

Verifying Noise Monitoring System: an Operative Procedure

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Aircraft noise pollution has been monitored around Milano-Linate airport since early 80s. Accomplishing EU principle “the polluter pays”, Italian law in 1995 assigned to airport handling companies the responsibility of noise monitoring systems, operating costs and maintenance. The Lombardia airport system consists of three main airports: Milano Malpensa (international hub), Milano Linate (international and city airport), Bergamo Orio al Serio (international and cargo). About 23% of the whole Italian traffic involves this airport system (about 26 million of passengers and 400 kT of freight). Despite of the commitment in this activity (several Remote Monitoring Terminals (RMT) are installed around Malpensa, 5 around Linate and 5 around Orio al Serio) communities living around airports demand the presence of a neutral authority auditing the process from noise measurement, managed by handling companies, to environmental impact assessment, carried out by a special Committee collecting members from each Airport Authority. This audit activity can cut off some prejudices, connected with the handling company role, which has the responsibility of monitoring its customers (i.e. aircraft companies) and can achieve a major certainty about noise assessment. Regional Environmental Protection Agency (ARPA) acts as auditor: this is one of its insitutional tasks assigned by Italian legislation. Its aim is asserting the validity of measurement in order to achieve a good significance about noise indexes. ARPA elaborated a standard procedure for accomplishing this role, in analogy with the Quality Assurance approach. This standard procedure includes two steps: the first one concerns the collection of information by means of a questionnaire given to the airport monitoring system conductor; thereafter, an auditor team performs a complete inspection with the support of a checklist, providing also measurements close to remote monitoring terminals using a reference instrumentation. The checklist includes 16 steps, for a total of 128 items concerning the monitoring system, intended as a whole, and 58 items about remote monitoring terminals (RMT), which are controlled one by one. The checklist follows a logical track, starting from measures, following with data processing and concluding with impact assessment. Each item in the checklist is splitted into seven sections: legislation reference, answer to question, conformance, control flag, test description, annexes, presence of comment – if needed, a specific comment is included in the checklist related report. This structure has the capability to perform a complete survey on the whole system. The control of each monitoring system is periodical, and is carried out throught a minimum of two surveys per year. In the paper we present a brief outline of italian law about noise and we discuss in detail the checklist, its scope and pratical operating procedure.

Nomenclature

i	=	time index during day
j	=	daily index
k	=	time index during night
K	=	trailing-edge (TE) nondimensional angular deflection rate
LVA	=	Level of Aircraft eValuation: the noise index for assessing noise around airports used in Italy, in dB(A)
LVA_j	=	The Day/Night Level, computed daily, in dB(A)
L_{Max}	=	Maximum of Sound Pressure Level, dB(A) Fast
N_d	=	Number of noise events matched with aircraft operation during day
N_n	=	Number of noise events matched with aircraft operation during night
NAP	=	Noise Abatement Procedure
RMT	=	Remote Monitoring noise Terminal
SEL	=	Single noise Event Level, as in ISO 1996 L_{AE} , in dB(A)

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SEL_{10} = SEL calculated within 10 dB from L_{Max} , in dB(A)

I. Introduction

The Lombardy area is one of the most developed in EU: it is the richest region of Italy, and produces over 20% of gross domestic product with more than 750,000 businesses and 4 million workers. With a population equal to 2.6% of the EU Lombardy's contribution to the Community's gross domestic product is 3.7%.

There are 4 international airports: Milano Malpensa, Milano Linate, Bergamo Orio (also known as Milano Orio) and Brescia Montichiari.

In Table 1 is reported the traffic to/from Lombardy's airports compared to national total.

Milano Malpensa acts as a national hub, owned by the national aircraft company (i.e. Alitalia); the distance from the city is about 40 Km. In the surroundings is the Ticino River Park and lives about 20,000 people.

