Barcelona noise monitoring network

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Summary

The city of Barcelona has a particular acoustic complexity: its high demographic density, high traffic congestion, mild climate, busy nightlife, and many other factors cause an intensive use of the city streets with notable noise levels as a result of the coexistence of uses. Because of these factors and the fact that citizens increasingly demand quiet as a key element of quality of life, Barcelona City Council has worked hard to revert the trend of growing noise levels. In 2006 the city started to develop a noise monitoring network with the objective of evaluating sound levels in challenging areas and quantifying the noise reduction due to the implementation of action plans. The network consisted originally of class I sound level meters that continually monitored the noise levels of different areas of the city with fixed and mobile measuring points. The city has started to use noise sensors to reinforce the class I noise monitor network with the objective of increasing the number of measuring points. Moreover, this reinforcement follows the technological evolution and fits with the Smart City spirit of Barcelona. At the same time, the city has created *Sentilo*, a sensor and actuator data management and interconnection platform part of Barcelona's Smart City initiative. The *Sentilo* platform has been developed entirely with open source components and the city can use it directly to manage sensors and to store and publish data.

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1. Introduction

Noise is one of the variables becoming increasingly important as a means of assessing a city's quality of life. Recent years have witnessed the implementation of a "culture of acoustic comfort" which has led to citizens becoming increasingly demanding and appreciating peace and quiet. National, regional, and local legislation regulate in detail the noise measuring procedures for different kind of noise sources. However, in some occasions citizens' demands cannot be solved doing short time measurements.

Consequently, in 2006 Barcelona City Council started using noise monitoring terminals fully prepared to support bad weather conditions with the objective of making long term measurements with high quality results.

Furthermore, over the past few years Barcelona has been working hard to be one of the smartest cities in the world and is promoting the use of innovative solutions to manage its services and resources to improve its citizens' quality of life.

One of the Smart City projects is the strategic deployment of *Sentilo*, a sensor platform that allows the city to become self-sufficient and to improve the environmental sustainability.

Sentilo is designed to serve as a link between the sensors and actuators and the applications that manage urban services. With this new tool, the city can make a transversal use of the information to give a better service to its citizens.

A noise monitoring network has been developed with the objective of efficiently and smartly managing the noise in Barcelona. This network is made up of a main network of class I sound level meters and a complementary sound sensors network.

2. Noise monitoring network characteristics

The Barcelona Noise Monitoring network (figure 1) is structured into independent networks that give information in a different level. The main difference between the principal and the complementary noise control networks is the quality of the measures. Thus, the devices used have different characteristics and costs and the final uses are also different.

