Implementing the Dynamap system in the suburban area of Rome

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ABSTRACT

The DYNAMAP project is a LIFE project aiming at developing a dynamic noise mapping system able to detect and represent in real time the acoustic impact due to road infrastructures. Dynamic noise maps are achieved by updating pre-calculated basic noise maps as a function of sound pressure levels and weather conditions, provided by an automatic monitoring system, made of customized low-cost sensors and of a software tool implemented on a general purpose GIS platform. The feasibility of this approach will be validated installing the system in two pilot areas with different territorial and environmental features: an agglomeration and a major road. The first pilot area is located in Milan, in a significant portion of the town, while the second one is situated along the motorway A90 encircling the city of Rome. The two pilot areas show peculiar needs and characteristics, such as the presence of multiple noise sources, road junctions, traffic and weather conditions, that require different system's specifications. In this paper the main issues related to the preparation of the basic noise maps and the implementation of the Dynamap system in the suburban area of Rome are described.

Keywords: low cost sensors, dynamic acoustic maps, road noise sources, weather conditions I-INCE Classification of Subjects Number(s): 52.3,76.1.1

1. INTRODUCTION

The LIFE DYNAMAP project is a complex five years long project aimed at demonstrating the feasibility of preparing and updating real time noise maps using low cost sensors and a general purpose GIS platform. Scope of the project is the European Directive 2002/49/EC (END) (1) relating to the assessment and management of environmental noise. In particular, the project refers to the need for noise maps to be updated every five years, as stated in the END. Nevertheless, the updating of noise maps using a standard approach is time consuming and costly and has a significant impact on the financial statements of the authorities responsible for providing noise maps, such as road administrations and local or central authorities.

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, able to detect and report in real time the acoustic impact of noise sources. The system will be composed of low cost sensors, installed at relevant receivers locations, measuring the sound pressure levels emitted by the primary noise sources and of a software tool based on a GIS platform able to perform real-time noise maps.

The update of noise maps is achieved by scaling pre-calculated basic noise maps as a function of the noise level difference observed between measured and calculated original grid data for each source present in the mapping area. Scaled basic noise maps of each primary source are then energetically summed-up to provide the overall noise map of the area.

The feasibility of the Dynamap approach will be proved implementing the system in two pilot areas with different territorial and environmental characteristics: an agglomeration, i.e. the city of Milan, and a major road situated along the motorway A90 encircling the city of Rome.

Since the type and number of basic noise maps to be prepared depends on the parameters influencing noise emission and propagation, closely linked to ambient features, different studies were carried out to configure the system in the two pilot areas.

In this paper the study undertaken to define the system configuration in the pilot area of Rome is described.

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2. ROME PILOT AREA CRITICAL ISSUES

The pilot area of Rome is located along the ring road (A90 Motorway) surrounding the city. The ring road is a six lanes motorway, 68 km long, skirting many suburban areas where noise levels were found to impact critically on the residents. Critical areas are characterized by the presence of single or multiple noise sources, such as railways, crossing and parallel roads.

Two main critical issues related to the preparation and update of the basic noise maps can be ascribed to the pilot area of Rome: the contribution of multiple noise sources to the overall sound pressure level and the influence of meteorological conditions on sound propagation.

The first issue deals with the need for separating the noise level generated by the primary source from the contributions of the other noise sources included in the mapping area, as required by the END. This is a tricky problem, as usually major roads go through suburban complex scenarios, where many multiple connections to other transport infrastructures are present. As a consequence, the overall noise level depends on the number and contribution of the noise sources impacting in the area. Since noise maps should refer only to the primary source, the influence of the other noise sources should be eliminated or at least dramatically reduced.

As for the second issue, noise levels at receivers also depend on weather conditions, so that different basic noise maps should be prepared to take into account their influence on acoustic waves propagation. This requires the monitoring of meteorological conditions and the conversion of this information in classes of acoustic propagation (favorable, unfavorable or homogeneous).

3. AVOIDING THE CONTRIBUTION OF COMPETING NOISE SOURCES

In the pilot area of Rome the A90 motorway runs through different scenarios and it is connected to many other roads. For this reason, different type of sites, representative of the main suburban scenarios, have been identified and 17 critical areas have been selected to host the Dynamap sensors (see figure 1) (2). Eleven out of seventeen critical areas include the presence of road junctions, whose impact was not taken into account in the first and second cycle of the END by the road owner. This contribution is not negligible and must be included in the characterization of the motorway noise impact.