Milano Linate is the nearest from the centre of the city, only 7 Km. In the past it was a very busy airport, with a peak of 13 millions of pass. in 1998. With the Malpensa 2000 project its role was reduced and now acts as a city airport. Despite of its secondary role, near the airport lives about 250,000 people, which are very sensitive to the problem of noise annoyance.

Bergamo Orio is located near Bergamo, a small but beautiful town beside the Orobic Mountains. It is the 2nd freight airport in Italy, owing to some international freight carrier that operate from Italy to their hub. This makes nighttime noise very hard, and noise procedures takes into account different take-off directions for day and night.

Brescia Montichiari has an interesting development: it is located near Garda's Lake, between Lombardy and Veneto, so that could collect people and freight from Milan to Venice. In this area is being developed new highways and railways, especially the "High Speed Train". The development is more interesting because of not yet populated area beside airport.

This data show the importance of aircraft traffic for our region, that is a strategic issue for economical development, and must not be in conflict with communities who live beside airports. Monitoring of noise is an important component in order to assess the real impingement on communities in terms of annoyance, but it also can assess violation of Noise Abatement Procedures, with the aim to press aircraft companies to modify their behaviour and contain noise heard on the ground.

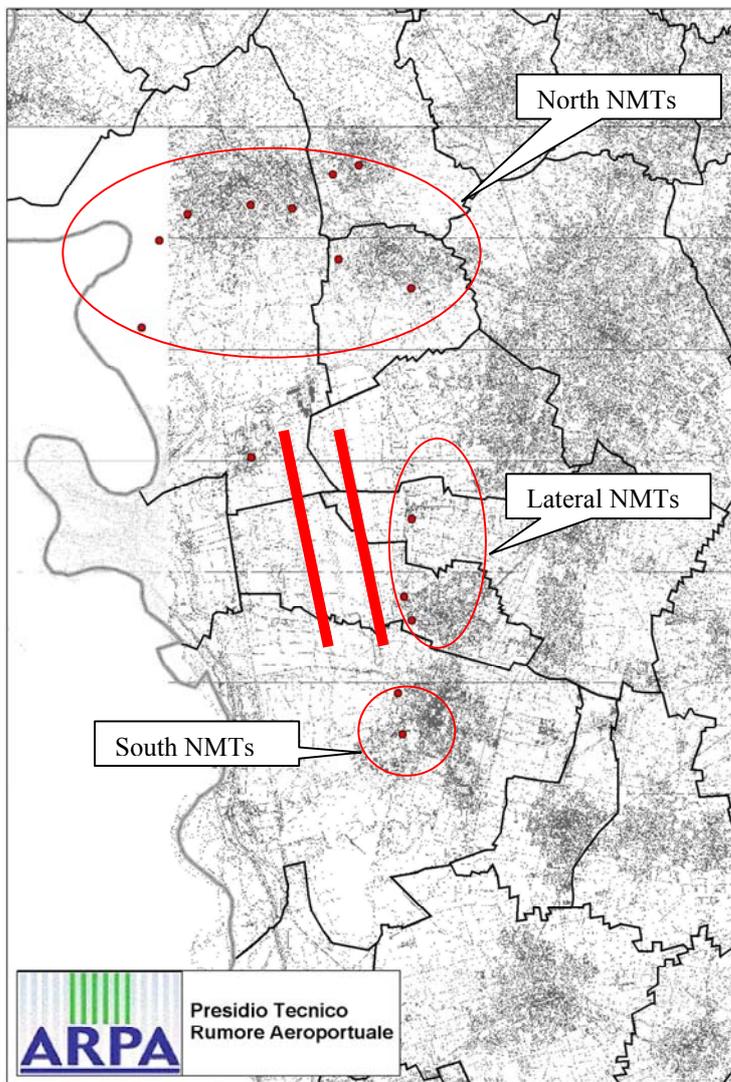
Airport	Movements	Passengers (millions)	Freight (KTONn)	Percentage (pass.)
Bergamo Orio (LIME)	29,144	1.287	113	1.4 %
Milano Linate (LIML)	86,588	7.814	1.1	8.6 %
Milano Malpensa (LIMC)	212,210	17.384	293	19.2 %
Brescia Montichiari (LIPO)	4,757	0.293	0.7	0.3 %
Lombardy Subtotal	332,699	26.778	408	29.5 %
National Total	1,216,750	90.610	736	100 %

Table 1: Aircraft traffic in Lombardy in 2002

II. Monitoring systems

In mid 70s noise around airports become an important subject: citizens created some group of interest asking to Public Health Organization to verify their exposure to aircraft noise pollution.

