



THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING

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The Environmental Noise Directive (END) requires that regular updating of noise maps is implemented every five years to check and report about the changes occurred during the reference period. The updating process is usually achieved using a standardized approach, consisting in collating and processing information through acoustic models to produce the updated maps. This procedure is time consuming and costly, and has a significant impact on the budget of the authorities responsible for providing the maps. Furthermore, END requires that simplified and easy-to-read noise maps are made available to inform the public about noise levels and actions to be undertaken by local and central authorities to reduce noise impacts. To make the updating of noise maps easier and more cost effective, there is a need for integrated systems that incorporate real-time measurement and processing to assess the acoustic impact of noise sources. To that end, a dedicated project, named DYNAMAP, has been proposed and co-financed in the framework of the LIFE 2013 program, with the aim to develop a dynamic noise mapping system able to detect and represent in real time the acoustic impact of road infrastructures. In this paper, a comprehensive description of the project idea, objectives and expected results is presented to inform about the potential breakthrough of the proposed solution.

1. Introduction

Dynamap is a Life+ project aimed at developing a dynamic noise mapping system able to detect and represent in real time the acoustic impact due to road infrastructures. Scope of the project is the Directive 2002/49/EC (END) of the European Parliament and of the Council relating to the assessment and management of environmental noise [1]. Aim of the Directive is to define a common approach intended to avoid, prevent or reduce the harmful effects due to exposure to environmental noise. To that end, noise maps must be provided and updated every five years in order to report about changes in environmental conditions (mainly traffic, mobility and urban development) that may have occurred over the reference period.

The updating of noise maps using a standard approach requires that authorities responsible for providing noise maps collect and process new data related to such changes. This procedure is time consuming and costly and has a significant impact on the financial statements of the authorities responsible for providing noise maps. As a matter of fact, many road administrations and local authorities are complaining about the huge financial effort of noise mapping activities. For this reason, the need for reducing costs, especially in conjunction with the current economic crisis affecting several European countries, has become a primary objective. Such a concern was also confirmed by the working group Road Noise of the Conference of European Directors of Roads (CEDR) in the report on END Noise Mapping (2013)[2]. In addition, the application of administrative penalties in some Member States makes this need far more urgent. As a consequence, a solution to reduce the resources necessary to update noise maps was solicited by CEDR in their report on “Road Noise Research Needs” [3] with high priority.

To facilitate the updating of noise maps and reduce their economic impact, noise mapping can be automated by developing an integrated system for data acquisition and processing that is able to detect and report in real time the acoustic climate due to noise sources. This approach seems quite promising in areas where noise sources are well identified, such as those close to main roads. In complex scenarios, such as in agglomerations, further considerations and testing are needed to make the idea feasible.

Furthermore, the END states that simplified and easy-to-read noise maps are made available to inform the public about noise levels and actions to be undertaken by local and central authorities to reduce the noise impact on the environment. To that end, a suitable on-line database will be equipped with different access levels to deliver simplified data for the public and different levels of information to skilled and authorised users.

Finally, a more integrated approach to environmental monitoring would be desirable, in order to achieve a comprehensive and complete overview of the environmental impact of infrastructures. For this purpose, the system will be also designed so as to be adaptable to other kind of sensors detecting information requiring periodic assessment, such as traffic data, air quality, meteorological and road conditions.

2. State of the art on dynamic noise mapping

Dynamic noise maps are acoustic maps automatically updated using measured data provided by monitoring stations located close to sound sources, such as roads, rails and industrial plants. This application is now days extremely fast as no further recalculation of the sound propagation is needed to adapt the noise map to the measured data. The monitoring stations are installed at relevant receiver locations where sound pressure levels are dominated by sources. For each of the monitored source a complete noise map covering the entire mapping area is calculated and saved.

Noise maps updating is achieved scaling the noise levels of pre-calculated (basic) noise maps as a function of the difference observed between measured and calculated original grid data. This operation is provided for each source present in the mapping area. The updated total map is achieved by energetic summation of single source updated noise maps. The updating process can either be based on traffic count data or other source parameters.

The idea of linking the output of sound level meters to noise calculation models to produce automatic and updated noise maps was developed some years ago.