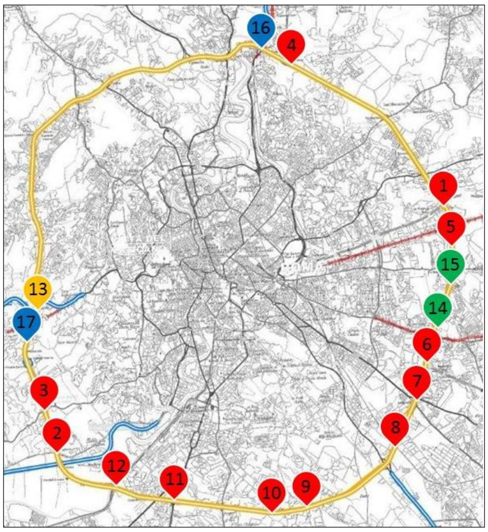


Figure 1 - Rome pilot area. Critical areas location identified with different colors: red (Single road critical areas); yellow (Critical areas with additional crossing or parallel roads); green (Critical areas with railways crossing or running parallel the A90 motorway) and blue (Complex critical areas with multiple connections)

To do so, a measurement campaign was accomplished using an innovative approach based on Kirkhhoff’s junction rule. This rule states that at any node (junction), the sum of electric currents flowing into the node is equal to the sum of currents flowing out the same node. This simple rule, developed for electric networks, can be also applied to traffic flows and allows to arrange a measurement scheme that reduces the number of sites to be monitored, as shown in figure 2.

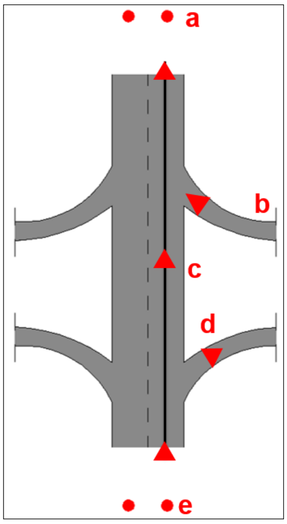


Figure 2 - Position of sound level meters and traffic counters needed in a simple intersection scheme

In this scheme, three monitoring points are necessary for each carriageway: two sound level meters placed on the main road axis (for instance, points a and e) and one traffic counter (point b or d). From the latter, the acoustic power level is calculated from traffic data to avoid the noise level contribution generated by the main axis and the connected roads. The sound power levels on the remaining arcs (for example those related to the measurement points b and c) are then assessed using the equations (2) and (4):

$$a = c + b \tag{1}$$

$$c = e - d \tag{2}$$

$$e = c + d \tag{3}$$

$$b = a - e + d \tag{4}$$

In order to reduce the estimate error due to local ambient conditions (slope, pavement type and traffic conditions (accelerated, decelerated)), the calculated power levels are corrected with calibration factors achieved from short-term parallel noise measurements on the same junctions.

To check the feasibility and veracity of the proposed scheme, this procedure was first applied to two test sites and then extended to the other junctions. To that end, the sound level meters were installed on portals, hosting Variable Message Panels (VMP), to get easy access to the electric power grid (figure 4) and prevent theft. Traffic counters were, instead, blocked with shaped brackets to road signs, placed close to the junctions (figure 3).

Figure 3 - A variable Message Panel (left) and a traffic counter on a road sign (right)

3.1 Test measurement set-up and results

Figures 4 and 5 show the measurement set-up applied to the two selected test sites (number 11 and 12). In green are highlighted the measurement points where sound level meters were installed (the *Px* code indicates the name of the portal where the devices have been placed), while in red are shown the positions of the traffic counters.

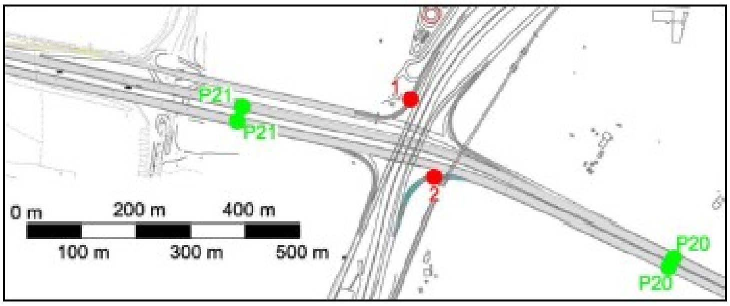


Figure 4 - Test site number 12: A90 motorway in light gray and junctions in dark gray

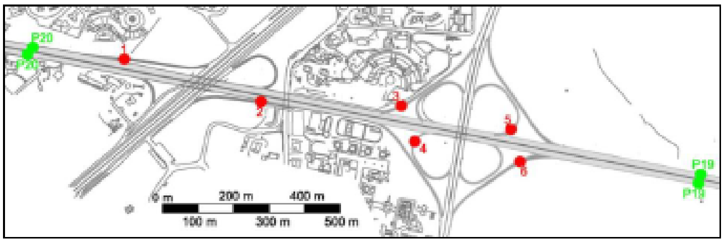


Figure 5 - Test site number 11: A90 motorway in light gray and junctions in dark gray

The measurement results show that the sound power levels difference between the carriages varies from 1 to 2 dB. This difference is very tight and doesn't justify in principle the cost of using two separated monitoring devices, as shown in figure 6, where the hourly trends related to the internal and external carriageways in a working and a weekend day are traced. Therefore, a general hypothesis of equally distributed traffic on the two carriageways can be made without leading to significant errors. This means that only one sound level meter can be placed on the main road axis without major consequences in terms of noise model calibration and its impact on receivers.