In five years was created the very first italian noise monitoring system, consisting of three RMT around Linate Airport. In 1993 the system was renewed, adding two more RMT. In 1996 a system based on eight RMT was installed around Malpensa Airport: nine RMTs has been added after 2000, when Malpensa became an hub for Alitalia Company. In 1995 a system based on five stations was installed around Bergamo-Orio Airport: the system software was upgraded in 2001, in order to analyse flight tracks.



At the present there are, only in Regione Lombardia, three monitoring system consisting of twenty-seven RMT; each system has a radar link to Air Traffic Control and to Airport Data system in order to match noise events with aircraft operations.

Figure 1 Milano Malpensa Airport and RMTs

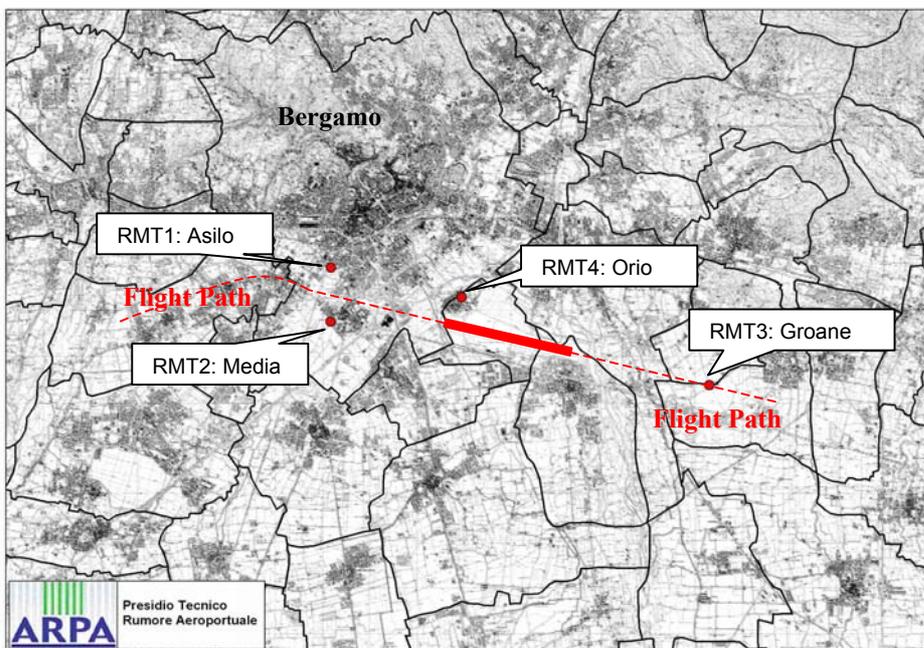


Figure 2 Bergamo Orio Airport and RMTs

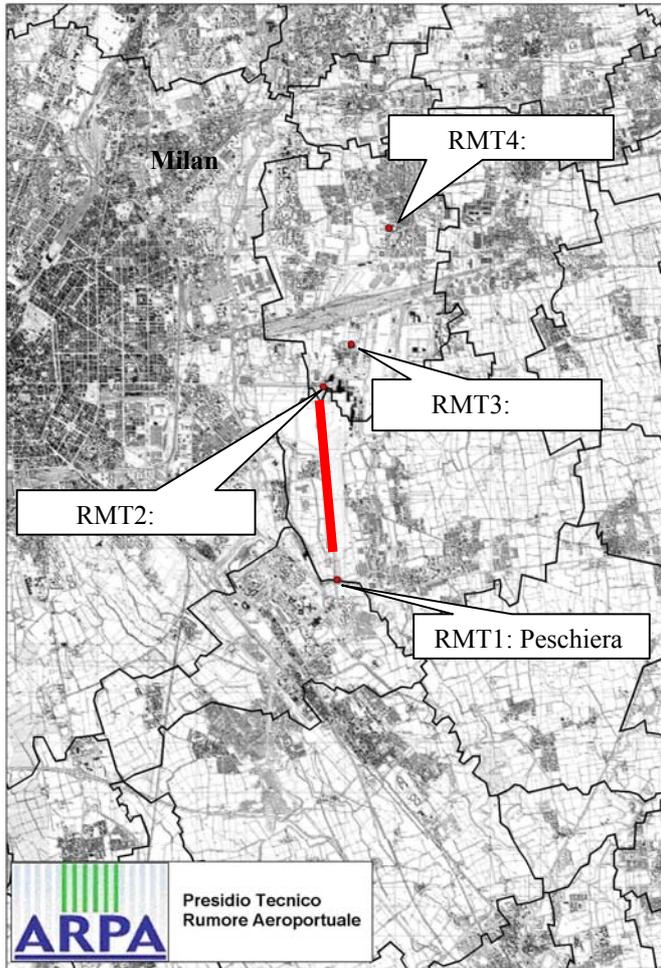


Figure 3 Milano Linate Airport and RMTs

three weeks in well defined periods) corresponding to high traffic situation

$$LVA = 10 \cdot \text{Log} \left(\sum_{j=1}^{21} 10^{\frac{LVA_j}{10}} \right) - 10 \cdot \text{Log}(21) \quad \text{dB(A)}$$