In 2003 Madrid Environmental Administration, together with Brüel&Kjær, decided to develop a new concept of data post-processing, based on dynamic noise maps or SADAM (Sistema Actualización Dinámica Mapa Acústico Madrid) [4,5]. Mobile monitoring devices equipped with GIS systems were used to measure sound pressure levels at strategic locations. For this purpose, Madrid invested in a system including the Noise Calculation Software Lima and several Noise Monitoring Terminals. This approach was supposed to support Madrid City Council to efficiently validate and

improve the quality of the strategic noise maps, which would have form the basis of the action plan required by EU Noise Directive 2002/49/EC, raising public confidence in the maps and avoiding unnecessary actions based on incorrect results.

Some critical aspects are evident in this approach. First of all the need of mobile monitoring devices to sample sound pressure levels, that makes the solution quite expensive and unsuitable to automatic noise maps updating. Secondly, no algorithm for eliminating spurious events are used to guarantee data reliability and provide accurate maps. In addition, very complicated and time consuming algorithm and software are implemented to update noise maps, thus drastically reducing the possibility of upgrading the system to real time operations.

In the meantime ACCON developed a simple system based on pre-computed maps linked to standard noise monitoring stations, but without any capability of partial maps summing, and without any user-friendly GIS interface for data presentation [6].

At present, a limited number of acoustic software producers provides interface modules to link sound level meters to acoustic simulation applications [7]. These modules need to run continuously in their original environment (the main simulation software) that is, unfortunately, usually quite expensive. In addition, for each investigated area a software license is needed, whereby if many noise areas were to be mapped, a very large number of licenses would be necessary. Furthermore, to update noise maps several noise monitoring stations should be interfaced (depending on the extension and complexity of the area) to scale the pre-calculated maps, thus contributing to increase the overall cost of the system. Therefore, this application, although extremely appealing from a technical perspective, sounds to be extremely expensive and, as a consequence, inapplicable on a large scale.

3. The project idea

The main project idea is focused on the research of a technical solution able to ease and reduce the cost of periodically updating noise maps, through an automatic monitoring system, based on customised low-cost sensors, and a software tool implemented on a general purpose GIS platform performing the update of noise maps in real time (dynamic noise maps).

The update of noise maps can be rapidly accomplished by scaling pre-calculated basic noise maps, prepared for different sources, traffic and weather conditions. Basic noise maps are selected and scaled using the information retrieved from low-cost sensors continuously measuring the sound pressure levels of the primary noise sources present in the area to be mapped. In order to guarantee the accuracy of the updating process, noise levels are first cleaned up from anomalous events before being used to scale the basic noise maps. Scaled basic noise maps of each primary source are then summed-up to provide the overall noise map of the area. In this way, the need for several and expensive software license is extremely reduced and limited only to the preparation of the basic noise maps.

The idea of developing and implementing a low cost monitoring network came from another interesting experience gained in the project SENSEable PISA (Italy - 2011), where large volumes of environmental data were gathered to extrapolate information on public health, urban mobility, air pollution, etc., using appropriate mathematical tools (data mining). To accomplish this task low cost sensors and data transmission devices were developed [8, 0].

Being inspired by this general idea, the system foreseen in the DYNAMAP project includes the development of customized low cost devices to collate and transmit data, and the implementation of a simple GIS based software application for maps scaling with reduced calculation load. Such a standalone dynamic mapping software (no need of running modelling software), together with low cost noise monitoring stations, makes the DYNAMAP system a very efficient and versatile noise mapping tool, virtually able to interface any existing or future noise modelling software, including the new European model CNOSSOS, which is expected to be operative for the next round of END.

The DYNAMAP system includes also some unique characteristics that are not available in commercial products, like algorithms for eliminating spurious events (recognizing and masking unwanted events: i.e. occasional noise, etc.), traffic model data features, and future adaptability to other environmental parameters.

In Fig. 1 a schematic representation of the DYNAMAP system is shown.