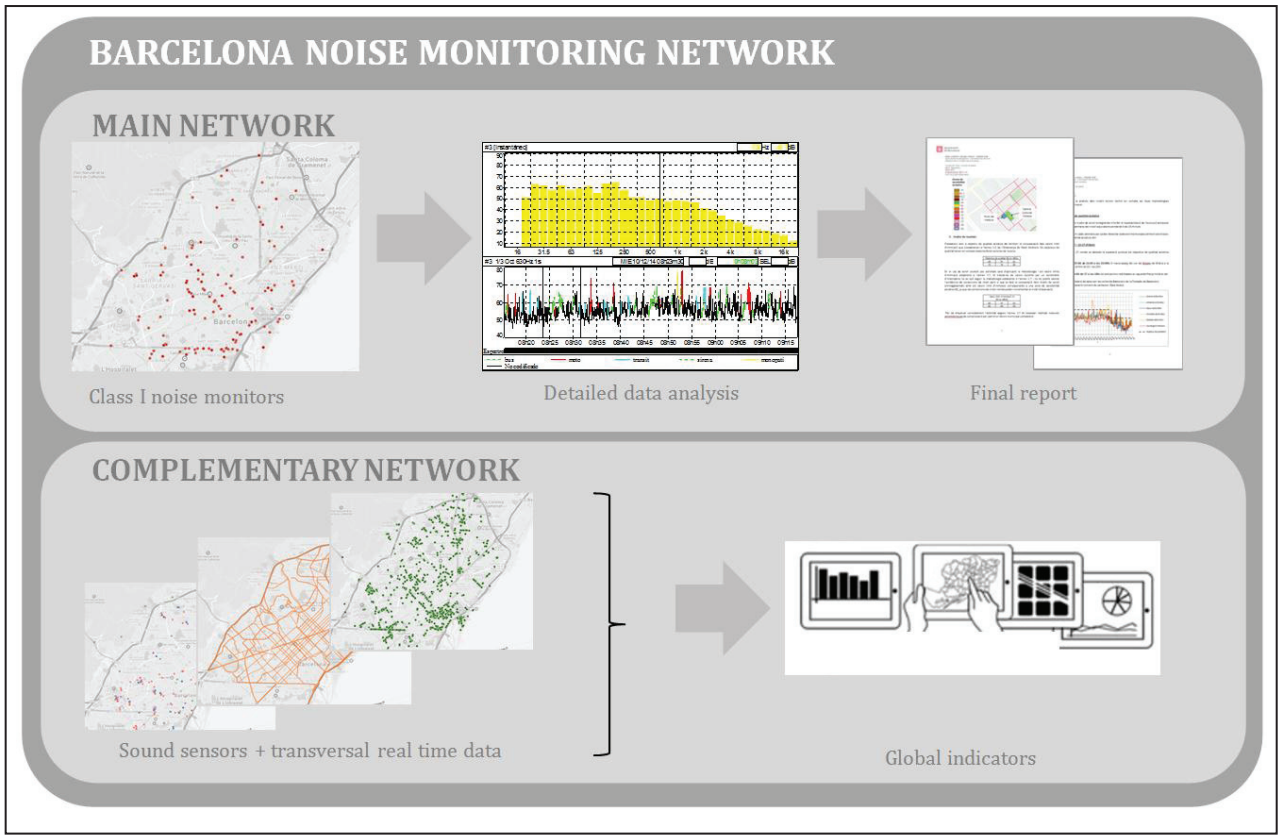

Figure 1. Noise monitoring network basic structure.

2.1. Main network: class I noise monitors

This network has currently 25 noise monitors and will have 31 in the near future. A part of these devices are installed in fix measuring points and the rest are used to give on-demand coverage.
The main objectives of this network are:

- To evaluate sound levels in challenging areas
- To quantify the noise reduction due to the implementation of action plans
- To update the noise map
- To identify noise sources and evaluate them in complex scenarios

Since 2006, 99 different points have been monitored. The noise sources measured can be divided in these main categories:

- Recreational noise (34.3%)
- Noisy activities in complex scenarios (23.2%)
- Noise map update (11%)
- Road noise (9.1%)
- Waste collection vehicles (7.1%)
- Outdoor events (4%)
- Ambulances (3%)

The noise monitors technical characteristics are defined by the Noise Control Department (Table I).

Table I. Class I noise monitors technical characteristics.

Type approval	CEI-61672 Class-I certification
Integration time	1 second
Acoustic indicators	LAeq LCeq LZeq LAIeq LAFMAX 1/3 octave spectrum 10Hz-20kHz
Tolerance	CEI-61672 Class-I
Measure range	23-137 dB(A)
Calibration and verification	Verification of the calibration of the sensor must be able to be undertaken in situ using an acoustic calibrator which fulfills the requisites established under IEC 60942.
Others	Weatherproof 19h battery (Charging time: 5h) 3G connectivity Audio recording

2.2. Complementary network: sound sensors network

The development of the sound sensor network is still in an early stage as the first tests started in 2012. Sound sensors were installed in two construction work areas and the quality of the measures of two kinds of low-cost sensors was tested.
The first results weren't very optimistic because the deviations detected were excessive (figure 2).

