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REVIEW ARTICLE

Generation of (industrial) noise maps from geographic information systems. An approach from the literature

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ABSTRACT

Context: Noise in the work environment, in all types of productive activities, represents a hazard and has not really been valued in its real dimension. Little has been seen that stakeholders have determined the urgency of managing noise control programs. Therefore, losses resulting from medical treatment and absenteeism, represented in health care and social services, result in hidden work-related costs that directly affect the gross domestic product in any country.

Method: This article compiles different case studies from around the world. The studies were divided for review into general studies on the effects of workforce noise and then particularized according to the effects of industrial noise on workers' health. At a control level, the assessment and measurement of noise is defined through the use of tools such as noise maps and their respective derivations, in addition to spatial databases.

Results: According to the collection of information and its analysis, we observe that in the medium term, the economies will be diminished in an important percentage due to the consequences generated by the exposure to noise. Specific information can be found in the development of the article.

Conclusions: The data provided by the case studies point to the need for Colombia, a country that is no stranger to this phenomenon, and which additionally has the great disadvantage of not having significant studies in the field of noise analysis, should strengthen studies based on spatial data as a mechanism for measurement and control.

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1. Introduction

Noise, an unpleasant auditory sensation that with prolonged exposure leads to a progressive decrease in hearing capacity, generating as a consequence, a decrease in the quality of life of the individual and negative impacts on his productivity.

It has been established that people who are exposed to noise at levels above 85 weighted decibels (hereinafter dBA), suffer hearing loss. This loss is sensorineural, bilateral and symmetrical, which implies damage to the inner ear, by supporting higher frequencies (3k, 4k or 6k Hz) and then extends to lower frequencies (0.5k, 1k, 2k Hz)[1].

The ear is a very sensitive organ and when subjected to high levels of noise, it can undergo anatomical modifications until it reaches definitive hearing loss. This pathology has two stages: the first one presents a hypoacusis that is completely relieved after a period of rest and makes temporary changes in the auditory threshold, and the second one occurs when the patient is chronically exposed to noise and permanent changes occur, which causes irreversible damage to the organ of Corti, in addition to sensorineural hypoacusis, evident after 10–15 years of exposure to casual auditory stimulus[2].

Another inconvenience caused by noise is the generation of costs in the industry, due to the loss of productivity, special education and medical care caused by hearing loss in workers[3]. For these reasons, industries should establish surveillance programs to monitor workers who are exposed to noise levels that pose a risk to their health and who may acquire occupational deafness[4].

This review article consolidates different studies on the effects of occupational noise on the health of the individual, as well as its controls, using tools for noise management and assessment, such as industrial maps that allow georeferencing the results with different methodologies and calculations.

The databases, another component of the article, show how a spatial data infrastructure is built by applying geoprocessing in interaction with geographic information systems and geographic positioning systems.

Currently, manufacturing companies have found a significant negative impact on the hearing health of workers and employees who spend more time in the area where the production plant is located[5] or where the machines are located.

2. Studies on the effects of occupational noise

Many analyses have been conducted on the consequences of occupational noise on workers. Among others, there are:

In the state of Aragua (Venezuela) a study was carried out with 122 workers in the industrial zone of the city of La Victoria, from which it was found that 30.4% of the workers presented hearing problems. 70.4% of the workers reported extra-auditory difficulties, the most frequent being insomnia in 49.1%, irritability in 40% and headache in 31.9% of the cases. Sexual problems were reported in 11.4%; 19.1% of the workers reported being hypertensive due to occupational exposure to noise; anxiety was diagnosed in 33.5% of them, and depression in 5.8%. Twenty-seven percent were permanently and totally disabled[6].

In Turkey, 126 workers were exposed to high noise levels for up to eight hours a day at a hydroelectric power plant. Although the company had provided the workers with hearing protectors, they did not use them. Seventy-one of the 126 workers exposed to noise were diagnosed with hearing impairment. Hearing impairment was generated during the first ten years of exposure; however, a minimal permanent threshold shift was detected over a period of 40 years[7].