» daily index is LVA_j , similar to DNL, with day period 6-23 and nighttime 23-6

$$LVA_j = 10 \cdot \text{Log} \left(\sum_{i=1}^{N_d} 10^{\frac{SEL_i}{10}} + \sum_{k=1}^{N_n} 10^{\left(\frac{SEL_k + 10}{10} \right)} \right) - 10 \cdot \text{Log}(86400) \quad \text{dB(A)}$$

- » noise is recognized as due to aircraft only if it is linked to a flight operation (from radar track or effective flights)
- » noise monitoring system is operated by airport handling companies, accomplishing the EU principle “the polluter pays”, which has the responsibility of well functioning.
- » ARPA is the organization who verifies the monitoring system

III. Italian noise regulations

Since 1995, many regulations has been adopted about noise measurement technique: three of this concerns airport noise. The main concepts are:

- » index of assessment about noise is LVA, obtained evaluating 21 days (i.e.

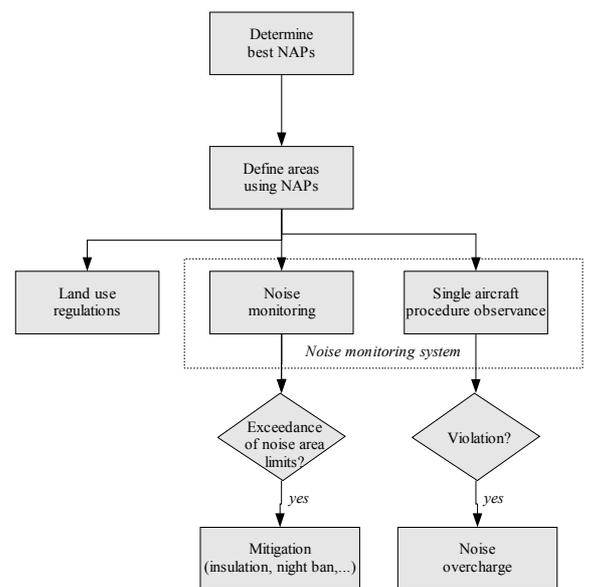


Figure 2: Noise monitoring and land use regulations in Italy

efficiency, and reports about it every six months to national Department of Environment.