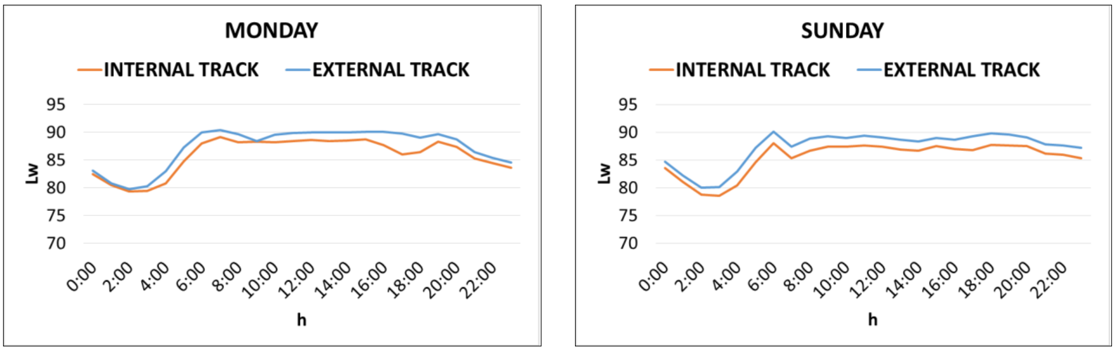
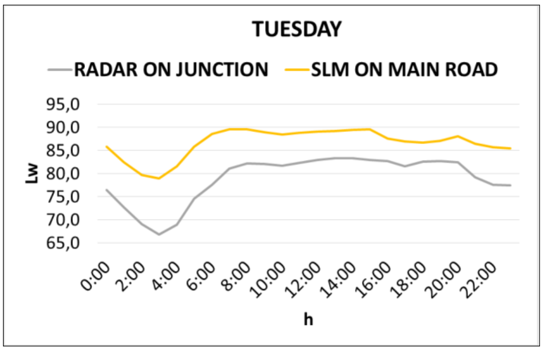


Figure 6 - Hourly sound power level in the two carriageways related to a working and a weekend day.

In order to find a relationship between the sound power levels generated by the motorway main axis and the related junctions, hourly traffic measurements were converted into sound power levels and compared to the measured values on the carriageways axis. This comparison shows that the hourly noise trends on the junctions and on the main motorway axis are almost the same (figure 7).

These results clearly show a real possibility of identifying a relationship between the sound power levels measured on the main axis and the related road junctions. Therefore, the method was extended to the whole pilot area. A monitoring campaign of five days was carried out for each site and the calculation procedure described above was used to determine the sound power levels on monitored and unmonitored junctions.



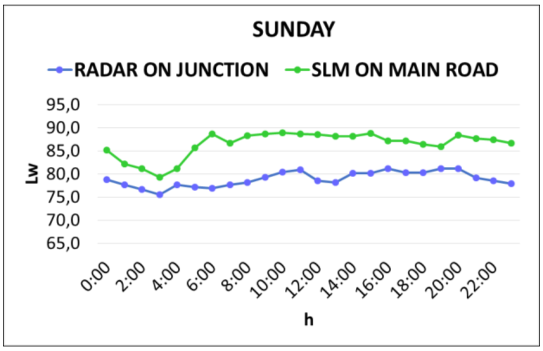


Figure 7 - Hourly graph of calculated sound power level on a junction (gray and blue lines) and on the main road axis (orange and green lines) for a working day (left) and for a weekend day (right)

3.2 Sound power levels relationship

Data collected during the measurement campaign were processed and the sound power level related to each junction was calculated. A statistical analysis was then accomplished in order to identify the sound power level relationships between the main motorway arcs and its junctions, with the final aim of reducing the number of monitoring points as much as possible. To that end the following steps were performed:

- Calculation of hourly correlation coefficients Δ(h)i,j related to the i-th junction and the j-th hour between the sound power levels generated by the A90 motorway and each junction;
- Calculation of daily correlation coefficients Δ(d)i,j related to the i-th junction and the k-th day between the sound power levels due to the A90 motorway and each junction;
- Calculation of working days Δ(wd)i, weekend Δ(we)i and weekly Δ(w)i coefficients related to the i-th junction;
- Clustering of junctions in homogenous classes.

The hourly correlation coefficients Δ(h)i,j are given by the difference between the sound power level measured on the A90 motorway main axis and the sound power level calculated on the related junctions. These coefficient were found to vary from 4 to 11 dB, with an average hourly value of 7.6 dB.