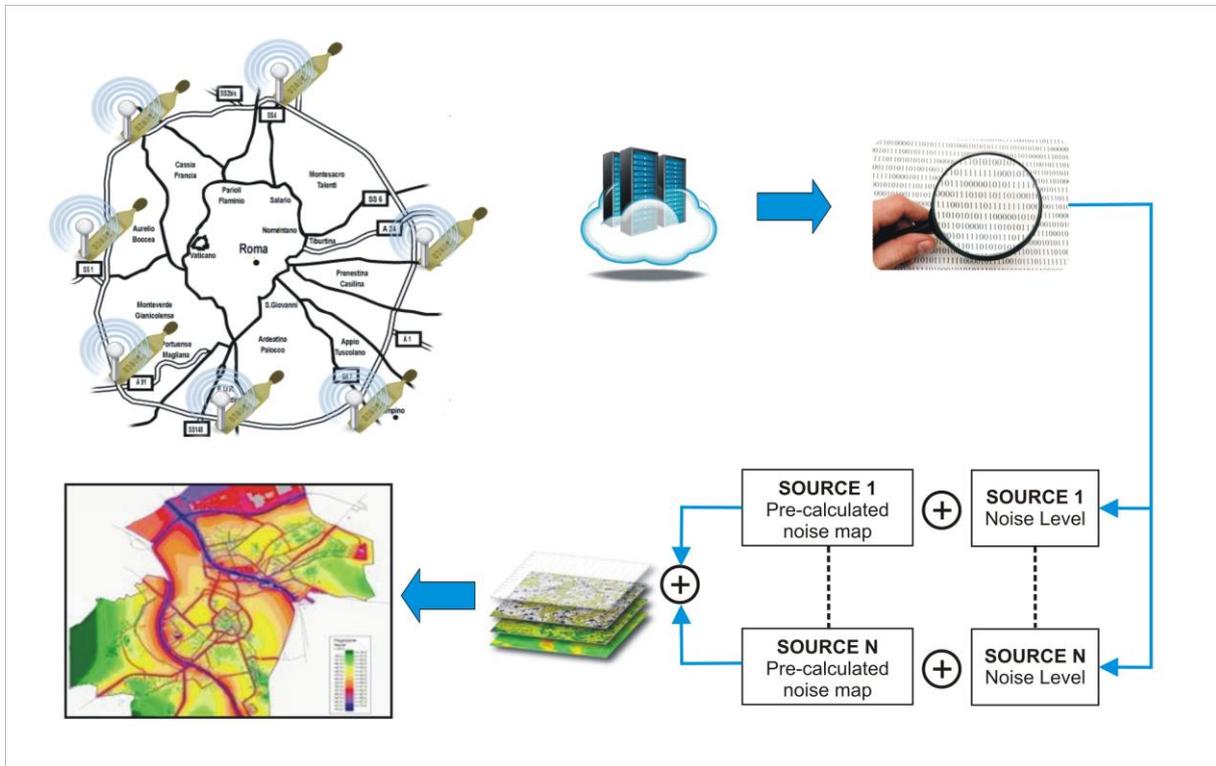


Figure 1. Schematic representation of the DYNAMAP system.

4. The project objectives

The main goal of the project is to demonstrate that noise maps can be automatically updated in real time using low cost sensors and a general purpose GIS platform. The noise levels detected by the sensors will be used to scale noise maps stored in the system database. To that end, customized sensors and communication devices will be developed, in order to reduce the cost of monitoring the road network. An advanced management and reporting interface will be designed to update noise maps and inform the public. Such an interface will be based on a general purpose GIS platform, thus eliminating the need for expensive dedicated acoustic software for data processing.

The feasibility of this approach will be proved implementing the systems in two pilot areas with different territorial and environmental characteristics: an agglomeration and a major road.

The first pilot area will be located in the city of Milan and will cover a significant portion of the town including different type of roads and acoustical scenarios. Roads will be classified and assigned to three clusters, based on traffic characteristics. Twenty four roads representative of the clusters will be continuously monitored to provide noise levels for noise maps updating. Traffic data collected by on site available vehicles counting devices will be integrated in the dynamic noise mapping system to improve and refine noise maps with real traffic information.

