apartment buildings. Sports activities are mainly interested by noise of anthropic origin, sound equipment and technical installations.

Conclusion of the complaint action and mitigation

In Figure 7 the mitigation of the complaint action for the period (1999-2013) is reported. Most proceedings were dismissed and about half of them solved noise mitigation interventions.

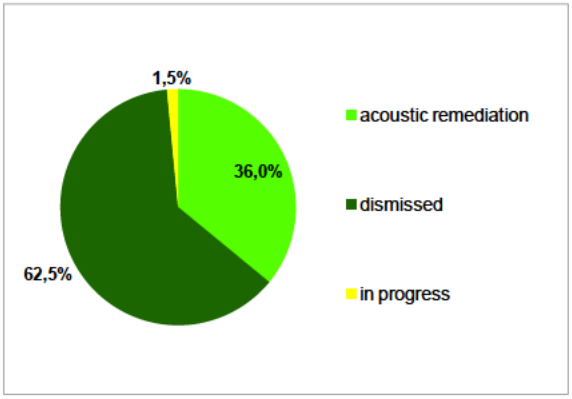

Figure 7: Mitigation of the noise pollution complaint report

Figure 8 briefly illustrates the more frequently adopted mitigation actions for complaint proceedings for the period (2014-2015): the direct intervention on the annoying source, because of the higher effectiveness, is favored (52%).

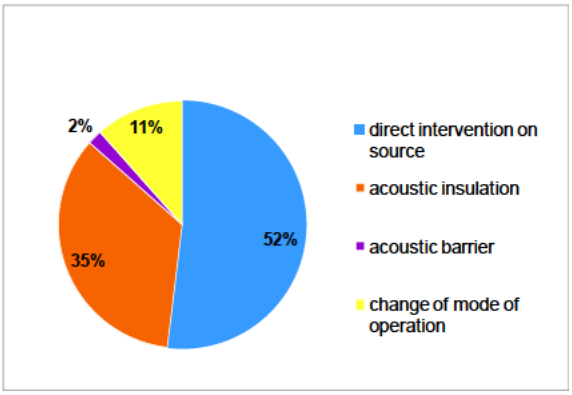

Figure 8: Acoustic mitigation: taken actions (years 2014-2015)

As for the average duration of the proceedings, more than 50% of them is closed, on average,

within two years since the submission date to the Municipality (years 1999-2013), reaching 75% in the three following years.

Spatial Analysis

The Geographic Information System (GIS) is a powerful tool that allows to manage and represent geographic data for the development of thematic maps and for a comprehensive analysis.

In this study, the GIS technology has been used to understand the spatial distribution of the complaints collected through the years (1999-2015) according to the source's types and the considered noisy activities. Finally, the GIS spatial analysis has been used to calculate density maps.

After the assignment of an identification number to every complaint, the geocode operation has been performed by comparison with previous geographic data containing the coordinates of every address of the city of Milan. Figure 9 shows the map with the georeferenced complaints of the years 1999-2015.