Hourly coefficients Δ(h)i,j were at first reduced to daily coefficients Δ(d)i,k, by calculating their weighed average value of the hourly coefficients. Weighing coefficients were given by the ratio between the number of hours related to the day (6-20, 14 hours), evening (20-22, 2 hours) and night (22-6, 8 hours) period and the total daily hours (24 hours).

Figure 8 shows a typical Δ(d)i,k pattern (black line) and the corresponding standard deviation for each day of the week (light orange area) of one junction. The average standard deviation related to all junctions was found to be 1.2 dB, and its maximum value 1.9 dB. Therefore, the relationship between the main motorway axis and its junctions can be reasonably reduced to a daily coefficient.

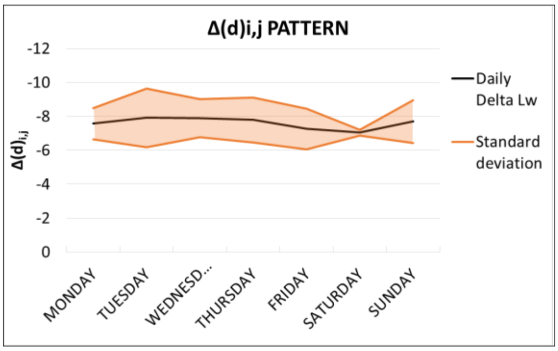


Figure 8 - Δ(d)i,j pattern and the corresponding standard deviation (i = analyzed junction; j = analyzed day)

In order to further reduce the number of coefficients linking the main motorway axis to its junctions, daily coefficients were finally analyzed to see if similarities among the different days of the week could be found. The results of this analysis are shown in figure 9. As it can be seen, sound power levels on working days and weekends seem to have a different trend. In particular, the trend shown by the working days daily coefficients (Monday to Friday evening) are quite similar and can be reduced to a unique coefficient, a working days coefficient Δ(wd)i for each junction. Similarly, a weekend coefficient Δ(we)i (from Friday night to Sunday) can be extrapolated. Δ values related to different junctions with their standard deviations are reported in figure 9. This figure shows that the standard deviation has a maximum value of 1.2 dB in the working days period and of 1.1 dB in the weekend period. By averaging the standard deviation of all junctions, a value of 0.4 dB for working days and 0.8 dB for weekend days was found.

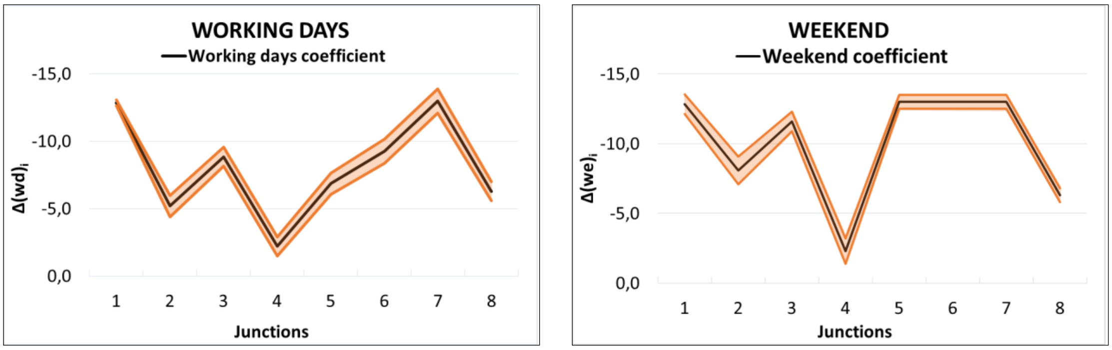


Figure 9 - Working days Δ(wd)i and weekend Δ(we)i patterns and the corresponding standard deviation for different junctions

As a consequence, the Δ(wd)i and Δ(we)i coefficients can be applied to each junction without leading to significant errors.

To further optimize the methodology, the daily coefficients were averaged to achieve a weekly coefficient Δ(w)i for each junction (figure 10). As it can be seen from figure 13, in many cases the standard deviation is higher than 2 dB (orange line), therefore in such cases the weekly coefficient can't be considered acceptable.

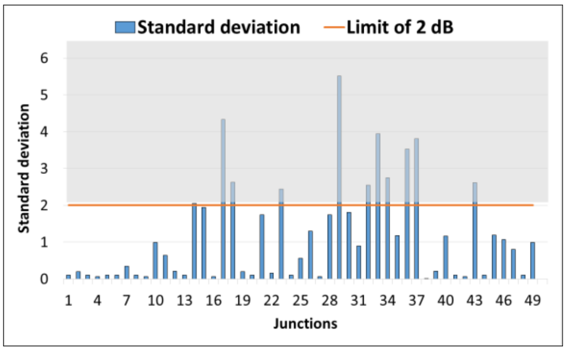


Figure 10 - Standard deviation considering a weekly coefficient for each junction

However, figure 10 suggests to split the junctions set into two clusters, fixing an acceptable threshold of 2 dB:

- Cluster 1: junctions with a standard deviation for weekly coefficients lower than 2dB. In this case the main road arc and its junctions can be mapped together as a unique elementary noise source using this coefficient, thus reducing the number of basic noise maps to be provided and the monitoring stations necessary to scale the maps.
- Cluster 2: junctions with a standard deviation for weekly coefficient upper than 2dB. In this case, the basic noise maps necessary to scale the contribution of the elementary noise source are two: one for working days and one for weekends.