In Cyprus[8], a study was conducted in more than 90 companies with a sample of 200 people and the following results were obtained: 71.6% of the workers surveyed were exposed to a dose lower than that allowed for their shift, while the rest (28.4%) were exposed to a higher dose. Out of a total of 90 industrial facilities, 14 exposed their workers to noise doses that exceeded the limit value by 100%. 27.8% of the respondents had a slight permanent threshold shift between 20 and 30 dB, while 7.7% of the examinees had a severe impairment with a permanent threshold shift above 30 dB. The percentage of people with hearing impairment was 35.5%.

In the city of Sivas (Turkey), the noise generated by polygonal concrete, iron and steel, cement and textile factories were investigated in a survey of 256 workers in these industries. The level of industrial noise disturbance reported by the workers was found to be 73.83%. The percentage of workers who, according to the company, expressed hearing problems was: 30.86% in the concrete and concrete-crosscutting company; 33.33% in the cement company; 23.96% in the iron and steel company; and 40% in the textile factories. 85.94% of the workers do not have regular hearing tests. Hearing protection accessories are used in industries with a rate of 32.94%[9].

A study was made of 82 workers at the factory of Productos Lácteos Escambray, in Cumanayagua (Cienfuegos, Cuba); the company is made up of three production lines: ice cream factory, cheese factory and pasteurizer. Twenty-four areas were analyzed, 15 (62.5%) had noise levels equal to or higher than 85 dBA, and the pasteurizer was the area with the highest number of problems of high noise levels (85.7%); the cheese factory had only three areas (42.9%) with levels higher than 85 dBA. The study determined that the company had 100% of the areas studied with continuous and not intermittent noise[10].

Another study was carried out on 98 workers of the Tomás Álvarez Breto Aluminum Carpentry, located in Havana. The company was divided into 13 areas, of which it was found that only four had noise levels equal to or lower than 85 dBA, the rest had high noise levels. It was determined that 78% of the workers had hypoacusis and only 22% obtained normal results. In the positions where the personnel were rotated, there were no hearing problems. It was determined that hearing impairment occurred in a higher percentage in women (45.9%) than in men (32.7%)[11].

In Venezuela, in a paper industry, audiometries were performed to their workers and measurements of the intensity of environmental noise. The workers were exposed to levels higher than 85 dBA; those exposed to noise had protection mechanisms such as earplugs and earmuffs, according to corporate policies, but they were not used by them. Most of the workers in the groups exposed to noise presented hearing problems[12].

In the Raja Passenger Train Company (Iran), a study was carried out in which two groups (154 and 146 workers) were established who were exposed to high and low noise levels, respectively, in their activity. They were blood tested with enzymatic methods to estimate triglyceride (TG), total cholesterol (TC) and high-density lipoprotein (HDL) levels. The analysis showed that working in a place with high noise exposure and increased working hours per week increased serum TG in the high exposure group. TC and HDL levels did not show a significant increase in either group, making it possible to determine that chronic noise increases systolic blood pressure, especially among male workers[13].

In Egypt, in 15 different industries, studies were conducted on their noise levels (with sound level meters), taking measurements at intervals of every 10 minutes for periods of 8 hours a day and at a height of 1.2 m above the ground. It was established that workers had to withstand noise levels exceeding 90 dBA as follows: industry food 71.4 dBA, beverages 73.1dBA, clothing 74.5 dBA, wood 80.7 dBA, furniture 83.6 dBA, hospital laundry service 86.2 dBA, wheat mill 87.4 dBA, printing establishment 89.3 dBA, power plant 91.5 dBA, metal working shop 92.6 dBA, vehicle maintenance 93.1 dBA, train maintenance 94.7 dBA, aluminum factory 97.2 dBA, iron factory 98.5 dBA and rivet work 100.4 dBA. This study also established those residential areas had noise levels of 91.5 dBA when the permissible level is 60 dBA. The maximum permissible noise levels in educational areas are 50 dBA, while the measured noise level was 89.3 dBA. The maximum permissible noise levels in industrial areas are 70 dBA, while the noise level measured in this area was 98.5 dBA[14].

