ICAO

ENVIRONMENT

Report on

Good Practices
of
Noise Monitoring Systems

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Notes

This report was produced by ICAO Committee on Aviation Environmental Protection (CAEP) Working Group 2 on Airport and Operations during the CAEP/12 cycle. Following the review by subsidiary bodies, the ICAO Council approved the technical recommendation made by CAEP and approved the publication of this report during the 235th Session, which took place from 9 June to 4 July 2025.

Disclaimer

FOREWORD

This report details how Airport Noise Monitoring Systems (NMS) can be efficiently and effectively used in combination with the ICAO Balanced Approach (BA), and in coordination with aviation noise management stakeholders, to support the management of noise impacts at airports.

The report is intended to be used in conjunction with ICAO Doc. 9829, Guidance on the Balanced Approach to Aircraft Noise Management published in 2008, ICAO Doc. 9184, Airport Planning Manual, Part 2 — Land Use and Environmental Control, latest edition in 2019, ICAO Doc. 9911, Recommended Method for Computing Noise Contours around Airports, latest edition in 2019, and expands and offers further recommended practice and guidance on one of the principal elements of the Balanced Approach (BA) – "Assessment of the noise situation at the airport" as outlined in Chapter 3 of ICAO Doc. 9829.

The information contained in this Report has been assembled by the ICAO Committee on Aviation Environmental Protection (CAEP) and provides background on current NMS practices and good practices for NMS use.

This report identifies and outlines NMS good practices that have been extracted from literature review, CAEP Working Group 2 on Airports and Operations exchanges and surveys to airports and NMS providers. It also presents case studies of generic and unique NMS uses globally. The opportunities and issues are addressed in this Report in a generic way but include practical examples where they are available. Wherever possible, a general indication of the magnitude of the benefits is also given.

The Report is aimed at airport operators, air traffic management and air traffic control service providers, civil aviation and airworthiness authorities, environmental agencies as well as other government bodies and interested parties.

It should be noted that this report is not intended as a basis for regulatory action, and the decision to implement noise monitoring at or around an airport should be made based on many factors specific to the goal of the organization considering implementing the noise monitoring system.

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ACRONYMS, ABBREVIATIONS AND DEFINITIONS

ADS-B: Automatic Dependent Surveillance-Broadcast
ACRP: Airport Cooperative Research Program
AIP: Aeronautical Information Publication
ANSP: Air Navigation Service Provider
BA: ICAO Balanced Approach
CAA: Civil Aviation Authority
CAEP: Committee on Aviation Environmental Protection
FAA: Federal Aviation Administration
ICAO: International Civil Aviation Organization
LADD: Limiting Aircraft Data Displayed
NADP: Noise Abatement Departure Procedure
NATS: National Air Traffic Services
NLR: Netherlands Aerospace Centre
NMS: Noise Monitoring System
NMTs: Noise Monitoring Terminals
UAM: urban air mobility
UAV: unmanned aerial vehicle

EXECUTIVE SUMMARY

This report aims at contributing towards using Airport Noise Monitoring Systems (NMS) in an efficient and effective way, in combination with the ICAO Balanced Approach (BA), and in coordination with aviation noise management stakeholders, to support the management of noise impacts at airports.

This report identifies and outlines NMS good practices that have been extracted from surveys completed by airport representatives and NMS providers, literature review, and WG2 exchanges. It also presents case studies of generic and unique NMS uses globally. The opportunities and issues are addressed in this Report in a generic way but include practical examples where they are available. Wherever possible, a general indication of the magnitude of the benefits is also given.

TABLE OF NMS GOOD PRACTICES

Table 1: NMS good practices identified by the Task Group, organized into 3 main categories

PLANNING FOR A NOISE MONITORING SYSTEM
✓ Identify the motivations for implementing.
✓ Proactively implement an NMS.
✓ Use NMS platforms that are thoroughly tested.
✓ Plan for the training needs of the personnel operating the NMS.
✓ Comprehensively understand the NMS potential and the functionalities needed to support the airport's noise management goals. Accordingly employ full time NMS processional(s) for its efficient operation.
✓ Consider appropriate number and location(s) for the noise monitoring stations when planning for implementation of an NMS.
✓ Consider NMS programs that allow the NMS user to obtain radar data.
✓ Consult with relevant stakeholders such as the ANSP, community representatives, airline and airport operators before implementing an NMS.
USING AND MAINTAINING A NOISE MONITORING SYSTEM

- ✓ Conduct maintenance of the NMS at least once a year, or as per the NMS providers advice.
- ✓ Understand that the full breadth of benefits can only be realized after operating an NMS for several years.
- ✓ Track trends and fluency of noise abatement departure procedure (NADP) use
- ✓ Conduct education and information efforts.

DISSEMINATING NOISE MONITORING SYSTEM INFORMATION

- ✓ Determine which entities should receive NMS data based on the goals of implementing the NMS and resources constraints.
- ✓ Determine the type of information that should be displayed on a public website and whether the data should be refined before it is made publicly available.
- ✓ Educate communities on noise data, metrics, thresholds and how an NMS works.
- ✓ Be transparent when the NMS is not functioning correctly.

SUMMARY OF LITERATURE REVIEW, SURVEYS, AND CASE STUDIES

- ✓ Results of the airport survey indicate the main motivation for NMS installation at airports includes:
  - meeting legal or regulatory requirements,
  - taking proactive action, and
  - responding to community request or public pressure.

- ✓ The majority of respondents also indicated that the role of NMS in the overall aircraft noise management process is to support noise calculation, noise mapping, verification of predictions, supporting community response to noise exposure measurements as well as in response to complaints, and regulatory compliance and reporting.

- ✓ The majority of respondents expressed their satisfaction with the NMS and it's use as a means to communicate with regulators and the general public.

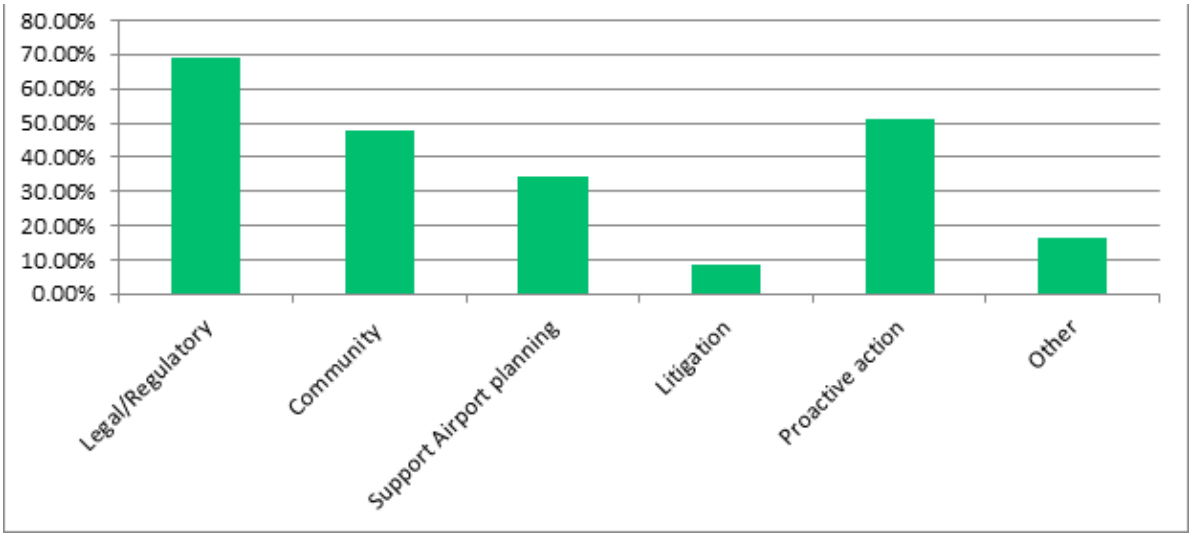


Figure 1 – Airport representatives' responses when asked for their reasons for implementing an NMS

- ✓ Airports indicated challenges of operating the NMS related to data processing, verification, validation, and analysis. At the same time, a number of airports expressed no issues with their system.

- ✓ Major benefits of an NMS cited by airports included improved trust, compliance support, transparency and improved stakeholder/community engagement. A definitive majority of examples cited the effective and efficient use of NMS included through reporting or information dissemination/disclosure.

- ✓ Negative impacts of operating the NMS mainly included unreasonable expectations by the public, confusion related to data interpretation, malicious use of NMS data, (e.g., for supporting political or litigation arguments), but also the additional resources needed to operate the NMS.

- ✓ From the NMS providers perspective, NMS is regarded as a tool that goes far beyond the management of airport noise impacts. It is viewed as a comprehensive mechanism integrated with an airport's sustainability programs and as a dynamic means for supporting effective and strategic communication and engagement.

- ✓ In the future, NMS providers envisage the NMS to evolve into integrated environmental management systems (e.g., alongside air quality pollution emission tracking) and to become a crucial component for meeting increasing expectations, not only from the communities' perspectives (e.g., related to Environment, Social, Governance (ESG) requirements), but also for supporting strategies for a better quality of life.

1. INTRODUCTION

Noise Monitoring Systems (NMS) have existed since the 1960s and play a role in the management of aviation noise around airports, by providing continuous data on the noise performance of aircraft. Today`s NMS technology boosts a wide range of features, functionalities, and possibilities for integrating into other airport planning tools.

Among other functions, NMS can support flight track analysis, noise analysis and noise contour mapping, replay of flight/noise scenarios in 3-D situations, weather monitoring, complaint handling and detection of track deviations from pre-defined departure/arrival routes. In addition, NMS information (e.g. information associated with aircraft flyovers and noise events) can be disseminated to communities, including through public internet resources and real-time web-based installations, to educate and inform people living close to the airport and under flight routes about airport noise exposure and its management. In that context, airports aiming at improving their noise management and community acceptance increasingly tend to install NMS and integrate them into their environmental management systems.

International and national standards exist for installing attended, or unattended NMS in the vicinity of airports (for example, ISO-1996, SAE ARP4721), as well as for defining requirements for reliable measurements (ISO 20906). What is missing though, is guidance on using these systems comprehensively, e.g. how to make the most out of an NMS for different local situations. Conducting the literature review, surveys, and case studies to support this document, it was revealed that some airports have stopped using NMS or use it non-comprehensively due to differing reasons (e.g. increased cost, lack of guidance material and misjudged planning (e.g. on correctly understanding the resources required for dealing with such complex systems, etc.).

This report provides good practices to help NMS users achieve efficient and effective noise management at and around airports. These good practices should be used in combination with the ICAO Balanced Approach (BA), to support the management of noise impacts at airports and in coordination with airport authorities, communities, and other stakeholders involved in noise management, while also supporting community engagement efforts.

The Balanced Approach1 consists of identifying the noise problem at a specific airport and analysing various measures available to reduce noise through the exploration of various measures which can be classified into four principal elements, described in Figure 12. The goal is to address noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.

[1] ICAO Doc 9829, Guidance on the Balanced Approach to Aircraft Noise Management.

[2] https://www.icao.int/environmental-protection/pages/noise.aspx

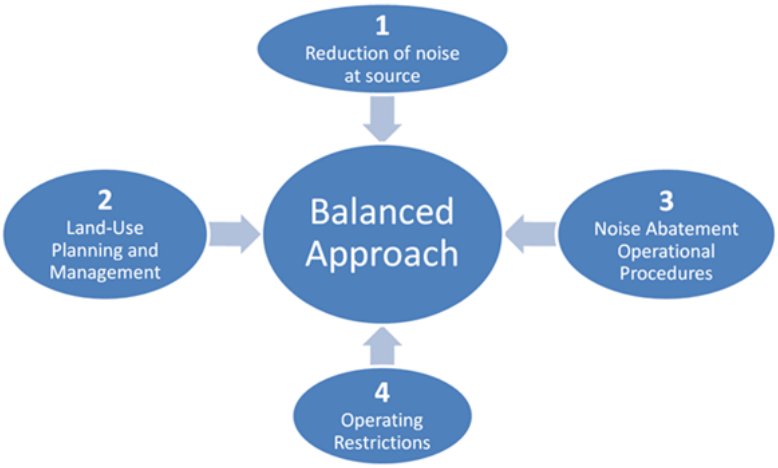


Figure 2. The four principal elements of the Balanced Approach to Aircraft Noise Management[1]

Findings from the surveys conducted in support of this document suggest that use of NMS is directly (e.g. various airports use NMS to correlate flight tracking data with noise measurements) or indirectly (e.g. NMS is implemented by various airports to support their planning) associated with the implementation of the ICAO Balanced Approach.

The ICAO Circular 3513 acknowledges the important role of community engagement in airport noise management, providing lessons learned and good practices drawn from case studies on community engagement by aviation stakeholders.

Findings from the surveys in this work show that NMS is a core tool for enhanced transparency with the community and to support community response to noise exposure measurements and complaints.