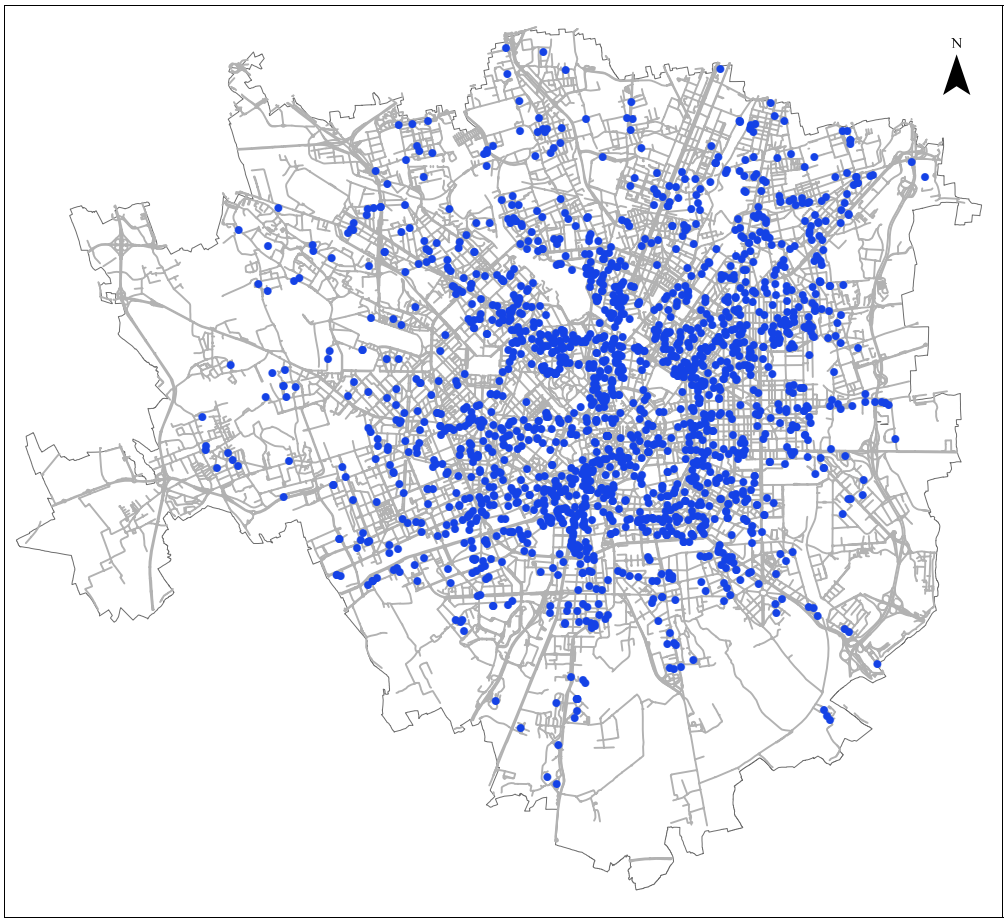

Figure 9: Distribution over the city area of the noise annoying complaints (years: 1999-2015)

Through proper geodatabase's queries, it has been possible to create maps of the complaints sorted by noise sources (Figure 10a) and disturbing activities (Figure 10b).