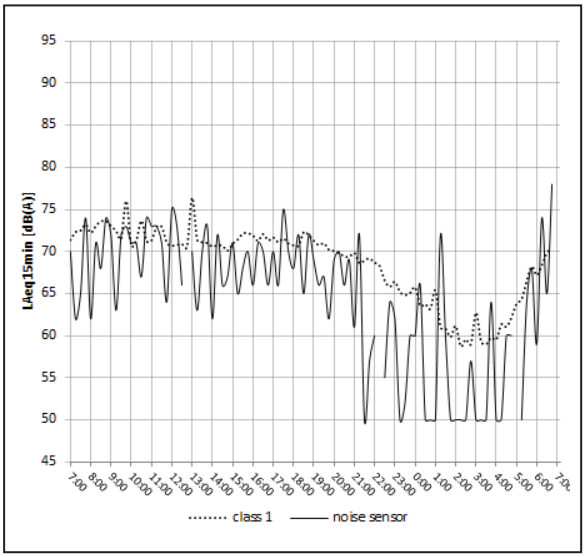

Figure 2. Results of the second test of a low-cost noise sensor

The Noise Control Department defined during 2014 the minimum characteristics of the sound sensors (table II) and started the implementation of a control system to validate the quality of the sound pressure measures before the installation of the sensors on the streets.
By the end of 2014, three different providers passed the tests with good results and the implementation of the sound sensors network started taking advantage of the redevelopment works carried out in the city.
Barcelona has currently 11 sound sensors installed and it is expected that this number will grow exponentially during 2015 (Figure 3).
The main objective of this lower cost network is to increase the number of measuring points to achieve a real-time noise indicator able to detect the change of the noise-level trends. The integration of these sensors to the *Sentilo* platform may improve the system with additional information from other Departments of the City Council.

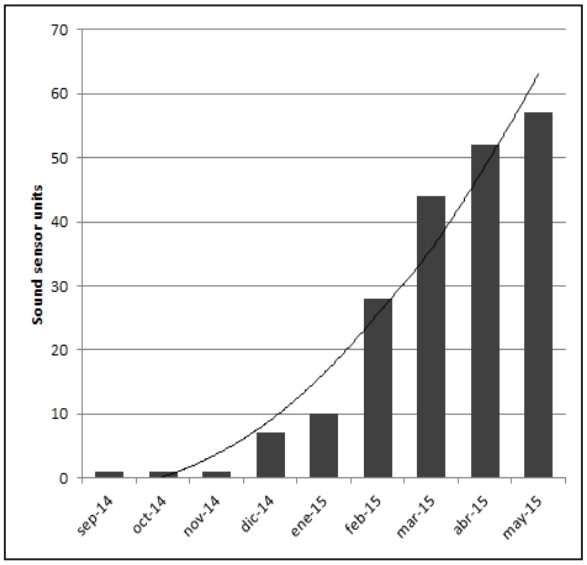

Figure 3. Sound sensors installation plan

Table II. Sound sensors technical characteristic

Type approval	-
Integration time	1 – 15 minutes
Acoustic indicators	LAeq
Tolerance	LAeq± 2 dB(A)
Measure range	40-100dB(A)
Calibration and verification	Verification of the calibration of the sensor must be able to be undertaken in situ using an acoustic calibrator which fulfils the requisites established under IEC 60942.
Others	Weatherproof LAN / 3G connectivity

3. Data transmission protocol

One of the main objectives of the Barcelona City Council is to break the silo between a measuring device and the data processing software, avoiding dependence on suppliers. In this regard, two different data transmission protocols, one for each network, have been defined.

3.1 Main network: integration to the COGNOS platform

The main network is currently using noise monitors from two different providers. With a view to unifying the data management, all the providers have to send the information using a defined template file. This template file is a .csv that was created by the Noise Department of the Barcelona City Council.
Providers store the data of their devices in an FTP server and the data is loaded in the COGNOS system on a daily basis. The user can introduce extra information to the system using the Data Entry platform (figure 4).