Although NMS use will always be subject to local conditions, developing and disseminating good practices reference material can assist the aviation industry, in particular airports and organizations responsible for aircraft noise, in effectively utilizing their NMS systems and document some of the benefits that they can offer in airport noise management.

This report provides relevant stakeholders, such as airport authorities, with reference material on how to use NMS to balance the need to operate their airports effectively with the community's need to understand how noise exposure is measured and how that relates to their real-life experiences. Additionally, there is a growing need for airport authorities to be transparent and provide the public with the information and tools they need to influence local land use planning decisions. A collection of good practices provides airport authorities with

[3] ICAO Circular 351, Community Engagement for Aviation Environmental Management

information on which NMS configurations, data outputs and functionalities can be the most beneficial for their airport management and impacted communities.

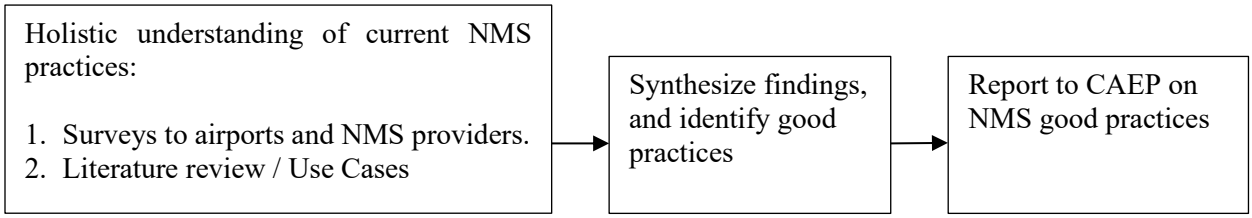
The information in this document can also help airports decide, according to their local circumstances (including regulation, resources, land use, number of air traffic movements, etc), on whether to invest in an NMS.

2. APPROACH AND METHODOLOGY

A necessary first step toward identifying good practices requires attaining a clear and holistic understanding of current practices and use cases of NMS from the point of view of different stakeholders, aiming to avoid bias due to approaching the task from specific stakeholder perspectives. Therefore, multiple different approaches were explored and developed to acquire a well balanced understanding to deliver good practice reference material, namely:

- ✓ A survey to airports and interviews with NMS providers (survey and guiding questions attached in Appendix A and results of the airport survey attached in Appendix B);
- ✓ Review of use cases (a summary of the Use Cases is in Appendix C); and
- ✓ A literature review (detailed summary attached in Appendix D).

The flowchart below illustrates the approach to the task.



LITERATURE REVIEW

The table below outlines the documents that have been reviewed by the Task group in support of the Task. Appendix D summarizes the main outcomes from literature review.

Table 2: Literature review material

1	ACRP237 Primer and Framework for Considering Airport Noise Monitoring systems
2	ISO 20906 2009-12 "Acoustics: Unattended monitoring of aircraft sound in the vicinity of airports"
3	SAE ARP 4721 2006 "Monitoring Aircraft Noise And Operations In The Vicinity Of Airports: System Description, Acquisition, And Operation"
4	CAEP 5 1998 Task MON5 "NOISE AND FLIGHT PATH MONITORING"
5	UK CAA CAP1149 "Noise monitor positions at Heathrow, Gatwick and Stansted Airports"
6	NLR CR-2016-089, 2016 "Verification of Heathrow Noise and Track Keeping Systems"

AIRPORT SURVEY, NMS PROVIDER INTERVIEWS, AND USE CASE STUDIES

A survey was developed for airport representatives and responses were collected and analysed. Ninety-five (95) airport representatives responded comprising 101 airports (some representatives provided responses for multiple airports). The survey was composed of open, as well as multiple choice questions. The responses were recorded across diverse regions, representing airports of various sizes and operational capacities. Figure 3 shows a graphical representation of the location of airports that responded to the survey.

In addition to the survey of airports, four interviews with NMS providers were conducted. This was done through live video conferences; Questions in Appendix A were used as a guideline, however, the discussion was 'open', to allow NMS providers to provide unbiased responses and advice.

In total, data collection through the survey and interviews, took approximately seven months (from August 2023 to February 2024). Reminder campaigns were implemented at regular intervals to maximize the response rate.

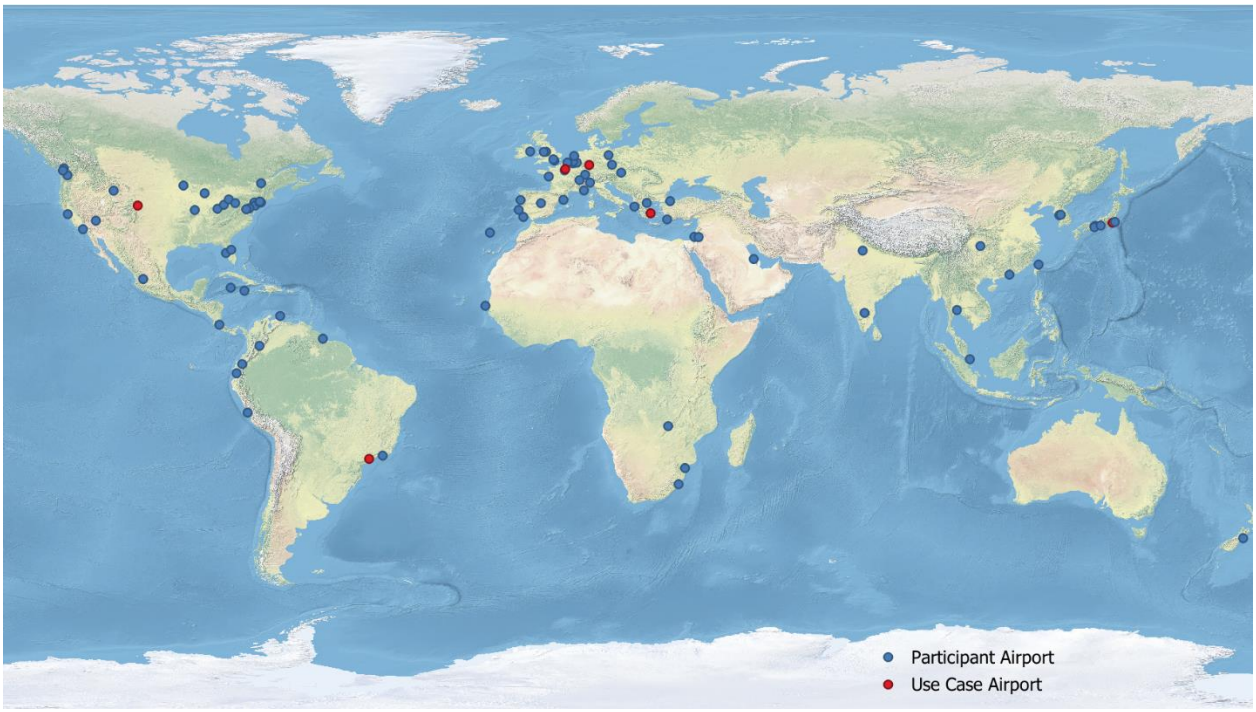


Figure 3: Map indicating locations of airports that responded to the survey and airports used as case studies.

Data analysis included descriptive analysis to provide an overview of the survey responses. This was composed of summarizing key statistics, such as the distribution of airport sizes or types of noise monitoring systems. Responses were analyzed categorically to identify trends and patterns in the types of noise monitoring systems utilized. The analysis included consideration of variations such as airport size and the underlying reason to implement an NMS

to identify trends or differences in the adoption and perceived success of noise monitoring systems. As an example, this analysis aimed to provide an understanding of how factors such as local regulations or community engagement practices influenced the implementation of monitoring systems and the perceived success of the NMS. Lastly, comparisons were made to identify any significant relationships between variables, such as airport size and the sophistication of noise monitoring systems. The NMS provider responses were reviewed in consideration of the airport representatives' responses to the survey in order to develop a more holistic understanding of NMS use.

The results of the survey and analysis performed provide a valuable snapshot of the current state of noise monitoring practices at airports globally and serve as a foundation for further research, policy development, and industry collaboration.

AIRPORT USE CASES

In support of the identified NMS good practices, airport use cases give a more in-depth review of NMS practices at six airports. Aim is to extract unique NMS practices, as well as benefits, challenges and future plans associated with their NMS (e.g. using further/unused features, updating their data process and dissemination practices, integration with other systems, enhance NMS contribution in effective airport noise management, etc.).

A more in-depth review of NMS at six airports was undertaken to gain additional insight into the reasons why airport representatives implement NMS, the challenges encountered, and practices that contribute to successful NMS implementation. Three of the six airports also provided initial input via responding to the airport survey. The six airports are:

- ✓ Frankfurt International Airport (EDDF)
- ✓ Tokyo International Airport (RJTT) - also responded to the survey
- ✓ Athens International Airport (LGAV) - also responded to the survey
- ✓ Denver International Airport (KDEN) - also responded to the survey
- ✓ Sao Paulo / Congonhas Airport (SBSP)
- ✓ Aéroport de Paris Charles de Gaulle (LFPG)

SUMMARY OF RESULTS OF THE AIRPORT SURVEY, NMS PROVIDER INTERVIEWS, AND AIRPORT USE CASE STUDIES

Detailed airport survey results are presented in Appendix B; a short summary of the results is provided below.

The main motivation for NMS installation at airports was meeting legal or regulatory requirements, taking proactive action, and as a result of community request/public pressure. The majority also indicated that the role of NMS in the overall aircraft noise management process is to support noise calculation, noise mapping, verification and predictions, support community response to noise exposure measurements, as well as in response to complaints and regulatory compliance and reporting. The majority of airports expressed their satisfaction with the NMS and their use for communication mostly with regulators and the general public. NMS functions, such as monitoring community noise levels or compliance with local regulations or supporting airport community engagement communication and education, were rated highly (i.e., "very good" or "good"). Functions such as monitoring specific noise abatement flight procedures or support for airport planning were scored lower, however (on average) still at above acceptable levels.

Airport representatives indicated challenges of operating the NMS related to data processing, verification, validation, and analysis. Another difficulty stemmed from the need to have the system tailored to communicate and collaborate with a number of different audiences (and their divergent priorities). This was further related to a lack of knowledge and resources, as well as lack of standard guidelines and practices available. Some airport representatives cited issues related to suitable locations for the installation of noise monitors, including the risk of damage and vandalism in the community. At the same time, a number of airport representatives expressed no issues with their system.

Major benefits of an NMS cited by airport representatives included improved trust, compliance support, transparency and improved stakeholder/community engagement. A definitive majority of examples cited their NMS benefits effective and efficient reporting or information dissemination/disclosure.

Negative impacts of operating the NMS mainly included unreasonable expectations by the public, confusion related to data interpretation, as well as malicious use of NMS data, (e.g., for supporting political or litigation arguments). It is interesting to note that the aforementioned negative impacts concern more than just data dissemination and use by the public, but also includes the operation of the NMS itself by the airport, specifically the need to train airport staff in the use and operation of the NMS and the resources needed to undertake the training as well as operate the NMS.

From the NMS providers perspective, NMS is regarded as a tool that goes far beyond the management of airport noise impacts. It is viewed as a comprehensive mechanism integrated with an airport's sustainability programs and as a dynamic means for supporting effective and strategic communication and engagement. Critical aspects of NMS include the ability to provide useful information from the data that can be used to further community and stakeholder involvement in the noise management process. One of the challenges noted was the lack of use of the full suite of functions that an NMS can provide. Specifically, NMS providers indicated

that little use is made of the marketing and social aspect of the data collected and monitoring carried out.

NMS providers note the benefits of NMS to include:

- ✓ determining the impact of aviation noise,
- ✓ verifying the effectiveness of noise reduction procedures,
- ✓ supporting airport management to minimize negative environmental impacts,
- ✓ allowing the collection of objective and comprehensive data, supporting the selection of optimal,
- ✓ ensuring legal obligations are met,
- ✓ enabling evaluation of reported complaints and indicate unreasonable public expectations,
- ✓ providing evidence for ongoing legal proceedings for compensation,
- ✓ supporting negotiations with airlines regarding the use of specific aircraft types,
- ✓ reporting to air traffic organizations regarding modifications of routes,
- ✓ verifying noise complaints, and
- ✓ supporting the land use planning.

In the future, NMS providers envisage the NMS to evolve into integrated environmental management systems (e.g., alongside air quality pollution emission tracking) and to become a crucial component for meeting increasing expectations, not only from the communities' perspectives (e.g., related to Environment, Social, Governance (ESG) requirements), but also for supporting strategies for a better quality of life. NMS providers indicated that the integration of artificial intelligence provides the potential for NMS to incorporate identification of the sources of the measured noise, analysis of the data, and provide recommendations to reduce the noise. This type of system may have other benefits such as identification of drones and preventing them from entering airport airspace.