More in detail, 10 main arcs and 71 junctions can be ascribed to Cluster 1 and 9 main arcs and 61 junctions to Cluster 2. It follows that the number of elementary noise sources achieved with the application of this ploy is 19 (Figure 11), leading to a 85% reduction of the sites to be monitored and noise mapped.

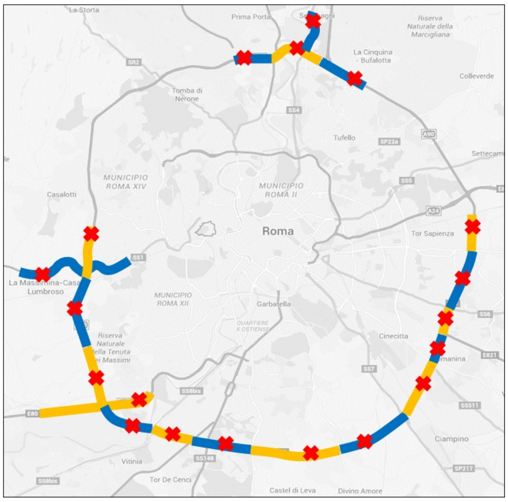


Figure 11 - Final number of elementary noise sources and location of the monitoring stations (x)

4. BASIC NOISE MAPS AS A FUNCTION OF METEOROLOGICAL CONDITIONS

In suburban areas noise levels at receivers are usually influenced by weather conditions. Depending on the site configuration (geometry, topography, ground characteristics, etc.), wind, temperature and humidity can cause acoustical fluctuations over time and space that might become relevant even at few dozen meters away from the source (road, railway or industrial noise) (3).

Atmospheric conditions alter sound waves propagation through thermal (heat transfer) and aerodynamic (wind profiles) phenomena. These phenomena can induce positive or negative vertical sound gradients, leading to favorable, unfavorable or homogeneous conditions, that must be taken into account when preparing the basic noise maps. This entails the study of two different, but strictly connected, aspects:

- the definition of a method to correlate weather information to sound propagation conditions in order to allow the selection of the most appropriate basic noise map;
- the identification of a set of meteorological scenarios, corresponding to as many basic noise maps, as a function of the acoustic model sensitivity to spatial weather variations.

4.1 Classification of sound propagation conditions

Two possible approaches to the classification of sound propagation conditions are currently available in literature: the first one is described in the standard ISO 1996-2 (4), while the second one in the recent NMPB 2008/CNOSSOS calculation model (2).

In the Standard ISO 1996-2 four classes are defined as a function of the parameter D/R_{cur}, where D is the horizontal distance of the receiver from the source and R_{cur} is the radius of curvature of the acoustic rays. The calculation of this parameter is quite tricky and requires a series of information that include wind speed and direction, cloud cover and the angle between sound and wind propagation directions. The latter is not easy to determine and depends on the geometrical features of the source. In case of a non-straight road source, this means that in the same mapping area many different values of R_{cur} should be calculated as a function of road orientation.

In the NMPB 2008/CNOSSOS model five classes of propagation conditions are identified as a function of aerodynamic and thermal conditions, corresponding to average values of meteorological data, observed over a 'short-term' period, related to wind speed and direction, cloud cover and rain rate, that can be easily measured or retrieved from existing monitoring stations (3). This method, although less accurate than the Standard ISO 1996-2, is much easier to be implemented.

4.2 Identification of the method to be applied to the Dynamap System

As one of the main objective of the project is to reduce the cost of the system as much as possible, the selection of the method to be applied to the Dynamap system should be based on costs in retrieving or measuring meteorological data, but also on the time needed to process data and prepare the basic noise maps.

If floating free data are used the cost of meteorological information is not more a parameter to be considered. In this case, the choice should be determined by other factors, such as the reliability and accuracy of data, the time needed to process and prepare the basic noise maps.

As for the time needed to process data and prepare the basic noise maps, the following considerations apply:

- The standard ISO 1996-2 requires the identification of prevailing propagation directions, that depends on road segments orientation. This information can be achieved on the basis of the road arc coordinates and stored in a database for the calculation of the parameter D/Rcur. Consequently the identification of propagation conditions is more time consuming, not only when preparing the basic noise maps (calculations of the prevailing propagation directions), but also when processing data (calculation of D/Rcur for all the prevailing propagation directions).
- The model NMPB 2008/CNOSSOS provides a qualitative approach for the identification of propagation conditions based on a set of meteorological information, that it is assumed to be less accurate (2), but simpler. In this case only information on the time of the day, cloud cover, wind speed and direction is necessary.