Having defined the technique and indices for noise assessment, Italian regulations assign to a specific Committee two main tasks:

1. to assess the impact of the airport, defining three areas:
 - A, above 60 and below 65 dB(A): no restriction to buildings or land use
 - B, above 65 and below 75 dB(A): restriction to buildings and land use
 - C, above 75 dB(A): only buildings linked to airport and land use only for airport facilities
2. to determine which noise abatement procedure enforce, if ICAO – A or ICAO - B

There is no strict relationship between noise monitoring and noise regulations: noise areas are defined by noise contours obtained from a model accomplishing ECAC 29, like INM.

However, in the B areas there will no exceedance of 65 dB(A), otherwise the airport handling company will have to mitigate in order to achieve 65 dB(A). Moreover, each aircraft will enforce noise abatement procedure, which could include a noise limit in terms of SEL or L_{Amax} or other single event noise index.

This is the only link between noise regulations and noise monitoring, and the logical sequence is outlined in the Fig. 1.

IV. Checklist approach

The checklist tool is essentially a list of items, ordered sequentially, owing to perform a complete verify of a task. To each item in the checklist corresponds an action. Two main aspects make checklist a well suitable tool:

- » The sequence of check is fixed in order to achieve a complete check in a logical manner
- » The progression on verifying implies that the operator completed the previous check

These characteristics are very precious, so that the tool is very useful in verifying noise system: the check depends only from the list and do not depend from the operator attitude or behaviour.

A. Checklist structure

Checklist is divided into two parts:

The monitoring system: a complete analysis has to be performed in order to verify a good discrimination between aircraft and ambient noise. The system must have every feature so that is able to control NAPs and identify violations

The single RMT: we must test the goodness of measure, its continuity; the interference with other noise sources must be as less as possible.

Items of the checklist are grouped into topics (Figure 2). Each topic, like “Noise Matching” is divided into one or more subtopics that fulfill the verify. For each subtopic item may exist a specific request, that is a question to be answered.

Checklist is then organized into sections, each one referring to a different “information layer”. This give

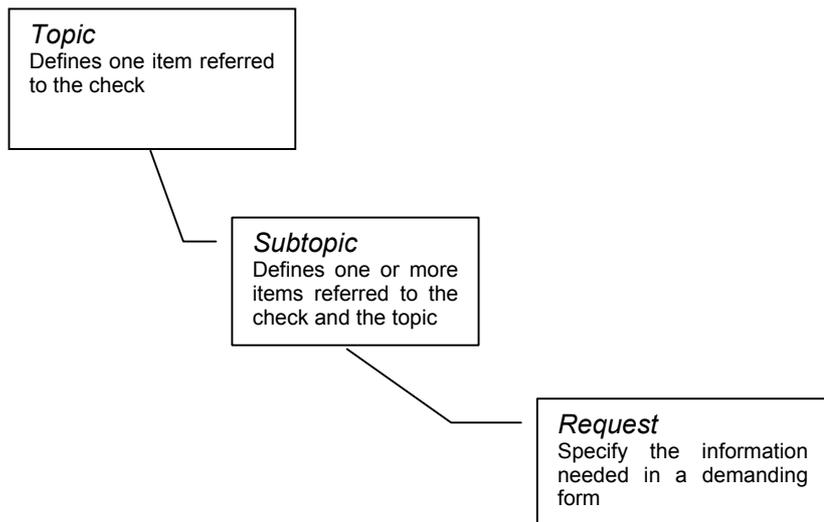


Figure 2: Main structure of checklist

Section	Title	Description
A	Applying regulations	The applying regulation and its reference is reported
B	Compliance	The brief judgment of compliance (compliant, non compliant, non applying)
C	Tests	A boolean field to indicate if there were tests conducted by ARPA
D	Test description	Tests list and brief description
E	Answer	Is reported the answer to the specific request: could be the owner’s answer (especially in case of self reported non compliance)
F	Attachment	If exists, the list of attachments (like test results, site photo, etc.)
G	Comment	A boolean field reporting the existence of a particular extended comment in the covering report.