GOOD PRACTICES

This Section presents the good practices identified as a result of this effort. Their value may vary between airports depending on local situations, but for practical implementation, the good practices have been organized into three categories:

- ✓ Planning for the NMS
- ✓ Using and Maintaining NMS
- ✓ Dissemination of NMS information

Table 3: NMS good practices identified by the Task Group, organized into 3 main categories

PLANNING FOR A NOISE MONITORING SYSTEM
✓ Identify the motivations for implementing.
✓ Proactively implement an NMS.
✓ Use NMS platforms that are thoroughly tested.
✓ Plan for the training needs of the personnel operating the NMS.
✓ Comprehensively understand the NMS potential and the functionalities needed to support the airport's noise management goals. Accordingly employ full time NMS processional(s) for its efficient operation.
✓ Consider appropriate number and location(s) for the noise monitoring stations when planning for implementation of an NMS.
✓ Consider NMS programs that allow the NMS user to obtain radar data.
✓ Consult with relevant stakeholders such as the ANSP, community representatives, airline and airport operators before implementing an NMS.
USING AND MAINTAINING A NOISE MONITORING SYSTEM
✓ Conduct maintenance of the NMS at least once a year, or as per the NMS providers advice.

- ✓ Understand that the full breadth of benefits can only be realized after operating an NMS for several years.
- ✓ Track trends and fluency of noise abatement departure procedure (NADP) use
- ✓ Conduct education and information efforts.

DISSEMINATING NOISE MONITORING SYSTEM INFORMATION

- ✓ Determine which entities should receive NMS data based on the goals of implementing the NMS and resources constraints.
- ✓ Determine the type of information that should be displayed on a public website and whether the data should be refined before it is made publicly available.
- ✓ Educate communities on noise data, metrics, thresholds and how an NMS works.
- ✓ Be transparent when the NMS is not functioning correctly.

PLANNING FOR THE NMS

As with any endeavour, conducting planning activities prior to investment of resources is important for the successful implementation of an NMS. This section outlines good practices related to the efforts that should be undertaken before implementation of an NMS.

A good practice is to identify the motivations for implementing an NMS

As a first step in the planning process airports should identify the motivation for implementing an NMS. Common reasons an NMS may be implemented include:

- ✓ To meet legal or regulatory requirements for noise control
- ✓ In response to public pressure or community requests
- ✓ To support airport planning
- ✓ In response to litigation
- ✓ In order to be proactive in noise management

Identifying the motivations for implementing an NMS in the planning phase allows the NMS user to establish criteria and functions that the NMS must meet in order to be effective. These criteria and necessary functions will aid the NMS user in choosing the most beneficial NMS, monitoring locations, and system requirements.

A good practice is to proactively implement an NMS

Airports that identified litigation as the motivation for implementing their NMS were found to have a higher rate of dissatisfaction with their NMS (i.e., a 30% dissatisfaction rate vs. 9% of those that implemented an NMS proactively). Those that proactively implemented an NMS had the lowest rates of dissatisfaction with their NMS (i.e., 9%). This indicates that a good practice would be to implement an NMS proactively and prior to litigation requiring an NMS be implemented.

A good practice is to comprehensively understand the NMS potential and the functionalities needed to support the airport's noise management goals and accordingly employ full time NMS professional(s) for it.

As noted by NMS providers, modern NMS' provide a wide array of functions beyond generating data and reports including novel technologies such as tracking air quality emissions. When planning for an NMS it is important to determine the necessary vs. desired uses of the NMS. For example, handling and exploiting the ample functionalities of modern NMS tools is often a highly demanding and time-consuming task. Implementing all possible functions of NMS may be a considerable burden on staff and/or budgetary resources, whereas limiting resources could lead to a basic (and unsatisfactory) use of NMS.

Consideration should be given to implementing an NMS that possesses all priority and desired functionalities but which can be accessed over time as the use of the NMS becomes more efficient through continued use.

Likewise, it is important to understand potential short and/or long-term challenges with NMS use, as well as to manage expectations. It will take time to adapt the NMS system and optimize its use, including communication of data to communities, to the local situations.

Airports that have dedicated full time professionals on staff rated their level of satisfaction higher than those without dedicated staff.

A good practice is to use NMS platforms, that are thoroughly tested

When planning for an NMS it is important to develop a comprehensive understanding of the potential uses of it. As noted by NMS providers, modern NMS' provide a wide array of functions beyond generating data and reports including novel technologies such as tracking air quality emissions. When planning for an NMS it is important to determine the necessary vs. desired uses of the NMS. For example, handling and exploiting the ample functionalities of

modern NMS tools is often a highly demanding and time-consuming task. Implementing all possible functions of NMS may be a considerable burden on staff and/or budgetary resources, whereas limiting resources could lead to a basic (and unsatisfactory) use of NMS. Consideration should be given to implementing an NMS that possesses all priority and desired functionalities but which can be accessed over time as the use of the NMS becomes more efficient through continued use.

Likewise, it is important to understand potential short and/or long-term challenges with NMS use, as well as to manage expectations. It will take time to adapt the NMS system and optimize its use, including communication of data to communities, to the local situations.

A good practice is to plan for the training needs of the personnel operating the NMS

Twenty-eight (28) of the airport respondents indicated that limited staffing resources and lack of training are primary reasons why they don't utilize their NMS to its fullest extent. During the interviews with the NMS providers the representatives indicated that they provide training to their customers, though the frequency and content varied among the providers.

When planning for an NMS it is beneficial to consider the frequency and availability of training for the personnel who will be responsible for managing the NMS. Request information from the NMS providers under consideration to ensure the appropriate level of training will be routinely provided.

A good practice is to consider the appropriate number and locations of noise monitoring stations when planning for implementation of an NMS

When planning for an NMS consider logistics related to the siting of noise monitoring stations. These considerations include: number, type (portable or fixed) and locations of NMS monitoring stations. Specifically, when siting noise monitoring stations consider:

- ✓ Location of flight routes - Typically noise monitoring stations are located near runway ends and along flight paths that are of particular concern to the community.

- ✓ Community desire for noise monitoring - Community views on the presence of noise monitoring stations within their community may vary. It is important to understand whether the community is supportive of the airport conducting noise monitoring or issues such as vandalism may occur. Monitoring locations may be determined by specific community request or compliance needs.

- ✓ Site ownership - Noise monitoring sites are best located on public property whenever possible, such as local government land, open space, schools and parks. When necessary, it is possible to locate a site on private land, but a lease agreement should be in place with

the property owner. Common areas in neighbourhood associations are also a good option but will require an agreement with the association. Determining the ownership of the property and its potential availability should be considered during the planning stage.

- ✓ Noise Monitoring Terminals - A noise monitoring system consists of noise monitoring terminals, radar data collection system and integration software for analysis and reporting of the data. Noise monitoring terminals typically have a useful life of 10 to 15 years. While the noise monitoring software system advance more rapidly and may need to be rebid every 3 to 5 years. It is a good practice recommendation to require the noise monitoring terminals to be non-proprietary that any potential future vendor could integrate. This allows the opportunity to select a future vendor without the limitation of having to replace with hardware if current vendor is replaced.

- ✓ Security of the site and potential for theft or vandalism - Conducting a brief risk assessment to inform the likelihood of theft or vandalism of the noise monitoring station can inform the most appropriate locations for the stations.

- ✓ Power and communication - Noise monitoring stations need power and communication. Most new or modern noise monitoring sites use cellular communication where services is available. Modern noise monitoring equipment and cellular communication can in most locations operate with solar power. Given airports goal of NetZero, and the cost of bring utilities to a site, it is recommended that solar power be used for any new noise monitoring location if utilities are not already at that site.

- ✓ Ambient noise - Consider the existing environment in which noise monitoring stations will be located to ensure the noise measurement reflect aircraft operations and avoid excessive non-aviation noise sources (e.g. powerplants, road traffic, etc.). It is difficult for a noise monitoring system to accurately separate aircraft noise from other noise sources when located near busy road ways or other non-airport noise sources.

In addition to considering the location of noise monitoring stations, the number of stations should be determined. This will vary depending on budget, the number of runways and the needs and desires of the community however, it should be noted that the majority of airports have 20 or more permanent or portable noise monitoring stations are satisfied or very satisfied with the performance of their NMS. However, most smaller airports have 10 or less. The highest cost of a noise monitoring system is the noise monitoring terminals.

Some general guidelines include:

- ✓ Located within or near noise sensitive land uses (i,e., residential, schools)
- ✓ A variety of noise exposure, including under the flight path, sideline to the flight path, departures/arrivals.

- ✓ Both close in and more distant locations from the airport, however, it is not recommended to be located too far from the airport or flight paths where the noise events are low, and it becomes difficult to measure the aircraft noise events.
- ✓ Use technically valid locations that can be used to help validate noise contour modelling input assumptions.
- ✓ Near noise contour boundaries is helpful at airports where there are established boundaries where home noise insulation programs are in place.

A good practice is to consider NMS programs that allow the NMS user to obtain radar data

Noise monitoring systems include both noise monitoring stations and a collection of radar data that provides operations and flight track information. The noise monitoring system software then link the noise event information to the aircraft that caused the events and uses the radar information for a live display and stores the data future analysis. There are a variety of sources for the data depending upon the ANSP at your airport and the availability of the data. The potential vendors will offer their solutions to obtaining this data. The following are suggestions for the radar data.

- ✓ Recommend minimum range of 50 nautical miles from the airport to have data to assess potential airspace changes.

- ✓ Radar data source is often a merged feed from various sources but should include ADS-B in that merged feed. This provides higher quality position information then a source based upon just conventional radar.

- ✓ Include Mode S code for every operation that is equipped with ADS-B. This allows the airport access to more detailed data about the aircraft that can be used for other purposes including air quality analysis.

- ✓ The data provided by the vendor should be provided without use restrictions. The airport should have full access and use of the data for any department and the ability to provide to other outside consultants when providing services for the airport. The noise monitoring system should include the ability of the airport to simply access, for export purposes, all of the flight operational information and radar track points without the need for support from the vendor.

A good practice is to consult with relevant stakeholders such as the ANSP, community representatives, airlines, and airport operators before implementing an NMS

Collaborative efforts are paramount in any noise management initiative. Before specific changes to aircraft noise monitoring are introduced, it is important for stakeholders to consult

with the airport and airline operators, regulators, the supporting ANSP, and community representatives about the potential benefits and technical limitations of such changes. Before contemplating any changes to infrastructure, it is also advisable to carry out a more general consultation and environmental review as may be required with the major aviation stakeholders and those who will be affected by the changes.

NMS users should consult with stakeholders such as airlines and airport operators in order to convey the motivations for implementing the NMS, seek input on monitoring site locations, and inform them whether the intent is to utilize the data to track pilot performance.

The number and location of the noise monitoring sites is often of great interest to the community. It is useful to consult with community representatives about potential site locations. There is typically great support for having a site in the community. But it is also important to inform community representatives that there are technical reasons for site locations, so that the NMS user does not end up with more sites then are necessary, and at locations too far from the airport to be useful.

USING AND MAINTAINING AN NMS

The performance of an NMS and the usefulness of its outputs can be improved through implementation of good practices during the operation of the NMS.

A good practice is to conduct maintenance once a year or as per the NMS provider's advice.

NMS data are used for numerous purposes, and typically, accuracy in absolute values, are key for ensuring consistency in a chain of other processes, (e.g., when using the NMS to verify and to calibrate what the modelling has shown, or compliance monitoring). Hence regular calibration and maintenance of the system are indispensable and should be planned according to the NMS provider's advice. Airports that calibrated their NMS once a year described their NMS as functioning well.

SAE ARP4721 5.1.3 says to "acoustical sensitivity should be checked at least every 6 months for systems used for continuous monitoring of aircraft noise." However, it also states that the checks:
"may be extended to annual sensitivity check if the system has demonstrated history of stability."

A good practice is to understand that the full breadth of benefits can only be realized after operating an NMS for several years

The airport survey indicated that operating an NMS for more than 5 years and making continuous improvements to the system or the outputs, as a result of the experiences in the initial years of operation, lead to highest benefits.

In combination with planning for NMS implementation, expectations should be well understood and managed. Most airports reported that they saw benefits after having already implemented the NMS for more than five years, specifically, after having learned how best to use the system and after having collected a substantial amount of data. Few airports stopped using their NMS because of not observing imminent benefits.

A good practice when using an NMS is to track trends and frequency of noise abatement departure procedure (NADP) use

Fly Quiet programs are voluntary programs that encourage aircraft and airport operators to follow a variety of identified noise abatement goals and acknowledge publicly those that do the best. The noise monitoring system data can be used to track how each operator complies with each of the fly quiet measures and the overall results. Measures may include the noise quality of the fleet, runway use goals, following noise abatement flight paths, minimizing night operations and minimizing high noise events. The overall score is a combination and weighting of all the goals.