These considerations seem to naturally make converge the choice on the scheme proposed in the NMPB 2008 model.

This scheme can be further simplified taking into account that currently available acoustic models are unable to manage unfavorable conditions, so that they are replaced by homogeneous conditions. This simplification tends to overestimate the actual sound levels, but it contributes to improve receivers protection (3). In the simplified scheme only three states are achievable (see Table 1): homogeneous conditions (H), favorable or homogeneous conditions in specific wind sectors (F or H) and favorable conditions in all directions (F).

Table 1 – Simplified scheme, where H states for homogeneous conditions, F or H for favorable or homogeneous conditions in specific wind sectors and F for favorable conditions in all directions

Time of the day	No wind	Light wind (ws≤3 m/s)	Strong wind (ws> 3m/s)
Day time	H	H	F or H
Sunrise or Sunset	H	F or H	F or H
Night AND cloudy	F	F or H	F or H
Night AND clear sky	F	F	-

As a consequence, the classification of propagation conditions can be achieved from information on wind speed and direction, and cloud cover. These data can be retrieved from existing weather stations publishing free data on the web with a sufficiently short time frequency (at least 1 hour), or from additional local meteorological stations.

Data provided on site by local meteorological stations can guarantee more reliable and accurate results, but in this case, their contribution to the whole system cost can't be neglected. This contribution depends on the number of sensors needed. In the simplest and, consequently, cheapest way to identify propagation conditions, only two or three temperature sensors positioned at different heights and an anemometer are necessary to measure thermal conditions and wind features.

In order to identify the number of meteorological stations necessary to accurate determine sound propagation conditions, the spatial representativeness of weather information was investigated. This last step was necessary to finally define the amplitude of the wind sectors and consequently the number of basic noise maps to be prepared for each elementary noise source. In order to check how sensitive is the simplified method to spatial weather variations, a sensitivity analysis was applied to local meteorological data.

4.3 Sensitivity of the noise model to spatial weather variations

The Rome pilot areas is composed of many test sites distributed along the motorway A90, corresponding to as many critical areas (5). Consequently, each site should be associated to reliable meteorological information. As one of the main objective of the project is to lower the cost of the system as much as possible, weather data should be preferably retrieved from existing monitoring stations. Two official monitoring weather stations are available in proximity of the motorway A90. Both are managed by the Italian Air Force and provide reliable data. The first meteorological station is located inside the airport area of Roma-Urbe, in the northern part of Rome, while the second one is located in the southern part of the town, inside the airport area of Ciampino.

Data from the meteorological station of Roma-Urbe are available with a time frequency of one hour, whilst those from the meteorological station of Ciampino are published with a time frequency of 30 minutes. As a matter of fact, data from Ciampino airport are used by the main forecast meteo websites to calibrate their models. Therefore, the possibility of feeding the Dynamap System with forecast data has been investigated as well. For this reason the sensitivity of the model to spatial weather variations was verified using both forecast and measured values.

As for forecast data, four zones (Ciampino, Northern Rome, Western Rome and Eastern Rome) were compared for 7 days and their influence in terms of propagation conditions was calculated using the simplified model described above.

The results of the sensitivity analysis related to forecast and measured data are shown in figure 12 (a) and (b) respectively. In figure 12 (a) the upper graph reports, for each zone, the trend of sound propagation conditions in the time interval ranging from 12:00 to 24:00 hours for seven days. As it can be seen, the four curves are almost superimposed everywhere, except in two cases when the wind speed is crossing the threshold of 3 m/s that separates light from strong wind speed conditions (lower graph). These results highlight that sound propagation conditions are the same in 95% of cases and that the model used is quite insensitive to small weather variations.

Weekly data measured by the two meteorological stations of Roma Urbe and Ciampino were also compared to check their difference. In this case, the study was limited only to daytime, as weather data from Roma Urbe were not available at nighttime. As shown in figure 12 (b) the actual situation is a little bit less favorable and the accuracy drops down to 92%. Also in this case differences are mainly due to measured wind speed values close to the threshold of 3 m/s.