3. Effects of industrial noise on workers' health

Through various studies it has been established that the human ear is affected when subjected to high noise levels and that hearing loss can be caused by noise, ototoxic substances and acoustic trauma. Of these, the most frequent, noise-induced hearing loss, considerably affects the quality of life and is established as an occupational disease. Nowadays it is easy to diagnose it by means of PTA (low tone audiometry) and the implementation of OAE (otoacoustic emissions test) with these tests is the best way to establish occupational sensorineural hearing loss in exposed workers. Thus, the test with the highest sensitivity for detecting cochlear damage is the OAE or PTA[15].

Noise also generates non-auditory effects such as pupil dilation, respiratory agitation, increased blood pressure, decreased blood flow, decreased gastric secretion, increased cholesterol, increased blood glucose, insomnia, fatigue, stress, depression, irritability, hysteria, neurosis, social isolation and lack of sexual desire[4], depression, irritability, hysteria, neurosis, social isolation and lack of sexual desire[4].These deteriorations occur more rapidly during the first ten years of noise exposure, then their progress is slower[7].

Also, noise has health effects such as[16]:

- Discomfort: since it interrupts the activities that are being carried out. This begins to be experienced at levels of 50 dBA and above.
- Interference with communication: a moderate conversation where the speaker is one meter away, the pressure level is between 50 dBA and 55 dBA. Shouting can reach 75 dBA or 80 dBA. It is established that background noise levels above 40 dBA will cause difficulties in oral communication. From 65 dBA of noise, conversation becomes extremely difficult.
- Loss of attention, concentration and performance: noise interferes with perception and this causes problems in the performance of a task.
- Sleep disturbances: noise can cause difficulty in falling asleep, as well as alterations in blood pressure, cardiac arrhythmia and body movements.
- Hearing loss.
- Stress.
- Habituation to noise: the organism habituates to noise in the medium or long term.

In some countries, such as India, hearing loss has been determined as a compensable disease since 1948 under the Employees' State Insurance Act and the Workmen's Compensation Act (1923). But it was not until 1996 that the first compensation case was filed and about 250 workers alone are receiving compensation for hearing loss[1].

4. Noise control

It has been established that hazardous noise levels are easy to identify and can be technically controlled through the application of commercial technology, remodeling or transforming the equipment/process[17].

Likewise, hearing loss is entirely preventable, this can be achieved through engineering controls and employers providing their workers with at least two means of protection: (a) personal protective equipment (PPE), which are the most common controls and (b) management decisions, such as periodic shift rotation and limiting noise exposure when noise levels exceed 85 dB[15].

To prevent hearing loss, it is necessary to: reduce exposure to noise, use earplugs when exposed to long periods of noise, use materials that absorb noise and reduce it at home or at work, do not use several noisy machines at the same time, and try to avoid hearing undesirable noise with other sounds and periodically perform a hearing test to assess their hearing ability[15]. One mechanism to protect workers against noise is hearing protectors; when selecting them, the personnel who will use them, the compatibility with other safety equipment and the working conditions such as temperature, humidity and atmospheric pressure should be taken into account[1].

Developing countries have focused on noise control through standards aimed at establishing a permissible exposure limit of 85 dBA and an accumulation factor (time/intensity interdependence ratio) of 3 dB, and technical methods, such as the implementation of periodic audiometric testing, use of hearing protectors, training and record keeping[17].

When a company establishes a noise control program, the first thing to do is to determine what is acceptable noise in your industry, so you can establish whether to build a new plant, expand its facilities or purchase new equipment. Then it should distribute the equipment and procedures according to the noise they generate, seeking that the noisiest processes/machines are together and separated from the quieter areas by intermediate noise zones[18].