It is a good practice is to use the NMS to show trends in noise and operations at the airport over time and to track measures and goals. The NMS can be used to track NADP use trends and also on how the noise levels are changing over time, and if aircraft operations are following established noise abatement goals. If a noise abatement program exists, or is being developed, the NMS can be used to track compliance with those measures and the results can be published.

DISSEMINATING NMS INFORMATION

The vast majority of airports use their NMS to disseminate information whether this be limited to internal audiences or also include providing information externally. The perceived success of an NMS is intrinsically linked to the usefulness of the information provided.

A good practice is to determine which entities should receive NMS data based on the goals of implementing the NMS and resource constraints

It is important to determine whether the data generated by the NMS will be used for internal reporting and tracking purposes or whether it will be disseminated to the public.

The majority of airports disseminate NMS data to the public as well as to internal stakeholders such as to the airport board of directors. The purpose and goals of the NMS will provide direction on which entities should receive NMS data and what type of data.

A good practice is to determine the type of information that should be displayed on a public website and whether the data should be refined before it is made publicly available

If using a website to provide the public with data obtained though the NMS consideration should be given to the format, frequency, and amount of information that is made available. Airports noted that a key issue with their NMS is the public's lack of understanding of the data they are reviewing unless it has been refined and interpreted by NMS professionals before being uploaded to the website. However, many airports cited the immediacy of data uploads to the public website as a benefit.

A good practice is to educate communities on noise data, metrics, thresholds and on how an NMS works

Current NMS users identified a number of challenges related to providing communities with NMS data. These challenges include:

- ✓ Frequent confusion regarding noise metrics (e.g., (cumulative metrics (LEQ) vs single event (Lmax))
- ✓ Perception of dishonest or inaccurate reporting
- ✓ Unreasonable expectations regarding how the data will be used (e.g., air traffic routes will be modified).

Providing data to communities that are unfamiliar with NMS leads to the issues listed above. Providing communities with educational opportunities and resources to become better informed community members will lead to less confusion and potentially improved community relations.

Examples of measures to provide educational opportunities and resources include (but are not limited to):

- ✓ Holding regularly scheduled meetings with affected communities (e.g., roundtables) where NMS subject matter experts and airport representatives present information regarding the NMS, the data generated and how it is used and seek questions from participants.
- ✓ Participating in community requested meetings.
- ✓ Including succinct descriptions of the NMS and metrics used on noise webpages.
- ✓ Sending out newsletters on a regular basis updating the communities on the NMS.

A good practice is to be transparent when the NMS is not functioning correctly

When asked about the motivation behind implementing an NMS, 47% of respondents indicated that requests or pressure from the community informed their decision. Additionally, over 60%

of respondents indicated that they use the NMS to support community response to noise measurements and complaints. Finally, some respondents indicated that they have concerns regarding the NMS data being used by airport adversaries to initiate or inform litigation. Along with educating the community and NMS data users about the data and its limitations it is a good practice to be transparent when the NMS is not functioning correctly and thus, the data is flawed or lacks fidelity. Transparency can lead to improved community relations.

3. CONCLUSION

This report details how Airport NMS can be efficiently and effectively used in combination with the ICAO BA, and in coordination with aviation noise management stakeholders, to support the management of noise impacts at airports.

After conducting a literature review, survey of airports, interview with NMS providers, review of case studies, and gaining input from WG2 participants with experience in airport NMS 15 good practices have been identified and described (as shown in Table 4 below). These 15 good practices are divided into three categories including:

- ✓ Planning for an NMS,
- ✓ Using and maintaining an NMS, and
- ✓ Disseminating NMS information.

Table 4: NMS good practices identified by the Task Group, organized into 3 main categories

PLANNING FOR A NOISE MONITORING SYSTEM
✓ Identify the motivations for implementing.
✓ Proactively implement an NMS.
✓ Use NMS platforms that are thoroughly tested.
✓ Plan for the training needs of the personnel operating the NMS.
✓ Comprehensively understand the NMS potential and the functionalities needed to support the airport's noise management goals. Accordingly employ full time NMS processional(s) for its efficient operation.
✓ Consider appropriate number and location(s) for the noise monitoring stations when planning for implementation of an NMS.
✓ Consider NMS programs that allow the NMS user to obtain radar data.
✓ Consult with relevant stakeholders such as the ANSP, community representatives, airline and airport operators before implementing an NMS.
USING AND MAINTAINING A NOISE MONITORING SYSTEM

- ✓ Conduct maintenance of the NMS at least once a year, or as per the NMS providers advice.
- ✓ Understand that the full breadth of benefits can only be realized after operating an NMS for several years.
- ✓ Track trends and fluency of noise abatement departure procedure (NADP) use
- ✓ Conduct education and information efforts.

DISSEMINATING NOISE MONITORING SYSTEM INFORMATION

- ✓ Determine which entities should receive NMS data based on the goals of implementing the NMS and resources constraints.
- ✓ Determine the type of information that should be displayed on a public website and whether the data should be refined before it is made publicly available.
- ✓ Educate communities on noise data, metrics, thresholds and how an NMS works.
- ✓ Be transparent when the NMS is not functioning correctly.

This report is aimed at airport operators, air traffic management and air traffic control service providers, civil aviation and airworthiness authorities, environmental agencies as well as other government bodies and interested parties.

APPENDIX A -NOISE MONITORING SYSTEMS GOOD PRACTICE QUESTIONNAIRE

Background and motivation

The ICAO Committee on Aviation Environmental Protection (CAEP) Working Group 2 on Airports and Operations is currently working on a task to develop a *Noise Monitoring Systems Good Practices Report*. The Report aims to detail how permanent or portable Noise Monitoring Systems (NMS), can be used efficiently and in combination with the ICAO Balanced Approach, for supporting airport noise management, while also upholding community engagement efforts.

You are invited to participate in this short survey inquiring about the use of NMS at your airport, which will take approximately 15 minutes to complete.

The information collected will be used to gain a clear and holistic understanding of current practices and use cases of NMS. This is imperative for identifying objective and non-biased good NMS practices and/or opportunities for improvement.

Data collected from individual airports through this questionnaire will be deidentified, and results will be shared on an aggregate basis i.e. responses won't be attributed to specific responders or the airports they represent. However, if we determine it is beneficial to include specific information from your airport (e.g. in order to provide case study examples), we will contact you to seek consent.

Once completed, the *Noise Monitoring Systems Good Practices Report* will provide airport authorities with information on which NMS configurations, data outputs & functionalities would provide the most benefit for their airport management and impacted communities. While the potential benefits of NMS at airports are recognized and their implementation has been increasing globally, their use has remained incomprehensive, due to a perceived lack of guidance, unique airport needs, as well as technical complexities. It is believed that airports have lots more to gain from using NMS more comprehensively.

Being the core NMS users, your unique experiences and views are invaluable to the success of the Task. Your contribution is essential to the development of global good practices in the NMS area and can lead to the improvement of environmental management policies globally.
Thank you for your contribution.

Part 1: Survey Respondent Identification

Q1.1- Please select the region where your airport is located: (only one to be selected)
For ICAO Regions click here.

- ❑ Asia and Pacific (APAC)
- ❑ Eastern and Southern African (ESAF)
- ❑ European and North Atlantic (EUR/NAT)
- ❑ Middle East (MID)
- ❑ North American, Central American and Caribbean (NACC)
- ❑ South American (SAM)
- ❑ Western and Central African (WACAF)

Q1.2- ICAO Member State where the airport is located:

Q1.3- Name of the airport:

Q1.4- Name and surname of the contact person:

Q1.5- Role of the contact person:

Q1.6- Email of the contact person:

Part 2: Airport information

Q2.1: Number of Runways

- ❑ Single runway
- ❑ Two runways
- ❑ Three runways
- ❑ Four or more runways

Q2.2: Airport size based on aircraft movements per annum (MPA)

- ❑ Less than 30 000 MPA
- ❑ Between 30 001 and 50 000 MPA
- ❑ Between 50 001 and 100 000 MPA
- ❑ Between 100 001 and 200 000 MPA
- ❑ Between 200 001 and 300 000 MPA
- ❑ Between 300 0001and 400 000 MPA
- ❑ 400 001 MPA or higher

Q.2.3. For year 2022, approximately how many noise complaints did your airport operations generate and what was the number of complainants?

Optional: Please also provide complaints and complainants numbers for 2019; this will serve the purpose of detecting effects of Covid 19 Pandemic on complaints.

- ❑ Number of Complaints in 2022……....._____
- ❑ Number of Complainants in 2022……....._____
- ❑
- ❑ Number of Complaints in 2019……....._____
- ❑ Number of Complainants in 2019……....._____

Part 3: Your Noise Monitoring System

Q3.1. Please indicate for how long your airport's NMS has been in operation? If it is no longer in operation, please indicate for how long it was in operation?

- ❑ Less than 5 years
- ❑ Between 5 and 15 years
- ❑ Between 16 and 30 years
- ❑ More than 30 years

If your NMS is no longer in operation, please state why:

If your NMS is no longer in operation, please move directly to Part 5: NMS Challenges

Q3.2 Who is your NMS provider? (Optional)

- ❑ Casper
- ❑ Envirosuite
- ❑ TopSonic
- ❑ 01dB
- ❑ Other (please specify):

Q3.3. How often is your NMS audited and/or calibrated?

- ❑ Less than once a year (e.g., Biennial)
- ❑ Once a year
- ❑ More frequently than once a year
- ❑ No need for audit or calibration.

Q3.4. What was the motivation for implementing an NMS at your airport? (Select all that apply)

- ❑ Meet legal/regulatory requirements
- ❑ Community requests / Public pressure
- ❑ Support Airport planning
- ❑ Litigation
- ❑ Proactive action
- ❑ Other. Please provide details:

Q.3.5. What is the role(s) of the NMS in the overall aircraft noise management process at your airport? (Select all that apply).

- ❑ Regulatory compliance and reporting
- ❑ Measuring effectiveness of noise abatement procedures
- ❑ Detecting compliance / violation of specific noise limits at terminals
- ❑ Application of taxes/charges to airlines based on NMS data or conformity to noise limits at noise monitor locations
- ❑ Reporting to public (community)
- ❑ Supporting community response to noise exposure measurements and complaints
- ❑ Supporting of noise calculations, noise mapping verification & predictions
- ❑ Correlation of flight tracking data with noise measurements
- ❑ Other (please specify)

Q3.6. Please specify the number of permanent and portable noise monitors of your NMS:

- ❑ Permanent Installation (i.e. having a fixed location):……..……___
- ❑ Portable Setting (i.e. mobile stations, temporary on tripods or handheld):…….___

Q3.6.1 How do you decide on the location of noise monitors?

Q3.7. How many people are involved (full or part time) in the operation of your NMS (please indicate number of people working full / part time)

- 🕐 Full time :……___ people
- ❑ Part time:…….....___ people

Q.3.8. Do you utilize all of the functionalities of your NMS?

- ❑ No, there are clear opportunities to increase utilization
- ❑ No, but we are satisfied with current use
- ❑ Yes
- ❑ I don’t know

Q3.8.1. What would be the main reasons for not utilizing all functions of your NMS?

- ❑ Current usage meets our needs
- ❑ Lack of training/knowledge
- ❑ Lack of resources

- ❑ Additional costs
- ❑ Other (please specify)_____
- ❑ I don't know

Q.3.9 Is your NMS data published on a website, by displaying noise related to aircraft flight path? If yes, please, indicate the link to it and inform how it is helpful in communication with the community?

Part 4: NMS Benefits

Q4.1. What benefits can you note from the use of the NMS?

Q4.2. How overall satisfied are you with your NMS and how well do you think your NMS performs in each of the applicable functions?

Please select those relevant to your airport and rate accordingly.

Overall satisfaction

- ☐ 1-very dissatisfied
- ☐ 2-dissatisfied
- ☐ 3-neither dissatisfied nor satisfied
- ☐ 4-satisfied
- ☐ 5-very satisfied

- Monitor community noise levels;
  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good
  - ☐ N/A

- Monitor compliance with local regulation and apply associated measures (e.g., noise charges)
  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good
  - ☐ N/A

- Monitor specific noise abatement flight procedures;
  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good
  - ☐ N/A

- Support airport planning;
  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good
  - ☐ N/A

- Support airport community engagement, communication & education
  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good
  - ☐ N/A

- Other function/objectives, please explain and rate

  - ☐ 1- very poor
  - ☐ 2-poor
  - ☐ 3-acceptable
  - ☐ 4-good
  - ☐ 5-very good

Q4.3. What stakeholders do you coordinate and/or communicate with through the NMS?

- ☐ General public
- ☐ Regulators
- ☐ Airlines
- ☐ No stakeholders- only for internal airport purposes (e.g., noise management).