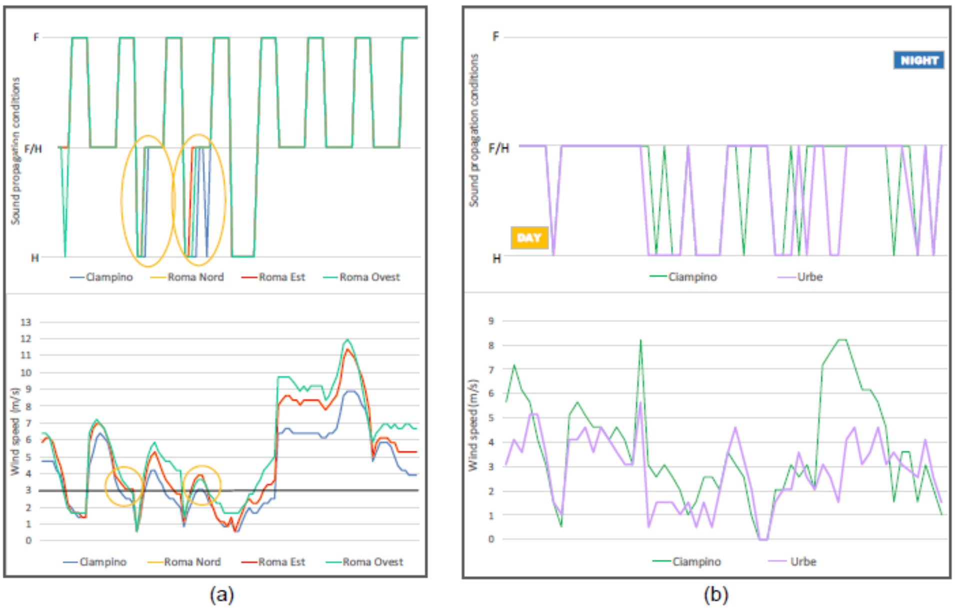
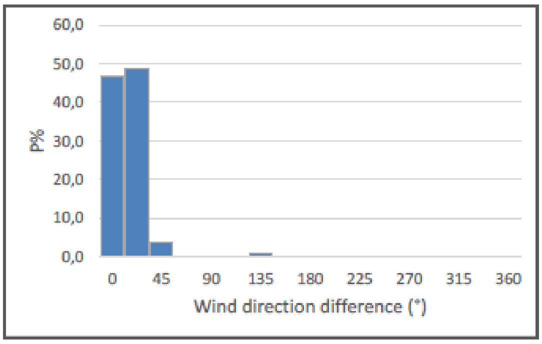


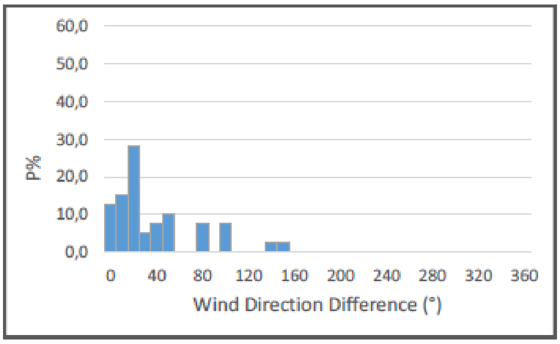
Figure 12 - Results of the sensitivity analysis applied to forecast (a) and measured data (b). The upper graphs report the results related to the classification of sound propagation conditions achieved using the simplified scheme. The lower graphs show the wind speed predicted in the four investigated zones (a) or measured (b) by the two weather stations of Roma Urbe and Roma Ciampino

These results lead to the main conclusion that information gathered by one meteorological station can be considered sufficiently accurate to classify sound propagation conditions in the whole pilot area.

The same analysis was then carried out to see how sensitive is the model to wind direction. Also in this case the analysis was applied to both forecast and measured data. As for forecast data, figure 13 (a) shows that the difference in wind direction of the four investigated zones is substantial only in a few cases and the probability that the difference is less than 22.5° is 95%. However, the difference in wind direction that can be attributed to measured data is less favorable, as it can be seen from figure 13 (b). In this case the differences are distributed in a wider range, varying from 0° to 150°. A probability of 90% can be assumed for differences ranging from 0 to 90°.

The uncertainty associated to wind direction can be reduced by widening the wind sectors. Wind sectors are usually defined by steps of 20°, leading to a total number of 16 wind sectors, therefore increasing the amplitude of wind sectors from 20° to 90° can bring to more reliable and stable results, as in this way most of the differences in wind direction can be absorbed (error ≤ 1%). This solution allows to considerably reduce the number of basic noise maps to be prepared, as only four wind sectors (North, East, South and West) are necessary for each elementary noise source (see figure 14).





(a) (b)

Figure 13 - Cumulative distributions of wind direction differences related to forecast data (a) and measured data (b)

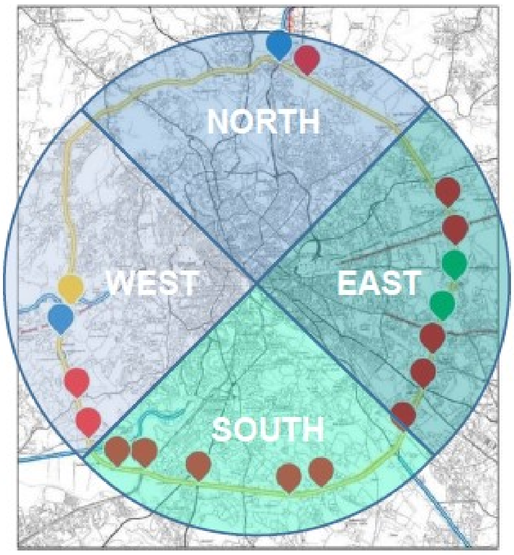


Figure 14 - The four wind sectors of the pilot area of Rome

These results show that a reasonable number of 6 basic noise maps for each elementary independent source are needed: one for totally homogeneous conditions, one for totally favorable conditions and four maps for favorable conditions in specific wind sectors.