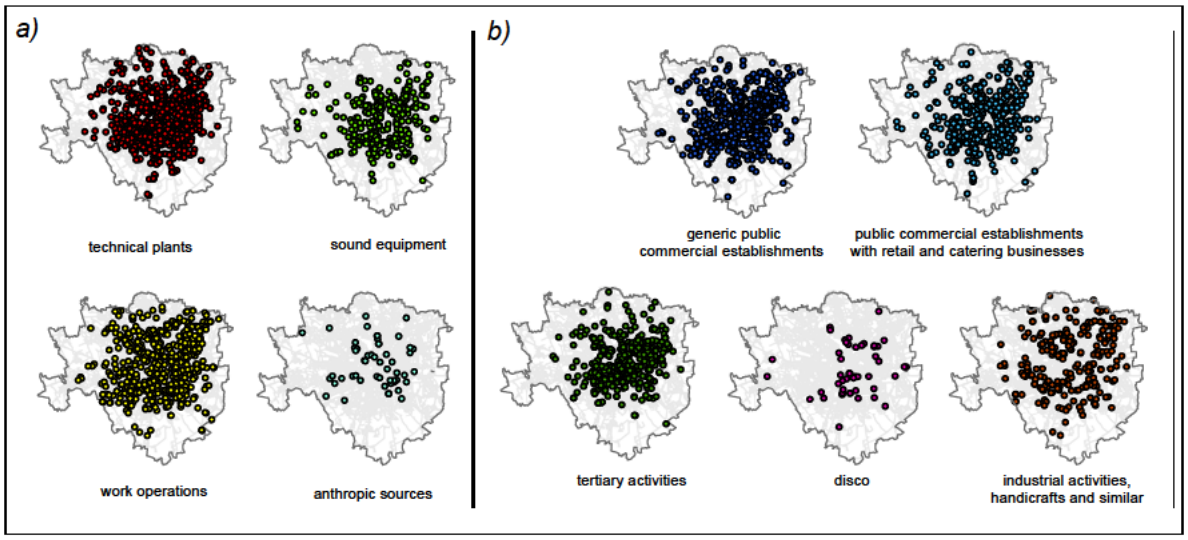

Figure 10: Distribution over the city area of the sources *a*), and the noise annoying activities *b),* (years 1999-2015).

It is noted from Figure 10 that the most annoying sources, such as working operations, music and technical facilities are also those more diffused in the city; those maps generally show good agreement with the spatial distribution of commercial activities such as pubs, cafes, restaurants and shops, that are mainly concentrated in the central area of Milan.

The anthropogenic noise, with the exception of few areas in the city centre, is mostly perceived in the peripheral areas; this geographical pattern is probably related to the presence of sport centres.

The density maps (or hot spot maps) represent the magnitude of a phenomenon throughout the study area according to a chromatic scale.

Using ISTAT census data it has been possible to calculate the density of complaints related to the population density (Figure 11).

For the data clustering, a classification into five groups has been performed using the Jenks natural breaks optimization method for non-normal distributions. This method identifies natural interruptions in the points of discontinuity of a series of values, minimizing each class average deviation from the class mean, while maximizing each class deviation from the mean of the other groups: the calculation is carried out by equation (1).

$$SSD = \sum_{K=j}^{j} A[k]^2 - \frac{\left(\sum_{k=j}^{i} A[k]\right)^2}{j-i+1} \qquad (1)$$