☐ Others: (text box)

Part 5: NMS Challenges

Q5.1. What are/were the challenges of **operating** the NMS in your opinion (this should exclude installation challenges)?

Q5.2. If you overcame these challenges describe how?

Q5.3. Are there any examples where NMS had a negative impact on community engagement / communication (e.g., confusion due to communicating raw metrics, miscommunication, unrealistic expectations etc.)?

Part 6: Examples from your airport

Q6.1. Could you please describe an example of how you effectively and/or efficiently utilize NMS in your overall noise management program?

In your answer, could you please include information on NMS metrics and/or data you communicate to your stakeholders, as well as your NMS data dissemination practices (e.g., means and forms of dissemination, such as public webpage, noise reports, visual representations etc.)

May the Task Leads follow up via email to discuss this survey further?

☐ Yes

☐ No

GUIDING QUESTIONS FOR INTERVIEWS WITH NMS PROVIDERS

- ✓ How long have you been working with airports on their NMS?
- ✓ What benefits of NMS use have you seen?
- ✓ What challenges have you seen airports have been having? How did they evolve?
- ✓ What do you think are the common barriers/pitfalls in NMS implementation?
- ✓ What do you think are solutions to overcoming these challenges?
- ✓ What is in your opinion good practice when it comes to effective and efficient NMS use?
- ✓ Could you provide an example of some NMS good practice use cases that you might know?
- ✓ Are you able to recall any unexpected, positive or negative, effects/outcomes of an airport NMS use?
- ✓ Do you believe that NMS are used to their fullest ability? Why?
- ✓ What training support do you provide when selling your NMS?
- ✓ How can NMS systems and the acquisition of the systems be improved?

QUESTIONS FOR CASE STUDIES

- ✓ 1. What is the motivation for installing your NMS?
- ✓ 2. How do you use your NMS, and are there any unique features?
- ✓ 3. Do you disseminate NMS data / information to the public? If yes, what information do you provide (e.g. metrics). How do you decide what to provide?
- ✓ 4. What are the benefits from using your NMS, is there anything you would change if you could?

APPENDIX B – AIRPORT SURVEY RESULTS

Airport Survey Results

The survey was distributed via multiple channels including direct outreach to airport authorities and through ACI. Survey responses were collected between August 2023 and February 2024. After removing duplicate and incomplete responses 95 survey responses comprising 101 airports (some respondents represent multiple airports) were evaluated. The survey consisted of 33 questions including several that were open-ended allowing the airport representatives to provide additional detail regarding their perspective of the airport's NMS.

Response Rate and Regional distribution

The initial questions in the survey included requesting identification of which ICAO region the airport is located within.

As displayed in Figure 1 below, airports from seven regions were represented in the responses including:

- 21 within Asia Pacific (APAC)
- 4 within Eastern and South Africa (ESAF)
- 34 within Europe and North Atlantic (EUR/NAT)
- 2 within Middle East (MID)
- 32 within North America, Central America and the Caribbean (NACC)
- 6 within South America (SAM)
- 1 within Western and Central Africa (WACAF)

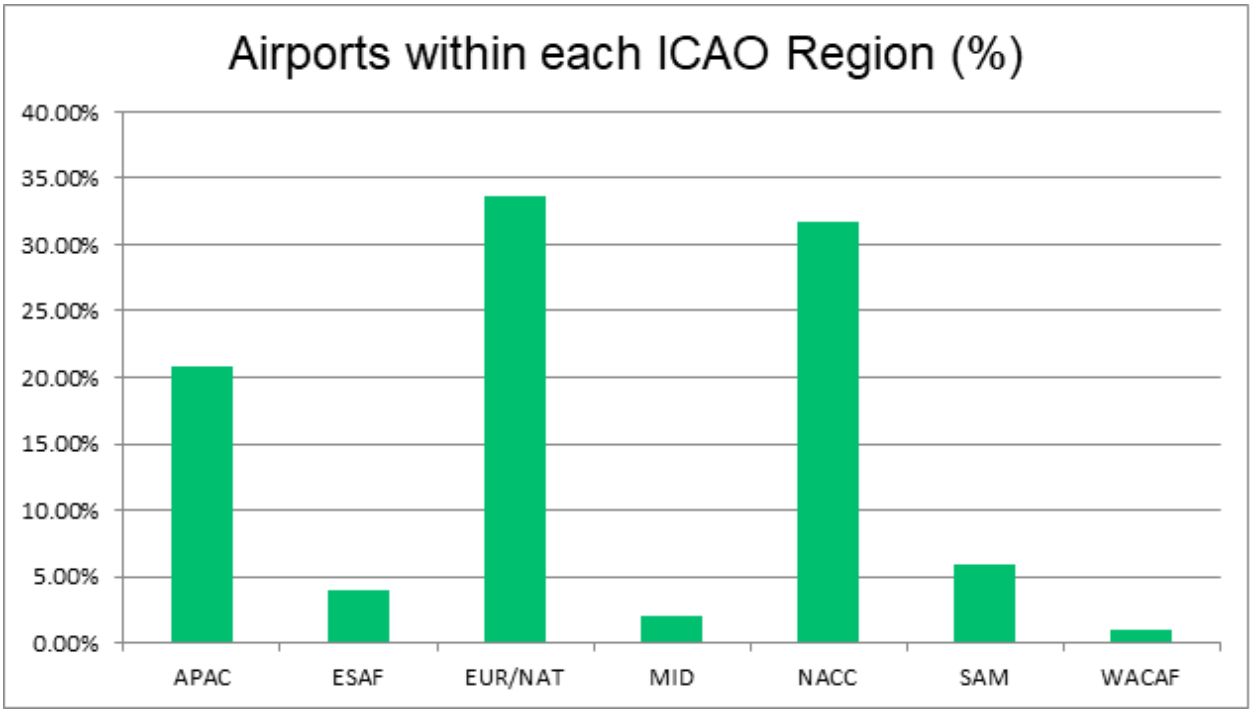


Figure 1 – Airports within Each ICAO Region

Eighty-one (81) of the respondents indicated that an NMS continues to be in operation at their respective airports, while 14 of the respondents indicated that the NMS is no longer in operation at the airport. The reasons stated for not having an operational NMS include shrinking noise contours, lack of national legislation requiring an NMS, and being cost prohibitive.

Runways and Operations

Figure 2 below indicates the percentage of airports with 1 to 4 or more runways. The majority of airports have one or two runways (61%).

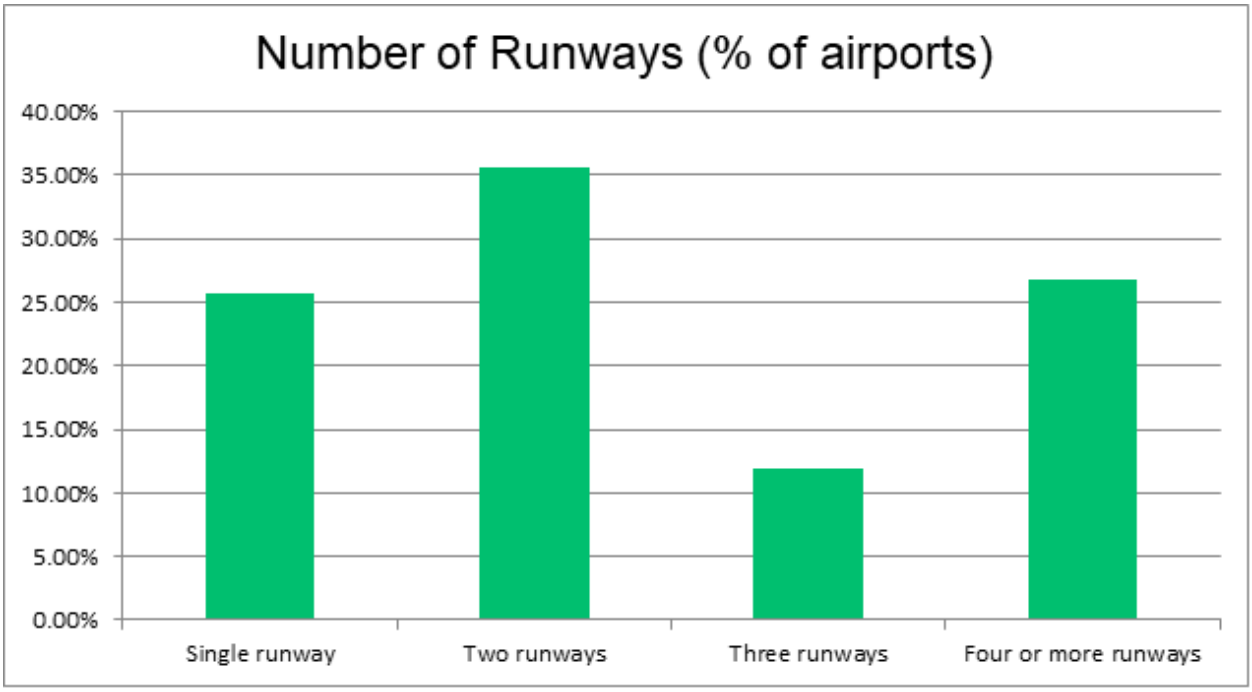


Figure 2 – Number of Runways

Figure 3 indicates the percentage of airports with movements per annum (MPA) between less than 30,000 and over 400,001. Slightly more than half of the airports surveyed have more than 100,000 MPA (54%)

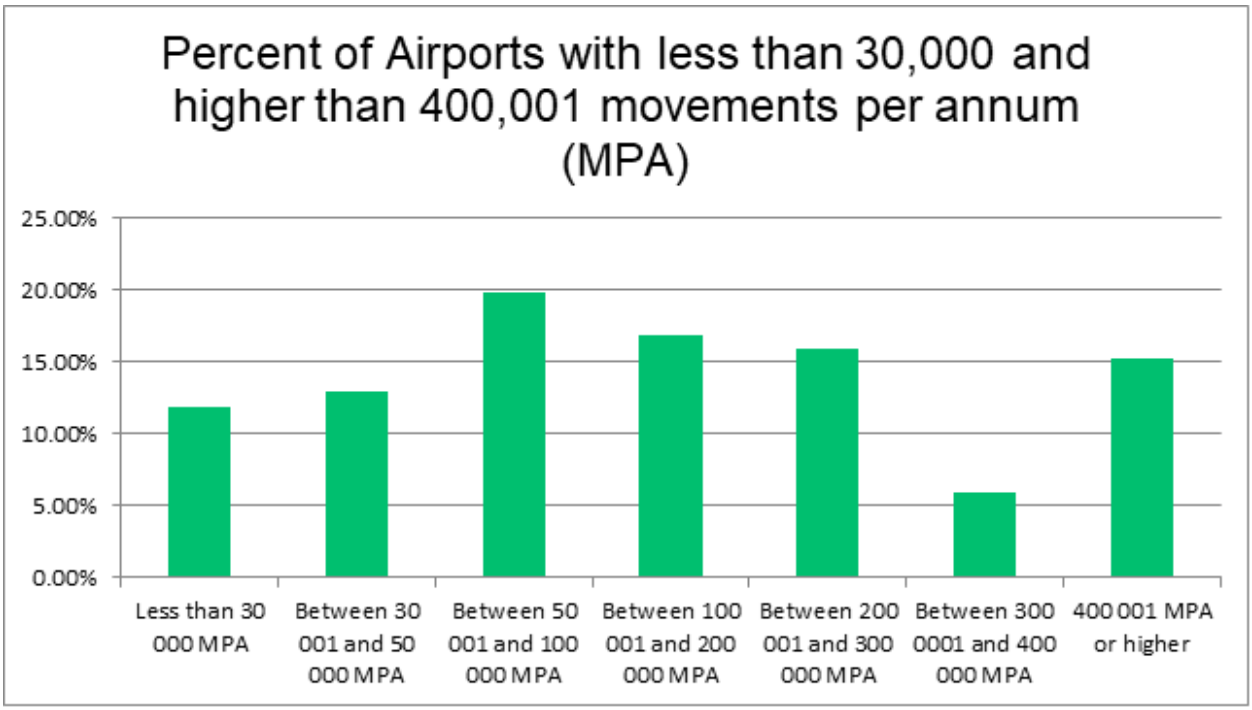


Figure 3 – Percent of Airports with Less than 30,000 and more than 400,001 Movements per Annum

Noise Complaints

The average number of noise complaints in 2019 across all airports was approximately 34,000 while in 2022 the average number of noise complaints received was 27,700. The average number of complainants across all airports in 2019 was 338 while in 2022 it was 230. If dividing the number of complaints by the number of complainants this data would indicate that in 2019 each complainant generated approximately 100 complaints while in 2022 each complainant generated approximately 120 complaints. Thus, this would support a trend of fewer complainants generating a larger proportion of complaints.