The next step is to determine the sources of the noise. There are some techniques that help to identify the origin or source of the noise[18]:

- Measure the frequency spectrum and plot the data graphically.
- Measure the sound level, in dBA, as a function of time.
- Compare frequency data with similar equipment or production lines.
- Isolate components with temporary controls or connect and disconnect one piece

of equipment after another, whenever possible.

The first step in the noise control process is to treat the source directly. Noise can also be controlled by enclosures and acoustic barriers, which block or protect the receiver from the direct sound path. Another way to control noise is to install soundproof booths to isolate the employee from excessive noise. Also, work shifts should be created so that the employee can recover from the noise[18].

5. Noise assessment and measurement

In industries it is necessary to perform noise emission measurements of fixed sources, for this the following general conditions must be taken into account[19]:

- The data must be obtained through a class 1 or class 2 sound level meter according to the standard.
- IEC 61672-1:2002 or any superseding standard. They must be calibrated according to IEC 60942:2003.
- Suitable atmospheric conditions must exist, i.e., dry weather and the pavements and surfaces on which the measurements are made must be free of moisture.
- Resolution 627 of April 7, 2006, of the Ministry of Environment, Housing and Territorial Development, determines that the sound pressure levels measured must be corrected for impulsivity, tonality, meteorological conditions, schedules, types of sources and receivers.

There are parameters for measuring noise emissions from stationary sources, the main ones are[19]:

- Equivalent continuous sound pressure level with A-weighted filter, LAeq,T and fast time weighting (F).
- Residual noise level, LAeq,T, residual, measured as equivalent continuous sound pressure level with A-weighted filter and fast time weighting (F) or as L90 dwell level.

The measurement time is one (1) hour and this can be done continuously or with intervals of no less than 15 minutes, to capture the necessary information at least 3 measurements of 5 minutes each must be made, so that the results are representative. Measurements should be taken during the day and when noise emissions are at their highest. Two measurement processes should be performed, one with the noise emission source(s) operating, during the period of highest emission, to obtain the equivalent continuous sound pressure level with A-weighted filter, LAeq, 1h, and another without the source(s) operating, to determine the residual noise, LAeq,1h, residual[19].

For the evaluation of the acoustic quality of closed enclosures there are three main criteria: noise criteria curves (NC), room criteria curves (RC) and balanced noise criteria curves (NCB); however, it is the latter that has acquired the greatest relevance since it considers a wider range of frequency bands. These curves were created with the purpose of ensuring that the background noise does not interfere with the type of activity that takes place in a given room, allowing, in addition, that communication between people is satisfactory[16].

Noise is measured with instruments such as sound level meters, dosimeters and auxiliary equipment. Sound level meters are classified according to their accuracy, from the most accurate (type 0) to the most inaccurate (type 3). The most commonly used filter is the weighting network. Modern sound level meters are equipped with octave band and one-third octave band filters to provide more detailed results[20].

According to the international standard[21], it determines that noise can be measured according to three types of methods:

a) Control: the work areas are measured with a sound level meter, using a limited number of measurement points.

b) Engineering: the sound level is measured through the A-weighting factor. The number of measurement points and frequency ranges are determined according to the measurement objectives. The time factors must be recorded.

c) Precision: overall sound level measurements are supplemented with octave or one-third octave band measurements and appropriate time interval histories are recorded depending on the duration and fluctuations of the noise.

Noise at work can be measured under two basic criteria[20]:

- The exposure to which each worker is subjected can be measured.
- Noise levels can be measured in several areas, making a noise map to determine the areas at risk.

6. Noise maps, a tool for noise management and assessment

The diversification of human activities means that an increasing number of citizens are exposed to different noise sources, to complex sound environments (combined noises).

Several studies have highlighted the impact of noise on human health and well-being[22] and defined that there is a causal relationship between the sound level and the degree of discomfort it generates in people, although the physical and cultural characteristics of the individual can relativize the level of impact that noise has on health[23].

Society has long been aware of the environmental and health implications of noise. As a result, different entities and individuals have proposed and developed actions aimed at noise control and reduction. One of the most important tools for the evaluation and management of environmental noise is the noise map[24].