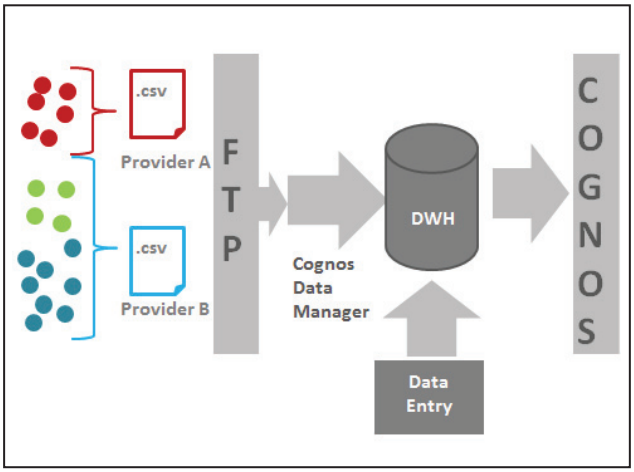

Figure 4. Noise monitors data transmission

3.2. Complementary network: SENTILO

The sound-sensors network is not an insulated network because is part of the City Sensors Network which uses *Sentilo* as the platform designed to serve as a link between sensors and actuators and the applications that manage urban services (figure 5).
Sentilo is not a data warehouse, nor a trends analyzer, nor a tool for citizen participation. *Sentilo* is conceived for cities that want to control the deployment of sensors and actuators in a centralized and common way.
This platform is open source and has no licensing costs. All the details of the application programing interface are defined at the *Sentilo* website (http://www.sentilo.io)

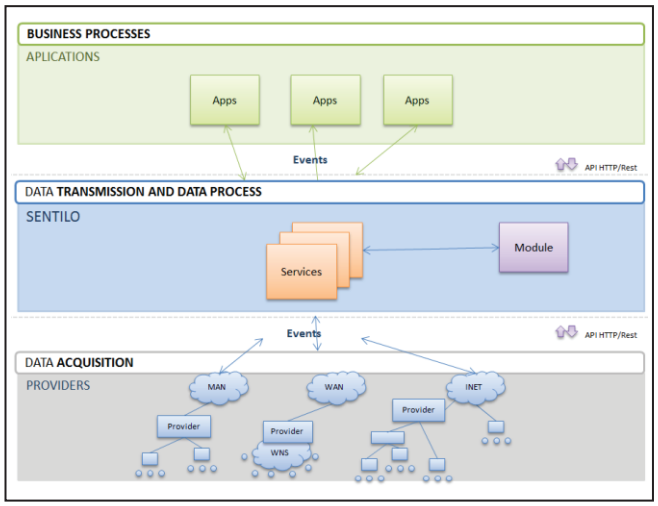

Figure 5.*Sentilo* structure

4. Management and reporting interface

To manage efficiently the noise issues of the city and give a quick response to the citizen demands, we use two different reporting interfaces.
IBM Cognos Query Studio is used to make a detailed data analysis. A corporative platform called Situation Room is used to obtain an overall view of the city status in real time (Figure 6).

4.1 Detailed data analysis

The issues that the Noise Control Department has to deal with are not always easy to solve. For this reason, the Department needs a flexible an efficient tool able to analyze complex scenarios.
The Cognos Query Studio has been set up according to the Department's needs and is able to do the spectral analysis of the noise levels, calculate predefined indicators, and detect different noise sources.
This platform can make the analysis of the data collected by the whole noise monitoring network, including the class I noise monitors and the sound sensors.

4.2. Situation Room

Situation Room is a platform that aims to integrate and share information about the city and its services.