Figure 4 compares the average number of complaints received in 2022 when considering the various reasons airports chose to implement an NMS. Airports that indicated community requests and/or public pressure as well as those that identified taking proactive action as reasons to implement their NMS received significantly more noise complaints in 2022 than those airports that identified meeting legal or regulatory requirements, supporting airport planning, or litigation as reasons for implementing an NMS.

Figure 4 – Average Number of Complaints in 2022 Compared to the Reason Airports Implemented NMS

Twelve (12) of the airports had in excess of 5,000 noise complaints in 2022. Of these 12 airports 2 are located within EUR/NAT and the remaining are located within NACC. Fifty-nine (59) out of the 101 airports have implemented an NMS to meet legal/regulatory requirements. Forty (40) considered community requests/public pressure as a reason to implement an NMS. Twenty-nine (29) implemented an NMS to support airport planning. Ten (10) airports noted litigation as a reason to implement their NMS. Forty-three (43) of the airports implemented an NMS in order to take

proactive action. Fourteen (14) of the respondents indicated other reasons for the need to implement an NMS including to monitor noise departure noise limits, to meet intergovernmental agreements, and imposition of collecting noise charges for airline responsibility.

When considering the number of complaints in comparison to the number of operations it is clear that airports with higher levels of operations also experience greater frequencies of noise complaints. Figure 5 displays the average number of complaints in 2022 in comparison to the number of operations.

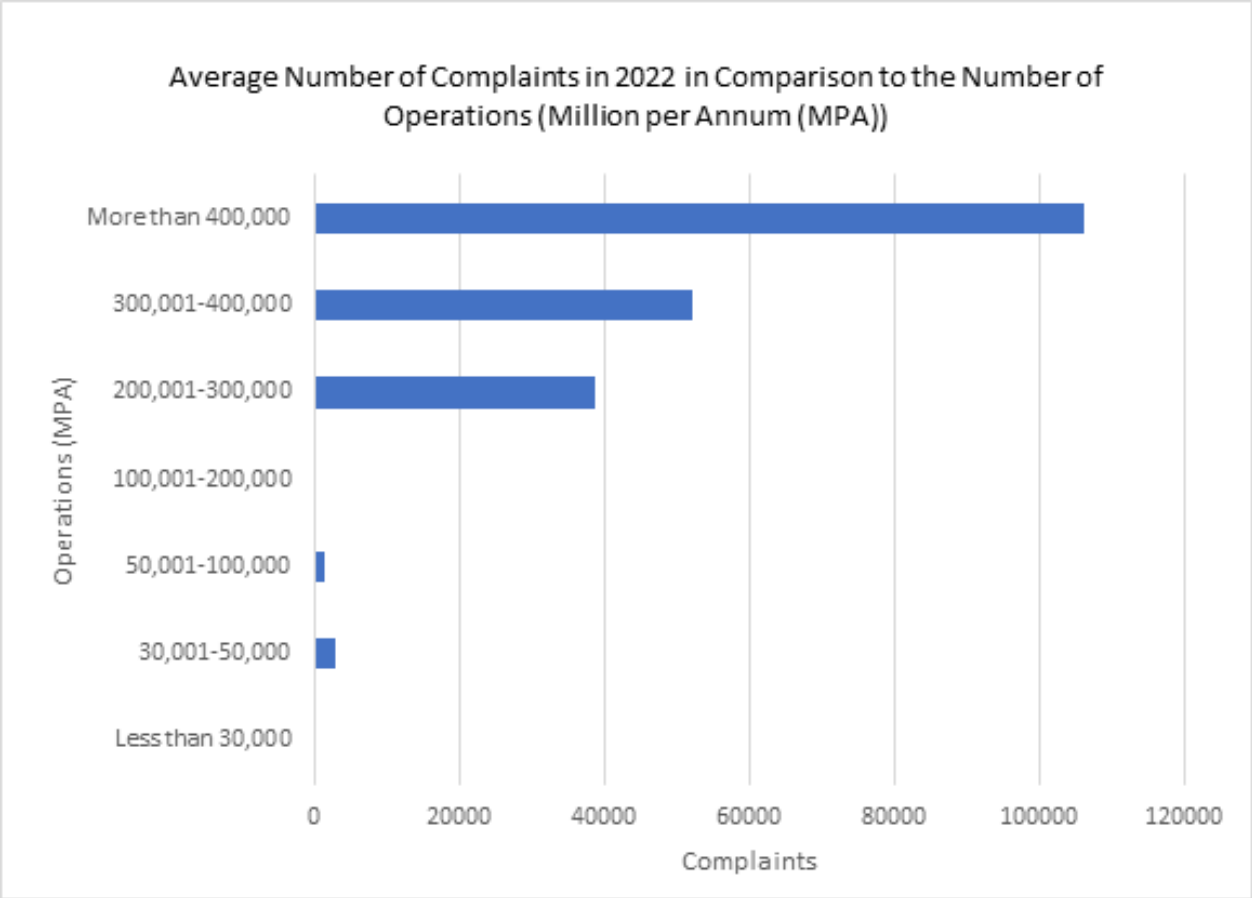


Figure 5 – Average Number of Complaints in 2022 in Comparison to the Number of Operations

Noise Monitoring System Characteristics

Figure 6 displays the length of time NMS have been in operation. The majority of airports have had an NMS in operation between 16 and 30 years (42%). Fourteen percent of airports no longer have an NMS in operation.

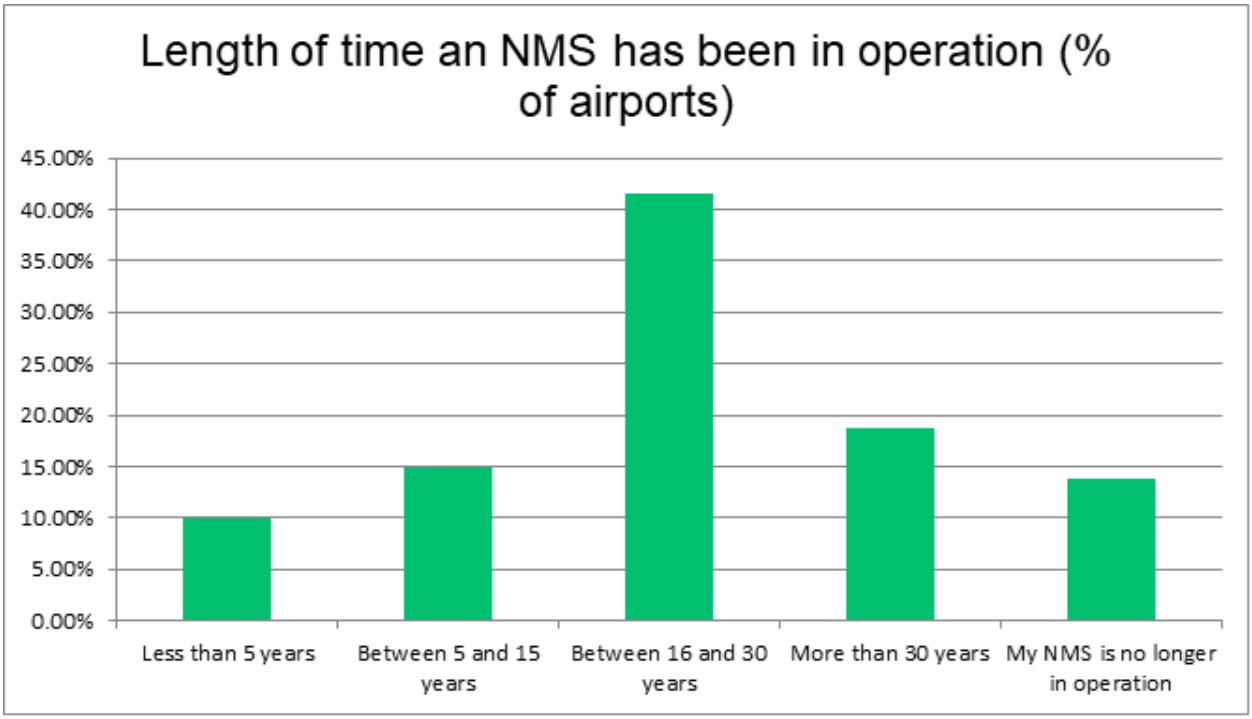


Figure 6 – Length of Time an NMS has been in Operation

The reasons cited as to why the NMS is no longer in operation included:

- A decrease in overall aircraft noise levels due to ongoing and completed noise mitigation efforts helped reduce overall noise complaints. Additionally, financial challenges made the operation of the NMS no longer feasible.
- It was never installed. Noise abatement is handled by aircraft approach and departure patterns
- There was no reason to implement
- No longer needed due to shrinking noise contour
- Noise Monitoring was discontinued in 2010
- No regulatory requirements

Eighty-two (82) airports identified their NMS provider. Out of those that responded the majority use the same provider (45%). Thirty percent indicated that they use a different provider, one that was not listed in the multiple-choice question.

As shown in Figure 7 below, the majority of airports calibrate their NMS once a year (62%). While 28% of airports indicated that they calibrate their NMS more than once a year.

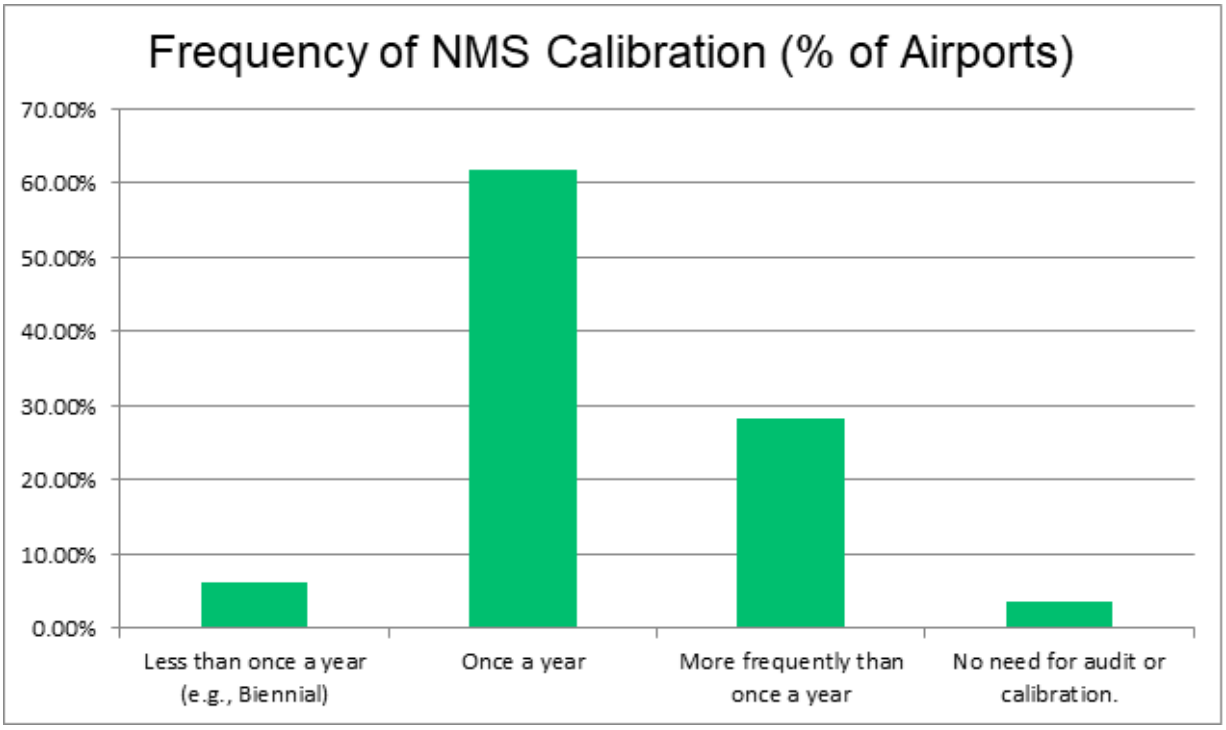


Figure 7 – Frequency of NMS Calibration

Reasons to Implement an NMS and Roles/Responsibilities

The majority of airports indicated that they implemented an NMS in order to meet legal or regulatory requirements (70%). The next most common reason for implementing an NMS was in an effort to be proactive (51%) closely followed by community request or pressure (47%).