The second pilot area will be located along a major road, i.e. the ring road surrounding the city of Rome. Sensors devices will be installed in hot spots where traffic counting is unavailable to feed the dynamic mapping system with real time information on noise levels. About 25 devices will be used to provide noise levels information alongside the road and dynamically update the noise maps.

The two pilot areas will be monitored for at least one year to check the reliability and accuracy of the system. Static maps accomplished using standard acoustic models and software will be compared with those provided by the Dynamap system. Fault events will be also analysed in order to detect system malfunctions and define the specifications for future system and devices upgrade.

As a secondary objective, the project aims at demonstrating that dynamic mapping can be also applied to monitor and report the information related to other environmental parameters, such as those related to air quality, meteorological conditions, traffic, etc. Integrated information can be effectively used by decision makers to monitor polluted areas and take the appropriate actions to restore critical situations. To test this option, two monitoring sites will be equipped with additional sensors to assess the feasibility of feeding and integrating the dynamic mapping system with multiple information.

Finally, the Dynamap system will be also equipped with a GIS web software application to inform the public on noise issues. A group of selected users will be monitored to check the accessibility of the system and help developing a user-friendly interface for public information. The system will be validated by testing stakeholders ability in managing the tool and assessing their agreement through ad hoc tutorials. Case studies related to the most common environmental problems will be proposed in order to assess the effectiveness of the dynamic mapping system.

The general public will be also involved in the project monitoring to evaluate the system versatility and its contents comprehensibility. A sample of people with different age will be used to take into account the diverse background and ability in managing computers and software applications. Assisted and stand-alone tests will be provided in order to check people reactions to the specific system application.

5. The project structure

The project will be accomplished through four main steps:

1. Development of low cost sensors and tools for the management, processing and reporting of real time noise maps on a GIS platform.
2. Design and implementation of two demonstrative systems in the cities of Milan and Rome.
3. Systems monitoring for at least one year to check criticalities, analyse problems and faults that might occur over the test period. Test results will then be used to suggest system upgrade and to extend its implementation to other environmental parameters.
4. Provision of a guideline for the design and implementation of real time noise mapping.

The four steps will be implemented through 14 main actions (Fig. 2):

- 2 preparatory actions to collect information on the state of the art of real time noise mapping, analyse the road networks and find areas to be used for implementing the demonstrative systems, acquire information on the pilot areas.
- 9 implementation actions to size the monitoring network, develop hardware and software, implement and test the system in the pilot areas, provide a guideline to real time noise mapping.
- 3 monitoring actions to assess public response and user ability in consulting and managing the system, evaluate costs and benefits, provide future visions on system applications.

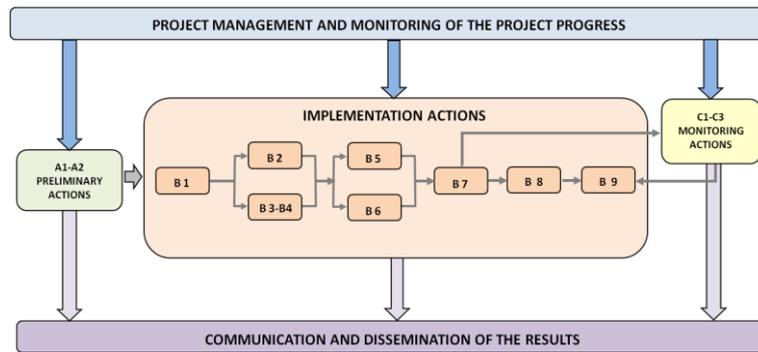


Figure 2. Main actions.

6. Expected results

The project is expected to provide seven main deliverables:

1. Development of low cost sensors to measure the noise levels generated by the sources included in the mapping areas. A cost reduction of about 50% for noise mapping activities is expected by implementing the Dynamap System.
2. Development of a software tool for dynamic noise mapping – Data retrieved from sensors will be sent to a data management system, through a dedicated software application for real time data managing and processing.
3. Implementation of two demonstrative systems – The system will be installed and tested in two different sites: the first one located inside the agglomeration of Milan and the second one along a major road surrounding the city of Rome.
4. Test results of the systems – The system will be tested for one year in order to assess its reliability, detect and solve problems, determine its accuracy and calculate the uncertainty associated to noise maps.
5. System upgrade feasibility – The possibility of strengthen the system with applications for dynamically reporting integrated environmental impacts (noise, air quality, meteorological conditions, etc.), will be analysed.
6. Test results on public response and user ability in consulting and managing the system – The software tool will be structured with different data access levels based on the privileges assigned to users. The tool will be tested to check the public response and user ability in consulting and managing the system.
7. Dissemination – The project will provide for an extensive dissemination campaign based on traditional and web communication channels, such as conferences, seminars, workshops, papers, a dedicated website, social networks and forums.