Table 2: Sections of the checklist

the reader the capability to point out only the information needed. In Table 2 is reported the structure of every section.

In order to achieve a fully operating procedure, checklist is then organized into a database, with a graphical interface for data entry and an automatical procedure for print the report in electronic format (Portable Document Format).

Checklist is a technical document that could not be easily understood from non technical people; in fact this tool is intended to be a complete repository of test and verify operations and not a report to people. Practically checklist is followed by a comprehensible report that summarize the test results in order to assert if the monitoring system is fully efficient (i.e. it works with sufficient continuity and gathers enough data) and effective (i.e. it works depicting the exact situation of aircraft noise pollution, so that every aircraft operation is characterized in term of noise heard on the ground and takeoff/landing procedure). Section G permits a link between general report and checklist.

B. Topics

In Table 3 we report only topics, which are 16: the first 11 are related to system whereas last 5 are to be verified for each RMT.

Topic id	Topic	Topic description
1	General description	Informations about system, continuity of functioning, number and causes of malfunction, synoptic view of RMT and flight tracks
2	Acoustical data acquisition	Noise parameters, method of noise event identification, community noise assessment
3	Meteorological data acquisition	Quality and meaningful of measure, referring to each noise event
4	Flight data acquisition	Info about flight (Company id, flight id, acft type id, radar track, etc.)
5	Data transmission	Procedures about transmission fault
6	Flight-noise matching	Automatic matching, manual matching, non civil flight exclusion
7	Data validation criteria	Focused on italian index L_{VA}
8	Report and noise indicators	Noise indicators published, reference acoustical officer
9	Flight analysis	Noise abatement procedures control
10	Noise curves	Software used, compliance with ECAC, computational data
11	Complaint	Management of complaint

a)

Topic id	Topic	Topic description
12	Site description	Background noise influence, building influence, site localization criteria
13	Measuring features	Features of Sound Level Meter and microphone chain
14	Data transmission	Type of wire transmission, power fault
15	Acoustical event identification	SLM Event settings
16	Calibration	Biannual certification, periodical inspection with pistonophone, annual calibration data analysis

b)

Table 3: Topics applying to system (a) and RMTs (b)

Items about system have the scope to outline how system works intended as a whole. For example, the method of noise event identification is that mainly used. If a particular technique is used, this should be taken into account and reported as a note. In the RMT section one has to specify the local settings used to capture events, especially if a SPL threshold and a minimum duration is used.

In the system section are grouped items regarding flight analysis and noise reporting, as the data validation rules that are adopted. Moreover, in this section are reported informations about noise curves calculation and complaints.

In Table 4 is reported a Topic-Subtopic-Request organization as example.

Topic ID	Topic	Subtopic ID	Subtopic	Request
1	GENERAL DESCRIPTION	1	RMT Number	How many?
		2	Report RMTs location	Depict locations
		3	Minimal acquiring period of noise	How long?
		4	Power supply fault:	Is the CED/RMT fault tolerant?
				Are noise data gathered with no supply?
				If so, how?
		5	Automatic functioning of RMTs	Do the RMTs works with no supply?
		6	Informations about continuity of functioning in last period of time (almost 1 year)	How long has been system functioned?

Table 4: Example of the structure of checklist

C. Section A: references

Section A contains references to regulations or laws concerning aircraft noise. Each item is then linked to its reference, so that is possible to have a look to the proper regulations affecting item; this is useful in order to evaluate the relative importance of that item. A further aid consists in a brief description of the importance of the reference itself: if it is “mandatory” that means that a non exact conformance to the regulations implies a non conformance of the item; otherwise, if it is “preferred” a non exact conformance does not imply a non conformance of the item.