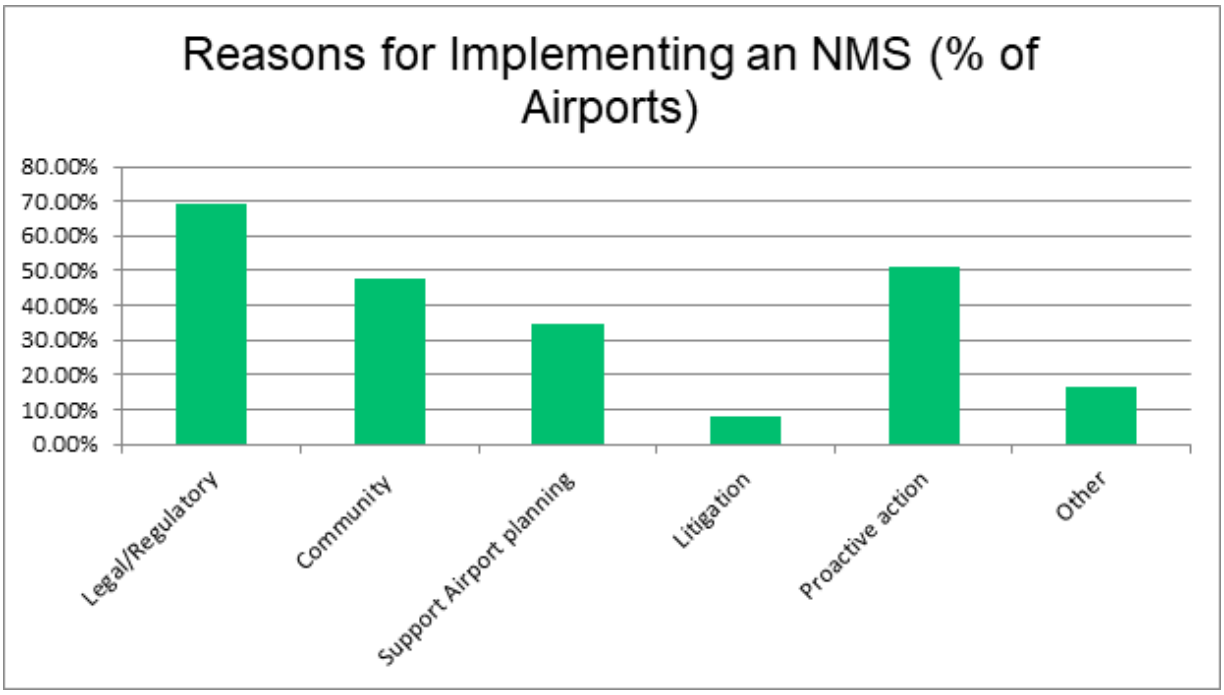


Figure 8 – Reasons for Implementing an NMS

Four (4) airports indicated that all these reasons motivated them to implement an NMS. While 14 airports provided additional reasons as to why they implemented an NMS. These reasons included:

- Transparency with the community.
- Monitoring Noise Departure Limit
- Providing more detailed monitoring and reporting publicly and to be consultative with committees
- Hire a consultant to conduct a noise study every 5 years
- Intergovernmental Agreement (IGA) for Building a New Airport 1988-1992
- Imposition and Collection of Noise Charge for Airline responsibility

Seventeen (17) airports did not provide answers when asked what their motivation was for implementing an NMS. Out of those, 14 airports had indicated that their NMS is no longer in operation which may be why they did not answer the question.

As indicated in Figure 9, the primary roles an NMS serves include:

- Supporting community response to noise exposure measurements and complaints (68 respondents),
- Supporting noise calculations, noise mapping verification and prediction (68 respondents),
- Correlation of flight tracking data with noise measurements (63 respondents),
- Regulatory compliance and reporting (61 respondents); and
- Reporting to the public (60 respondents).

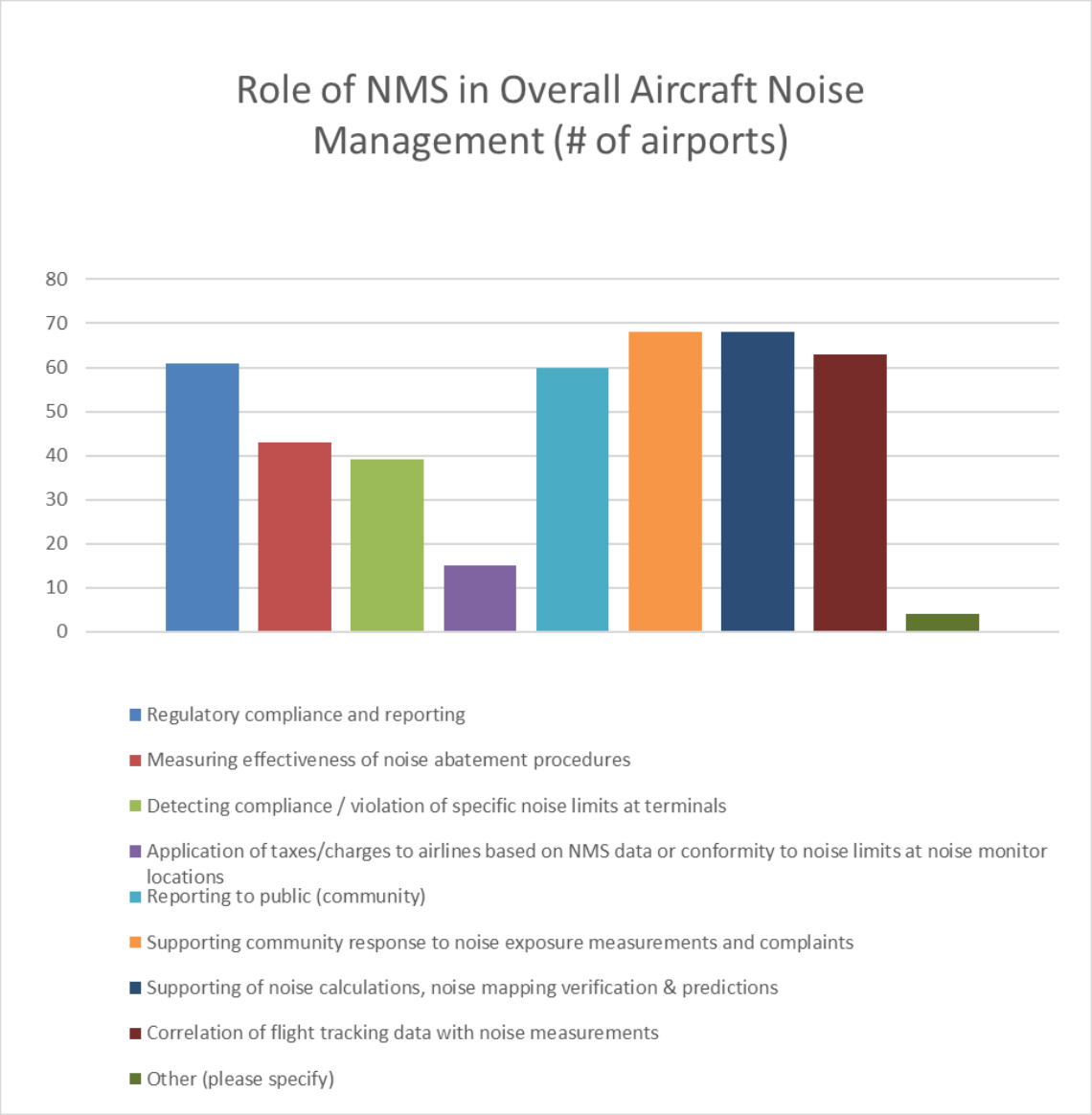


Figure 9 – Role of NMS in Overall Aircraft Noise Management

Seventeen (17) airports did not provide information on the role of the NMS on aircraft noise management at their airports. These are the same 17 airports that did not respond to the question on what motivated the airport to install an NMS.
Four (4) airports offered additional functions of their NMS. These included:

- Planning effectiveness of NADP
- Supporting the Noise Mitigation Plan
- Correlation of Air quality, meteorology and socioeconomic data with noise measurements (innovative methodology)
- To meet IGA requirements in specific areas at specific levels surrounding the airport

Thirty-five (35) of the 40 airports that identified community request/community pressure as a reason for implementing an NMS, also identified reporting noise measurements to the public as a primary role of the NMS.

Noise Monitors

On average airports have more permanent monitoring stations than portable monitoring stations. As shown in Figure 10, 15 permanent monitoring stations is the average across all airports that have permanent monitoring stations, while 9.5 is the average number of portable monitoring stations among airports that have portable stations.
Of the 84 airports that responded indicating that they have monitoring systems 58 (69%) have both permanent and portable monitoring stations.

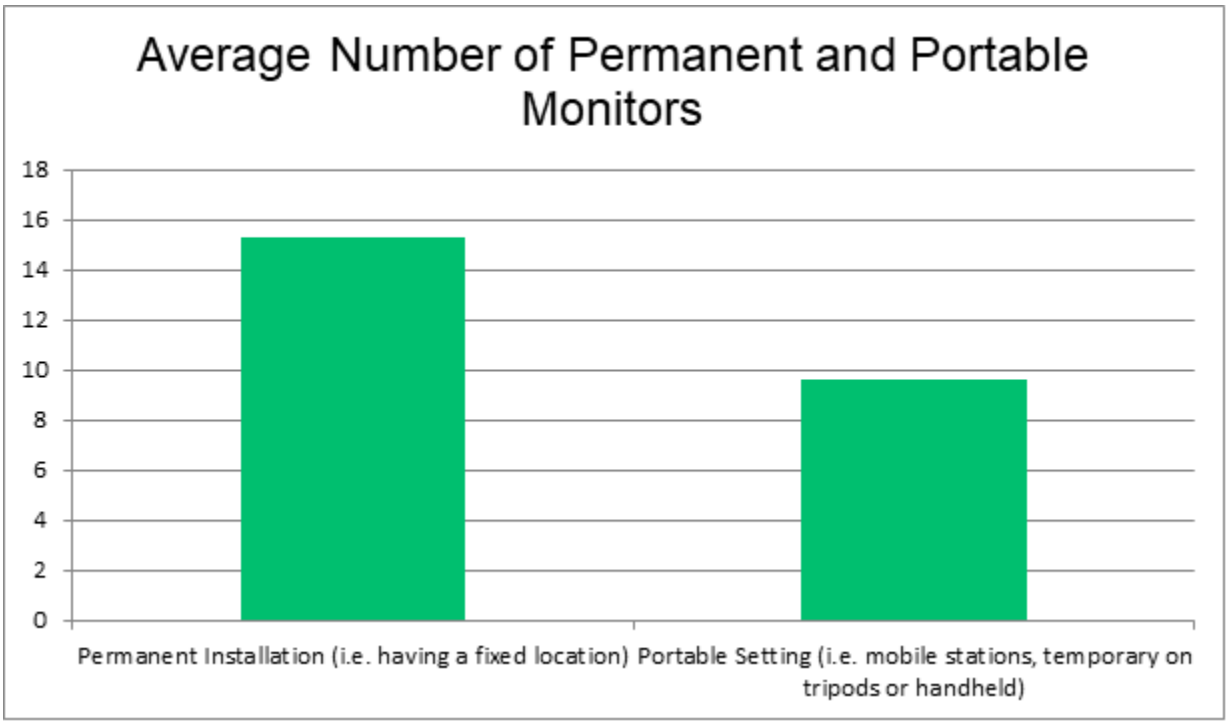


Figure 10 – Average Number of Permanent and Portable Monitors

By comparing the average number of portable and permanent monitoring stations with the number of runways it is shown that, on average, the more runways an airport has the more monitoring stations it will have, particularly with regard to permanent noise monitoring stations.