Noise maps have been used to examine the effects of noise pollution at sites such as airports, factory facilities, road routes and nearby residential communities. Their development has led to corrective measures such as the rezoning of industrial/residential areas, as well as the construction of noise screens to reduce the effect of noise in an area[25].

Taking into account the work done by the European Community in aspects of evaluation, control and management of noise (environmental or industrial), a noise map can be defined as follows:

[…] the presentation of data on an existing or predicted noise situation on the basis of a noise indicator, indicating the exceedance of any relevant limit value in force, the number of people affected in a specific area or the number of dwellings exposed to certain values of a noise indicator in a specific area[26].

It also defines a strategic noise map as "a map designed to enable an overall assessment of noise exposure in a given area, due to the existence of different noise sources, or to enable overall predictions to be made for that area"[26].

The development of noise maps can be generated experimentally or under mathematical calculation. Experimental maps involve a greater need for initial resources (human and economic), being slow to perform and their usefulness is reached in the diagnostic stage, because of the data taken in situ, which gives reliability to the information[27].

For environmental monitoring (in this case the noise factor) the data aspect is of particular relevance. In fact, today there is much demand from citizens, activist groups and even municipal administrations for the use of participatory technologies to address pollution[28], which if applied correctly, can achieve the same accuracy as standard noise mapping techniques[28].

Similarly, the development of calculated maps is more flexible (a larger study area can be mapped), they are more affordable and easier to update. Their shortcomings lie in the fact that their results depend on the mathematical model used and on the input data set introduced for their calculation[27].

In principle, a noise map consists of a spatial representation of data on an existing or predicted acoustic situation based on a noise index. In the most general case, it represents the sound levels by means of a set of isophonic lines made from the calculation of sound levels at receptor points covering the entire study area. However, noise maps can also represent the exceedance of a limit value, the number of people affected or the number of dwellings exposed to a certain noise index value[24].

It should be remembered that acoustic cartography offers many more possibilities: vertical maps, maps with numerical information at receptor points, maps analyzing the contribution of different sources, maps with exposed population, etc.[29].

7. Industrial noise maps

The development of noise maps in the last two decades has been extensively worked on, most large cities have technical departments for noise pollution control that regularly prepare noise maps and action plans; in other words, there are already procedures and significant experience for the management of environmental noise[29].

However, in a smaller environment, such as a business office or a factory floor, the use of a noise map is still limited, partly due to the difficulty in constructing noise curves[25].

An industrial noise map seeks to measure the noise levels in companies or industrial factories, both internally and the impact around them. It also seeks to define the emissions generated by the fixed sources inside the companies, for this, it is necessary to determine the distribution of the factory and in it the location of the machines. Once the noise levels at all points of interest are known, noise curves can be constructed[25].

8. Mapping methodology

Before starting to work on a noise map, it is necessary to establish the requirements and determinants of such a map; to know whether a general or specific map will be made on the source(s), the scale of work and accuracy of the data, the acoustic indices and results of the map[29].

Then the technique to be used is selected[29]: sound level meter measurements[30], forecasting methods, or a combination of measurements and forecasts.

Maps developed under direct measurement techniques (sound level meters) are costly (resources and time), but their results reflect a good level of accuracy. Those developed with forecasting methods present practical advantages with good reliability of their results, but many times establishing the behavior of noise sources (calculations) requires a very good level of mathematical model management[29].

The first noise maps made in the eighties and nineties, were elaborated with experimental measurements[31] and it is later on when a correct elaboration begins to be composed through a sampling plan[32].

The spatial sampling methodologies with experimental measurements most commonly used for noise mapping are[33]: a) grid methodology: dividing the area under study by a grid of a fixed distance and taking measurements at the nodes of the grid[31]; b) road or traffic methodology: performing a categorization of the roads and sampling different points of the roads assuming that those of the same category will present similar noise levels[34]; c) sampling in specific areas: usually used when it is desired to cover a specific area where a specific noise is centralized, such as nightlife; d) methodology according to land use: it is carried out taking into account the characteristics of the land, according to the land planning categories of the agglomeration: commercial use, residential use, etc.[34]; e) random zone methodology: it is common to use this methodology when a grid cannot be drawn, when the road method cannot be used, or when there is no specific area where noise is concentrated[35].