One of the main incongruence of italian regulations is that in ordinary law is included the reference to technical regulation. In this manner it is impossible to follow any improvement of technical regulation because it is not included in law. This became evident referring to IEC 60804-IEC 60651: the new IEC 60671, that improves the previous regulations, will not be used by law. In other terms, will not be possible to declare a non conformation to IEC 60671 because this regulation is not included in law (as we do not aspect that a new law will be published to upgrade the old law).

To have an idea of italian legislation we outline the most important:

- » *Reference law for noise pollution* (1995) contains the basic principles and the role of local authorities
- » *Methodology of aircraft noise pollution* (1997) fixes nomenclature and definition of index, some monitoring constraint as location of microphone, and land use regulations (see paragraph III).
- » *Regulations for reducing noise pollution around airports* (1997) defines the role of ARPA in monitoring noise
- » *Projecting noise monitoring system criteria* (1999) fixes the major features for noise monitoring system, as capability of measure without power supply or matching between noise measure and aircraft overflight.
- » *Noise abatement procedures* (1999) contains some criteria in developing NAPs
- » *Regional noise regulation* (2001) is the local reference that demands to ARPA the annual upgrade of noise curves.

Two characteristic of the whole regulation became clear: it is almost recent, ranging from 1995 to 2001, and it is fragmented so that one overlays the other.

The first effort in developing the check list has been re-organize the regulation in order to outline a logical path: from measure to index calculation. The “Section A” of the checklist is the only way to pass from checklist item to regulations and vice-versa: in fact, each item is linked to its proper reference, using the same words in the reference itself.

V. Check methodology

In order to answer to each item, there are four different kinds of check

- » *Documents check*: the monitoring system’s owner gives documents about each RMT, in order to demonstrate compliance with technical regulations, especially those that refers to microphones and sound level meters.
- » *On site check*: it is a visual verify about the location of the RMT, taking pictures of the context in which the RMT is placed
- » *Coupled measure of noise*: beside the RMT a measure is performed with another instrument belonging to ARPA, in order to analyse gathered data and to observe any difference
- » *Data analysis*: the monitoring system’s owner supplies primitive data, especially those from 21 days used for LVA calculation, so that ARPA could match noise and aircraft and then calculate LVA in an independent way.

A “Gathering Information Module” (GIM) was adopted: before any check this module has been given to monitoring system’s owner so that we could have an overview of the state of the system as the owner itself declare (number of RMTs, locations, etc.). In this way we could drive any effort to those items that seem not to be appropriate or fully compliant.

After examining the GIM, it is planned the compilation of the checklist, and particularly:

- » Inspection on the CED of the system, in order to examine the whole functionality and see how operators work
- » On site RMT inspection
- » Data analysis, including those gathered during coupled measure.

Coupled measurements take almost four hours: the aim is gathering almost 10-15 aircraft movements and get an exact comprehension of other sources. In this phase, an ARPA’s operator collects data and observes aircraft overflight to be sure of the source of noise events.

VI. First experience results

A. Applying checklist

The very first use of checklist was made in 2003 on Malpensa Airport System. Tests have been conducted during summer. Every location was verified for an amount of more than 64 hours of measurements. Data analysis took up more than 120 hours/operator, because the amount of collected data referring to past year.

The checklist team analyzed all documents about microphones and sound level meters, especially documents regarding compliance to IEC regulations. Moreover, they examined tests conducted by National Laboratories in order to determine whether or not compliance to IEC regulations still applying to that instrument. This detailed calibration is performed every two years in order to assess the quality of measurements.

Some non conformity was found just in quality of measurements, especially due to not consistent calibration. This could stake reliability of measure and indices calculations.

Another problem was showed about microphone position: most of them are fixed over roof in such a manner that is not possible to reach them without an aerial work platform, thus restraining the capability of maintenance activity.

The Linate monitoring system was checked in the end of summer 2003. Due to a less number of RMTs, the activity was less, but it was as strong as in Malpensa’s case.