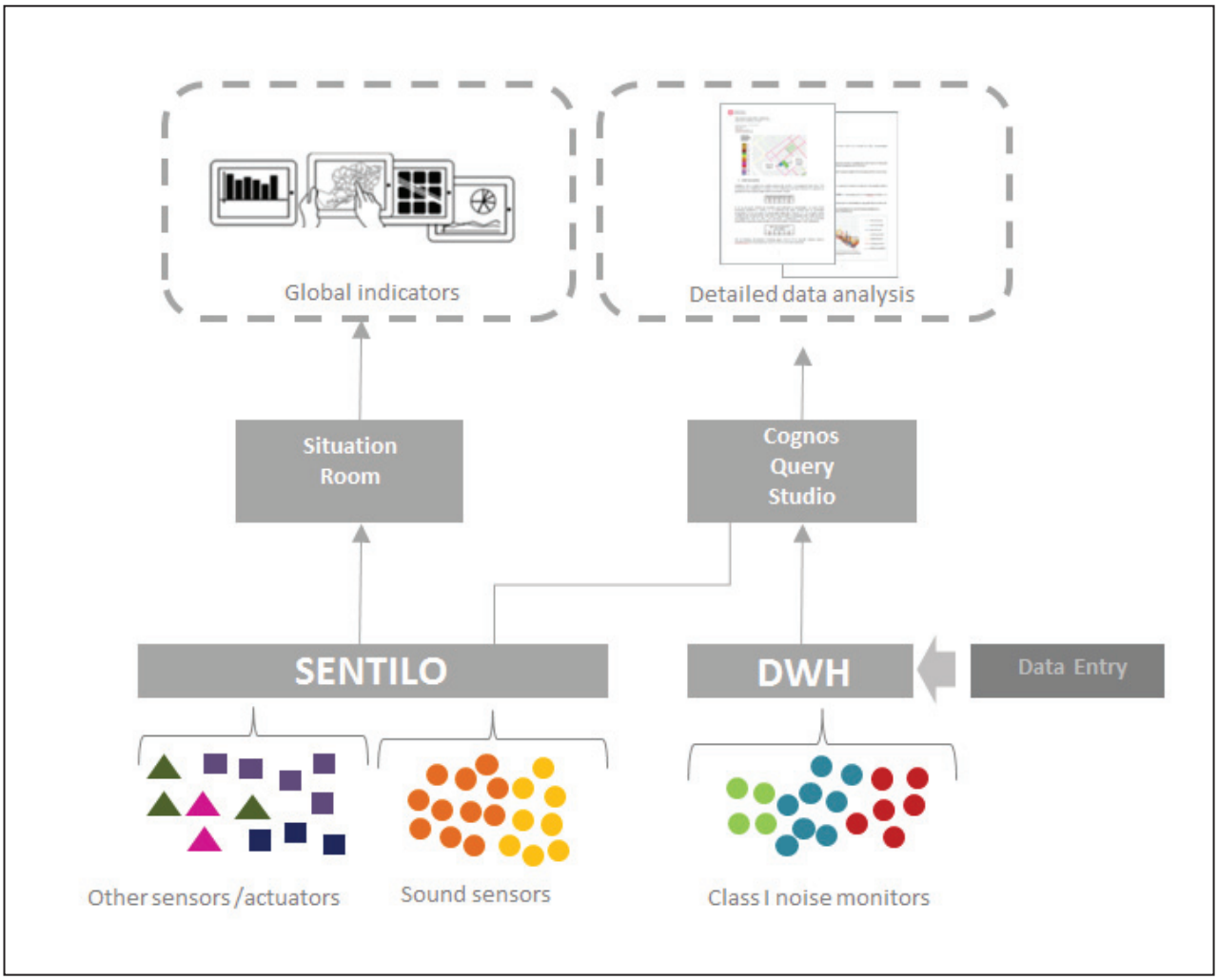

Figure 6. Management and reporting interface

The project was proposed to create a sustainable city model that could manage different resources in an efficient way including water, public services, temperature regulation, CO2 emissions, civil works, humidity, energy efficiency, and noise pollution.

Thanks to sensors monitoring, this urban platform will save energy and will reduce pollution. Moreover, the deployment and maintenance of sensors and processes that deliver information using a unified catalog will reduce costs because it will minimize the duplicity of data and infrastructure.

With this urban platform, the city will be able to capture information in real time, allowing for quicker decision making and response times. Furthermore, the platform will allow crossing the noise pollution information with data from other areas and sectors of the City Council as well as with data from public and private companies creating therefore new knowledge.

However, currently only data from the sound sensors can be managed from the Situation Room Platform.

5. Conclusions

Barcelona seeks to become a self-sufficient, hyperconnected, zero-emissions city. The key to reach this goal is to enable the city to manage resources efficiently and to reduce the impact of urban infrastructure on the environment.

With the improvement of the class I monitoring network and the new development of a sound sensor complementary network the city will achieve enough information to be able to give a quicker response to citizens' demands.

Additionally, the new Situation Room platform will interconnect the sound sensors data with information from other sources, giving a transversal vision of the city status in real time.