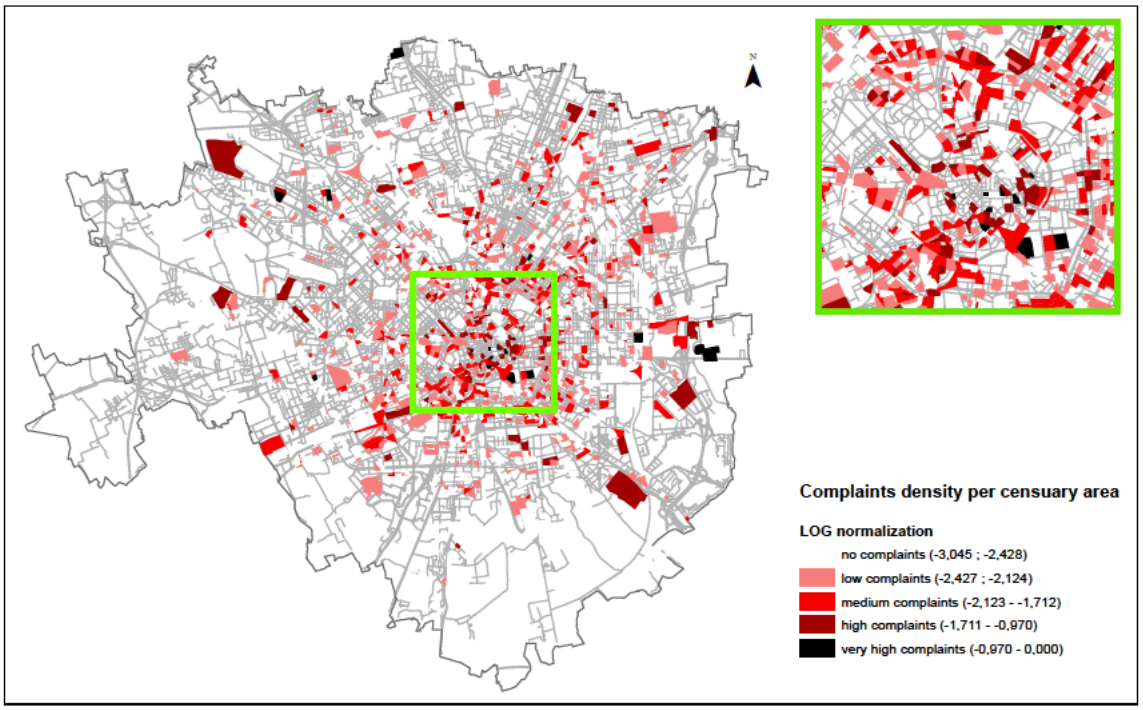

Figure 11: Complaint density per number of inhabitants (per census area) (years: 1999-2015)

Figure 11 shows that the higher complaint density is centred in the Milan center. Additionally, there are other high density complaint areas close to the city boundaries.

For a better comprehension of the real complaint density related to noise pollution, it has been decided to perform a spatial analysis based on the complainer's address.

The map in Figure 11 has been obtained through the use of "Kernel Density " tool that allows to identify the areas with high density of complaints (Hot spot). This geo-statistical technique is widely used in the geographic interpretation of social and economic phenomena such as the car accidents or crime events and it could be used also for the purposes of this study.

The KDE algorithm calculates the density of 'events' in a neighbourhood around those events. In other words, this approach weights the nearby features more than the distant ones.

Therefore, the crucial phase of KDE analysis is the choice of the reference search radius for the interpretation of spatial correlation between points (complaints, in our case): its calculation is carried out by equation (2) where D_m is the median distance, n is the number of points considered.

$$SearchRadius = 0.9 \times min\left(\sqrt{\frac{1}{ln\,2} \times Dm}\right) \times n^{-0.2} \qquad (2)$$

The resulting search radius is 628.75 m.

Furthermore, in order to correctly represent the real number of citizens affected by noise events, it has been decided to weight differently individual and collective complaints: the weight value "1" has been applied to the individual complaints, the weight value "2" to collective complaints, where many complainers are involved.

As shown in Figure 12, 5 density levels (excluding zero values) have been calculated according again to Natural Break classification method (the Jenks algorithm) used for non-normal distributions.

Figure 12: Density map (heat map) of the noise complaints reported to the Municipality (years:1999-2015).

Figure 12 presents four major areas where complaints are very frequent (the red areas of the map) and two other smaller hot spots. The identified areas are well-know noisy places with a high density of pub and restaurant related mainly to the nighlife entertainment such as: Alzaia Naviglio Grande, Alzaia Naviglio Pavese, Piazza del Duomo, Via Cordusio, Corso Giuseppe Garibaldi, Via Fiori Chiari (Brera district), Corso Sempione, Corso di Porta Ticinese, Corso Como, Via Paolo Lomazzo (Sarpi district), Corso di Porta Nuova, Porta Venezia, Corso Buenos Aires, Via Pietro Borsieri (Isola district).

CONCLUSIONS

Nowadays the sources of noise pollution in urban areas show a multiplicity of characteristics and an intrinsic complex nature. The present study, through the analysis of noise complaints, helped to further understand this matter in a city with a productive and economic specificity as Milan.

The analysis on the noise complaints reported since 1999 allowed to identify sources and activities primarily responsible of noise annoyance as well as the areas with major impact.

Results show how since 2007, the number of annoyance complaints (about 100-150 complaints per year) remains almost constant.

Spreading of leisure activities, malls, exhibition centers will likely determine a further increase of complaints in the next future (this trend is already clear for the years 2014-2015). Therefore,

municipal authorities will have to harmonize the protection of the resident population with the increasing demand for new activities.

Future developments related to the present work may take into account: the continuous updating of the database, the implementation of public surveys; the analysis of health-related, social and economic issues (housing depreciation); the analysis of reporting and requests for actions addressed to MPD. Finally, the analysis of the night life phenomenon (“movida”).

Acknowledgements

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