5. SIZING THE NUMBER OF BASIC NOISE MAPS

A basic noise map is an array that reports the contribution to the overall noise level of the elementary noise sources present in the mapping area for every point of the grid and for each sound propagation condition. Therefore, the basic noise maps to be prepared depends on the prevailing classes of acoustic propagation and traffic conditions.

As it was shown in chapter 3, a total number of 132 road arcs were counted along the seventeen test sites. In principle, each road arc should be considered as an independent noise source, however it is possible to find proper correlation coefficients between the main road arcs and their junctions, that allow to reduce the number of independent elementary noise sources to 19. Correlation factors can also depend on traffic conditions and a different trend was found in working and weekend days for 9 out of 19 elementary noise sources, leading to a total number of 28 different scenarios.

In chapter 4 it was also described the influence of meteorological conditions on sound propagation and it was shown that 6 basic noise maps (one for totally homogeneous conditions, one for totally favorable conditions and four maps for favorable conditions in specific wind sectors) are necessary for each elementary noise source and traffic condition. Since a different behavior of the elementary noise sources was observed in working and weekend days, two different basic noise maps must be prepared to reflect such difference for each propagation condition, one for working days and one for weekend days, leading to a total number of (2x6) = 12 basic noise maps.

The number of calculations to be carried out to prepare the basic noise maps depends on the method used to accomplish the maps. Basically, two methods are available: grid noise map and meshed noise map.

In the first method simulations are made on a regular spaced grid and the overall noise level is calculated for each point of the grid. In order to prepare the basic noise maps, simulations should be made separately for each elementary noise source in order to achieve their contribution to the overall noise level at receivers. This means that a total number of (10x6)+(9x2x6)=168 calculation should be accomplished.

In the second method calculations are made on an optimized grid based on the density of the receivers in the mapping area and the contributions of the different noise sources for each point of the grid are stored in a table, together with the overall noise level. In this case calculations are faster and the contribution of each noise source is available in a single run. It follows that only one calculation is necessary for each acoustic propagation condition.

Regardless the method used to calculate the maps, results should be arranged in bi-dimensional arrays, i.e. the basic noise maps, including for each point of the grid the contribution of the elementary noise sources to the overall noise level related to each point of the grid.

6. CONCLUSIONS

In this paper the design phase of the Dynamap system configuration related to the pilot area of Rome was described. The design phase mainly involved the sizing of the monitoring network and the identification of the basic noise maps to be prepared for the update of noise maps in real time. These aspects are mostly affected by two main critical issues: the influence of additional noise sources to the overall noise level and the effects of meteorological conditions on sound propagation.

As for the first issue, according to the Environmental Noise Directive acoustic maps should refer to single noise sources, therefore suitable sites should be identified to place the sensors and smart correlation factors between the main axis and its junctions should be identified, in order to reduce the complexity of the monitoring system. To that end, an extensive monitoring campaign was arranged in order to assess the contribution of each noise source and provide an accurate model calibration. This survey led to the main conclusion that along the A90 motorway traffic flow is more or less equally distributed between the two carriages and that noise levels can be detected on the main road axis without significantly affecting the accuracy of the acoustic maps, thus contributing to reduce the number of elementary noise sources to be monitored. This number was further decreased with the estimate of a correlation factor between the sound power levels on the main road axis and its junctions, leading to at most a total number of 19 independent elementary noise sources.

As for the second issue, dealing with the influence of weather conditions on noise levels, the study was focused on finding a low cost suitable solution to retrieve or measure meteorological conditions, so as to define a reasonable number of propagation classes to be taken into account when preparing the basic noise maps. The outcome of this study has shown that detailed weather data are not necessary and that the information provided by only one meteorological station is sufficient to classify sound propagation conditions in the whole pilot area with an accuracy of 92%. Furthermore, it was also found that the entire pilot area can be broken down into four wind sectors, thus reducing the variability of sound propagation conditions due to aerodynamic factors and the possibility of basic noise maps conflicts. This simplification allowed to cut down to six the number of basic noise maps needed for each independent elementary noise source: one for totally homogeneous conditions, one for totally favorable conditions and four for favorable conditions in specific wind sectors.

Since the A90 motorway is characterized by different traffic trends in working and weekend days, two basic noise maps should be prepared for each sound propagation condition, leading to a total number of (2x6)=12 basic noise maps.

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