9. Calculation methods for noise maps

The development of the industrial/point source calculation method[36] is one of the most widely used and stipulates the consideration of ISO standards that provide the development of the calculation of point source emissions[37] and their propagation calculation[38], as well as the determination of emissions from industrial areas.

In Bogota, the legislation applicable to the noise problem in the city[39], is, among others, the national noise emission and ambient noise standard (Resolution 627/06 MAVDT) and the one that establishes the business classification by noise impact UCR that allows assessing industries and establishments, regarding their noise generation level (Resolution DAMA 832/00).

Thus, point sources should be defined and their power level should be measured (day, afternoon and night), describing the geometry of the source, its location and directionality. For the above, it should be taken into account that measuring the sound pressure near the focus involves determining the sound power levels with engineering methods[40] and inspection methods[41].

10. Spatial databases

Since the earliest civilizations the need to represent spatial data in a pictorial way was seen. In the 18th century in Europe, the Geographical Information Society was formed with the establishment of national government agencies to produce cadastral and topographic maps of all countries. These institutes are still in force. Even through the last two centuries maps have been produced in individual styles; however, there are still standards within cartography that have not been broken[42].

Spatial databases arise from the need to store and represent geographic data. They constitute an electronic database that, in addition to registering and facilitating the administration of transcendental information of a business domain in a digital medium, allow storing spatial information[43].

A special advantage provided by the digital structuring of information is the geostatistical analysis; most software specialized in geographic information systems (GIS), such as *ArcGis, Quamtun Gis* or *GvSig*, present modules for the exploratory analysis of spatial data and tools to create statistical surfaces[44].

11. Spatial data infrastructure (SDI)

The Instituto Geográfico Agustín Codazzi (IGAC) remains the governing body of Colombian geography and in accordance with its mission, its development plan defines the following functions[45]:

- Increase awareness and understanding of the vision, concepts and benefits of SDI.
- Evaluate and implement the use of common methodologies for the production and maintenance of fundamental SDI support data.
- Contribute to the generation of cooperation strategies between the IGAC and other national and international organizations to promote and disseminate SDI development.
- Contribute to the development of common solutions for the discovery, access and use of geospatial data in response to community needs.

The IGAC[46]—as coordinator of the Colombian Spatial Data Infrastructure (CSDI), which is the sum of policies, standards, organizations and technological resources that facilitate the production, access and use of geographic information of national coverage, to support the country's economic and social development-seeks, among others, objectives to document the basic and thematic cartographic data produced and facilitate access to them (metadata) and harmonize information systems to ensure data interoperability (standards -spatial data standardization committee-) through the implementation of the National Technical Standard on Geographic Metadata (NTC4611)[47].

The backbone of SDI and mapping systems is spatial data (**Figure 1**). The various frameworks that make up the Mexican Data Infrastructure (SDIMex) are oriented towards spatial data. The SDIMex is the set of policies, legal, organizational, regulatory and technological framework, necessary for the effective creation and integration of spatial data and to facilitate the availability, access, sharing and use of these, as part of the Public Information System (PIS)[48].

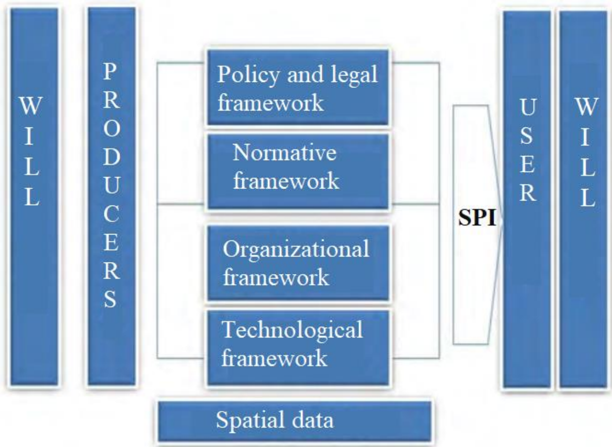

Figure 1. SDIMex conceptual model.