7. Added value of the project

The main added value that can be attributed to the project is the potential reduction of the financial effort required to central and local authorities to provide updated noise maps. The huge economic burden associated to the preparation of reliable noise maps is also made stronger by the presence, in some Member States, of administrative penalties that are applied in case END requirements are not met. As a consequence, the need for reducing costs, especially in conjunction with the current economic crisis, has become a primary objective.

The automation of the noise mapping process using a low cost monitoring network and a software application implemented in a general purpose GIS platform, will contribute to abate costs and

reduce the time needed to update noise maps, regardless of territorial contexts and geographical areas, thus making the measure suitable to all European Countries.

In the past, this solution was partially tested on small areas by means of standard sound level meters and expensive acoustic software, but it has never been tested at a large scale with low cost customized devices and a general purpose GIS platform for data processing and system management.

Another issue that makes the Dynamap System particularly valuable is the possibility of providing immediate actions in case high noise levels are reached. The real time monitoring of noise levels can be effectively used to generate alert signals and drive ITS systems interface to smooth traffic, for instance by remote control of speed limits, heavy vehicles banning, etc. Taking into account that about 75% of the receivers living close by the road networks are impacted by noise levels that do not exceed noise limits for more than 3 dB(A), mitigation measures based on ITS could be effectively used to bring sound pressure levels below the noise threshold. As a consequence of such measures, a noise reduction of 2-3 dB(A) can be expected when interfacing the Dynamap System with appropriate ITS systems.

8. Expected benefits

The Dynamap project is expected to impact mainly authorities responsible for complying with END obligations and, in particular, those appointed for providing updated noise maps for major roads and agglomerations at local and national level. As one of the main objectives of the project is to reduce the economic impact related to data collection and processing to update noise maps, the implementation of the project at a large scale will effectively contribute to abate the financial burden of public administrations.

From a social and environmental perspective, the project will also provide:

- a real time update of noise maps as a consequence of the mapping process automation;
- a reduction of the sites to be noise mapped with traditional tools and expensive monitoring campaigns to collect input data, now limited to new or changed residential areas;
- a faster response to noise mitigation requests, thanks to the real time availability of updated dynamic maps;
- a prompt response to alert events associated to specific noise thresholds through interface devices to ITS systems (for instance, speed limit reduction, traffic calming, etc.);
- a more comprehensive and reliable information on the environmental impact due to traffic, based on the number and type of additional sensors used to monitor the road network;
- a user-friendly tool for informing the public about noise pollution and other environmental issues.

9. Conclusions

In this paper, a comprehensive description of the Life Dynamap project is presented. The project involves the development of a dynamic noise mapping system able to detect and represent in real time the acoustic climate of road infrastructures.

The system will be composed of customized low cost sensors, measuring the sound pressure level of the noise sources present in the area to be mapped, and of a software tool, based on a GIS platform, able to automatically update noise maps in real time. The main goal of the project is to reduce the cost of the noise mapping process and to provide the authorities responsible for noise mapping activities with affordable and ready to use noise maps.

The system will be installed and tested in two very different sites: the first one located inside the agglomeration of Milan and the second one along a major road surrounding the city of Rome to assess its reliability and accuracy.

A dramatically reduced economic burden of noise mapping activities is expected from the DYNAMAP System, as well as more accurate and ready to use noise maps.

To conclude, it is envisaged that the idea of distributing low cost sensors to dynamically update noise maps will contribute in the future to enlarge the number of measured receivers, ideally extending the monitoring network to the whole territory to be noise mapped, with the advantage of ensuring updated and more reliable results.

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