Tests showed another kind of problems: NMTs monitored for a long time, but index LVA was not calculated upon 21 days. This was because many data were not validate, especially for bad weather conditions or because was not possible to match noise with radar tracks when radar tracks were not recorded from radar centre. In this case, italian regulation specify that matching has to be performed with takeoff/landing operation as gathered from Flight Information Service owned by Airport handling company: this procedure was not well implemented by this monitoring system.

Orio monitoring system was verified at the beginning of this year: we could find that two RMTs were not well calibrated. As you can see from Fig. 3, most RMTs are placed beside flight path; this is ineluctable when monitoring communities who live beside the airport. Far from airport this implies that the aim is not long term measurements, but aircraft noise surveillance, in order to ascertain whether an aircraft overflight has been observed over a populated area where planes do not usually fly.

B. Further improvements

Experiences made has outlined two main tasks requiring improve:

- » Data analysis must be standardized, in order to specify each step of independent calculation.
- » Data must be collected from monitoring system daily, in order to follow up any variation.

The last task involves institution of a computer system that collects data and a staff who can analyze it: in this way, the monitoring system functioning is strictly observed with the chance of quickly acting in case of malfunction.

VII. Improving regulation clarity

Bad weather conditions are an interesting item about noise monitoring: noise data have to record or not? Indices have to be calculated or not? How many rainfall is acceptable in order to judge that was affecting noise measure? And, after all, does rainfall affects noise propagation from aircraft source or affects only background noise? The international standard ISO 3891 establishes a precise range of temperature and humidity for noise measurement, but its scope is certification of aircraft not monitoring. Italian regulations establish that a noise measurement could not be performed with wind speed greater than 5 m/s, or atmospheric fall (rain, snow, ...) or fog or snow on terrain. But this was adopted for “legal” scope, or in order to assess the violation of a noise emission limit.

So we probably have to distinguish two kind of measurement:

1. Long term measurements, which are intended to assess the noise area and give information about how large is a specific noise curve; in this case there is no need to remove data gathered during bad weather conditions.
2. Violation measurements, which are intended to determine whether or not a noise limit on a NMT was exceeded in consequence of a NAP violation; in this case has to be completely assured that only aircraft noise was measured, in order to avoid a legal battle with aircraft companies.

This is implicit in our regulation (italian regulation state that NMTs must be placed under aircraft trajectories), but is not enough outlined: the experience of other countries could be very helpful, particularly in EU harmonization effort.

Another issue consists in SEL measure. Italian regulations specify that the SEL_{10} is the index that shall be used in compute LVA_j; at the same time, regulation says that background noise has to be measured. Differences between two indices are small, compared to intrinsic precision of Type 1 sound level meters. However, substituting SEL with SEL_{10} could give important differences in assessing background noise, especially when difference between L_{Max} and background noise is greater than 20 dB(A). Moreover, SEL could not be calculated if that difference is less than 10 dB(A), because part of non aircraft energy would be wrongly included in SEL.

Because the definition of LVA, but the same is for L_{den} , functioning of the system must be as continuous as possible: it is non consistent having a monitoring system based on fixed NMTs and collecting data just for some months.

VIII. Conclusion

Italian regulation about aircraft noise was recently adopted, even experiences in monitoring was conducted in Lombardy since mid 80s. Monitoring systems around regional airports was installed before the regulations, and had to be adapted to it. Both monitoring purposes exist: long term monitoring, used for assessing influence of noise on population and land use regulations, and NAPs monitoring, used for assessing violation of a procedure avoiding overflight on populated areas.

Checklist was adopted as a tool because monitoring systems are committed to handling companies; communities living around airports demand the presence of a neutral authority auditing noise measurement and environmental impact assessment: using this tool was possible to point out some inaccuracies in the monitoring process.

Hopefully, some clarification has to be made in order to improve consistence of noise measurement especially related to the aim of monitoring and the site acoustical situation.