Source: Esparza[48].

12. Applied geoprocessing

Efficient tools for extracting information from spatial data are crucial for organizations that make decisions based on robust spatial data sets, such as:

NASA (National Aeronautics and Space Administration), NIMA (National Imagery and Mapping Agency) and NSI (National Cancer Institute). These organizations are spread across many application domains, including: ecology, environmental stewardship, public safety, transportation, earth science, epidemiology, and climatology[49].

Taking into account both social and economic studies, and especially in econometric models, it is necessary to consider the spatial variables that are found in the work with georeferenced data; since the events that occur in one location have an influence on another that is apparently remote[50].

An example of this is Pacheco's project[51], which obtained the potential erosion index through the treatment of edaphic, pluviometric and thermal data, generating images in raster maps, with a spatial resolution of 100 meters through interpolation.

A kind of meteorological data display mechanism is recommended on the basis of G/S mode which is based on HGML (hyper geographic markup language) which is a uniform interchange standard. For the case of meteorological data which are characterized by being dense and complicated. According to the concept of "concurrency of information" and "polymerization service", which is grouped by ArcGIS geographic processing technology[52].

GIS technology was used to integrate data on malaria in Colombia from various sources for a recent period and to perform different spatial analyses in the five endemic zones identified. The spatial database developed allowed the periodic entry of data for monitoring the disease and thus to evaluate in a timely manner the effectiveness of the strategies adopted to reduce the incidence[53].

13. Interoperability in GIS

Considering the difficulties in the interoperability between the files generated by the GIS, which are then intended to be managed through another GIS, it is possible to solve using the "dxf" format, but at the cost of loss of information and that is where the need arises in the standardization of geo-information[54].

Because spatial data are saved in binary format, it represents a drawback for the use and sharing of data. In order to unify the management of spatial data, it is proposed to map data based on XML (extensible markup language) in the relational-spatial database; this, besides solving the two mentioned drawbacks, provides the way to access heterogeneous systems and as any Web GIS guarantees the radius of use of the information[55].

14. Geographic positioning system (GPS)

In contrast to vehicle positioning, the precise location of individuals is becoming increasingly important, especially in health cases, such as dementia patients, among others, where the Mobile Guardian architecture based on GPS and GSM (management system geographic) is recommended[56].

As a strategic project for Colombia's development, a cooperation agreement was established between the National Administrative Department of Statistics (DANE) and IGAC to generate cartographic products to support census operations, as well as basic cartography. The IGAC has advanced in the establishment of the MAGNA National Geocentric Reference Frame and the use of GPS (global positioning system) technologies to provide the precision coordinate system to which the different types of cartography for the census and other projects are linked[45].

15. Conclusions

The use of GIS is becoming much wider for many application domains, this added to the globalization and proliferation of networks, leads to a need to standardize the software tools used; it is noteworthy that in recent years most entities oriented to digital mapping use ESRI technology.

Industries in the world, in general, present noise above 85 decibels, causing irreversible auditory diseases and others associated with noise, such as: insomnia, irritability, headache, sexual problems, hypertension among others in the medium and long term of exposure and to the productive system, losses that have not yet been quantified.

On the other hand, it is important to highlight the importance of investigating occupational noise after learning that the industrial noise can generate affections, the most serious of which is the permanent perforation of the tympanic membrane of the ear.

Companies in some industrial sectors, such as metalworking, textile, food, plastics, graphic arts, among others, which are high generators of noise, generally lack programs to control it and, therefore, there is a lack of a culture of self-care, which shows little knowledge and management of this issue.

Conflict of interest

The authors declare no conflict of interest.

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