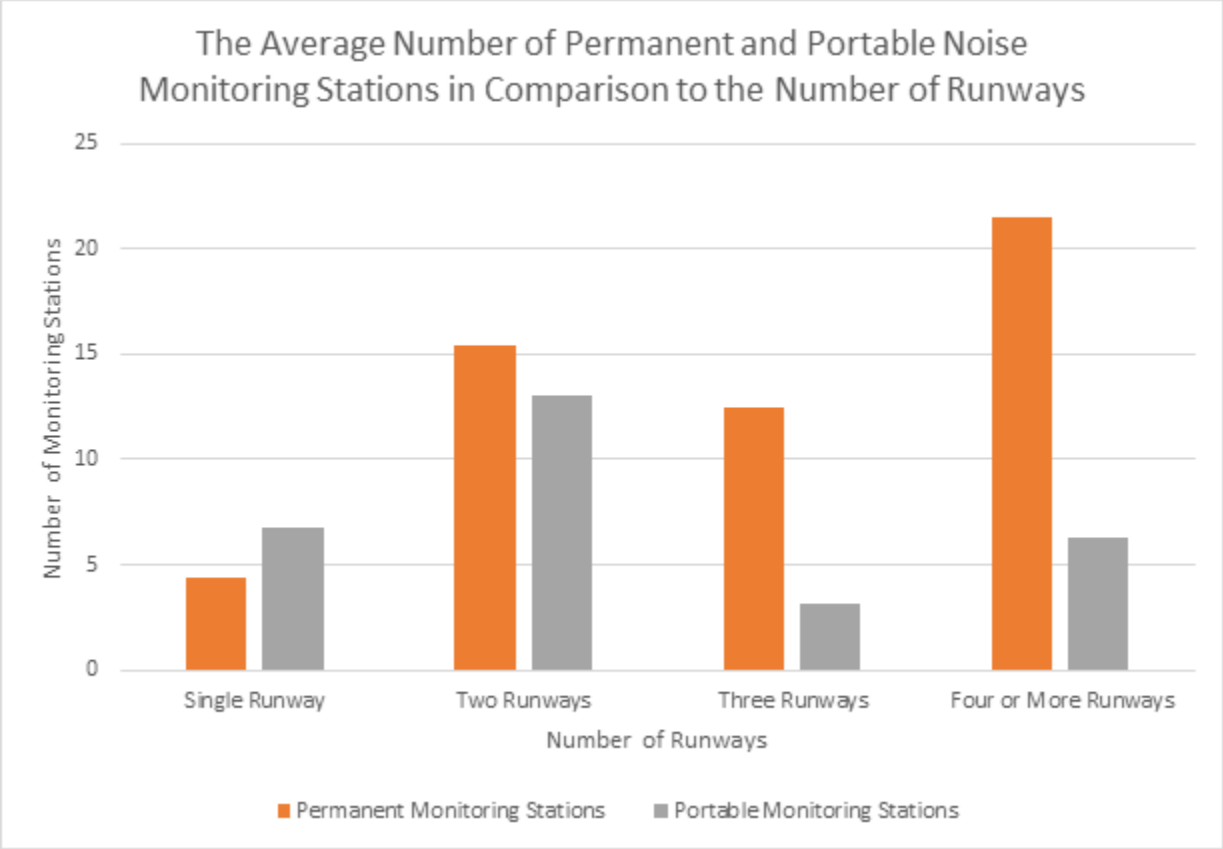


Figure 11 – Average Number of Permanent and Portable Noise Monitoring Stations in Comparison to the Number of Runways

The majority of airports that have 20 or more permanent or portable noise monitoring stations have indicated that they are 'very satisfied' or 'satisfied' with their NMS (i.e., 82% - 88%, respectively). Seventy-nine (79) airports provided information on how they decide on the location of the noise monitoring stations. In general, the locations of noise monitoring station locations included considerations such as:

- Relationship to flight paths, runways, or aircraft operations
- In response to requests by community members, advisory committees, or local political organizations
- Expert advice
- Results of studies or analyses
- In response to standards or legal requirements
- Land use and historic data
- Noise contours, mapping, and modelling
- Community complaints
- Ability of monitoring stations to function well

On average airports have 2.5 full time and 1.25 part time NMS professionals involved in operation of their NMS. Thirty-six (36) of the airports that responded to the question on the number of NMS professionals involved in operating their NMS have both full time and part time NMS

professionals involved (43%). Respondents most commonly indicated that one full time NMS professional is responsible for operating the NMS.

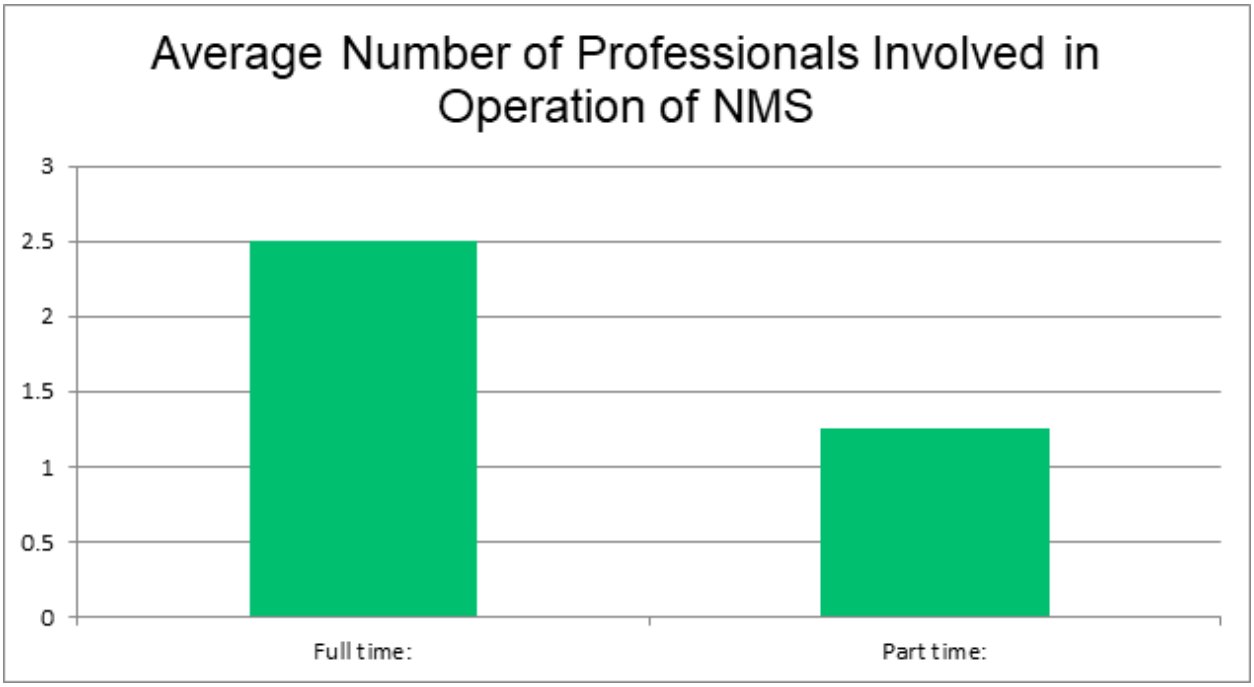


Figure 12 – Average Number of Professionals Involved in the Operation of NMS

Thirty-four percent (34%) of airports identified that there are clear opportunities to increase utilization of their NMS. Similarly, 26% of airports indicated that while they are not using their NMS to its fullest extent they are satisfied with their current use. However, 33% of airports are using their NMS to its fullest extent.

The majority (i.e., 25) of respondents indicated that their NMS meets their current needs and that is why they do not utilize all of the functions of the NMS. Lack of resources was cited as the primary constraint to using all of the NMS' functions (i.e. 18 responses). Followed by additional costs (i.e., 16 responses) and lack of training or knowledge (i.e., 10 responses). Thirteen (13) respondents provided additional reasons as to why they are not utilizing their airport's NMS to it's fullest potential. These reasons included:

- Due to the rapid implementation of the NMS they are focusing on certain functions
- Old software and lack of access to the databases
- Staffing limitations
- Security constraints

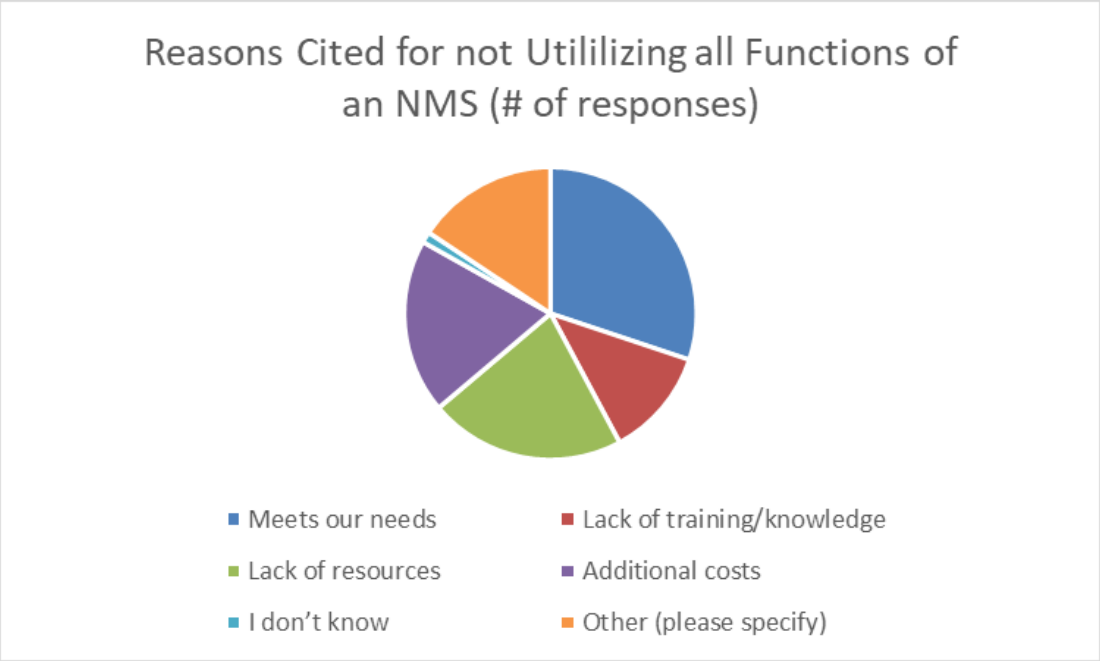


Figure 13 – Reasons Cited for Not Utilizing all Functions of an NMS

Forty-two (42) of the respondents indicated that their airports' NMS data is published on a website while 41 indicated that their NMS data is not published on a website.
Respondents provided the following information on how the websites improve communication with communities:

- Provide transparency of noise emissions as well as of the noise management activities undertaken by the airport.
- Provide information about noise emissions in a way that can be specific to individual community members.
- Used to make complaints and check on the accuracy of the complaint.
- Provide a mechanism to interact with the community and for the community to interact with the airport.
- Allow the community to provide feedback.
- Information from the NMS is used to educate the public about aircraft noise emissions and airport noise management measures.
- Improve the communities' ability to interpret noise data.

Benefits and Limitations of NMS

The majority of respondents are satisfied or very satisfied with their airport's NMS (78%). Approximately 10% of respondents indicated that they are dissatisfied or very dissatisfied with their airports' NMS.

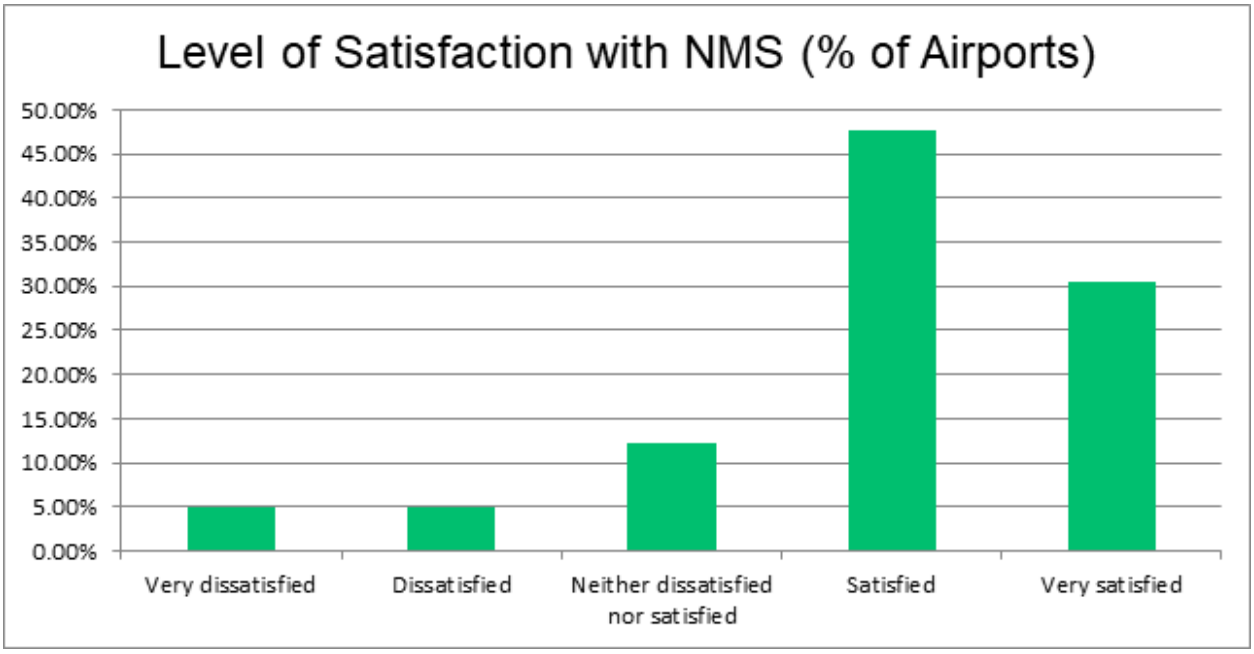


Figure 14 – Level of Satisfaction with NMS

Survey respondents were asked to indicate the level of their NMS' performance in five key categories, including how well the NMS:

- Monitors community noise levels,
- Monitors compliance with local regulations and apply associated measures (e.g., noise charges),
- Monitors specific noise abatement flight procedures,
- Supports airport planning; and
- Supports airport community engagement, communication, and education.

Figure 15 displays the results of this question by indicating the percentage of respondents rating for each of the categories.

The majority of respondents indicated that their airport's NMS functions well in all key categories except in supporting airport planning for which the majority of respondents indicated the NMS performs well.

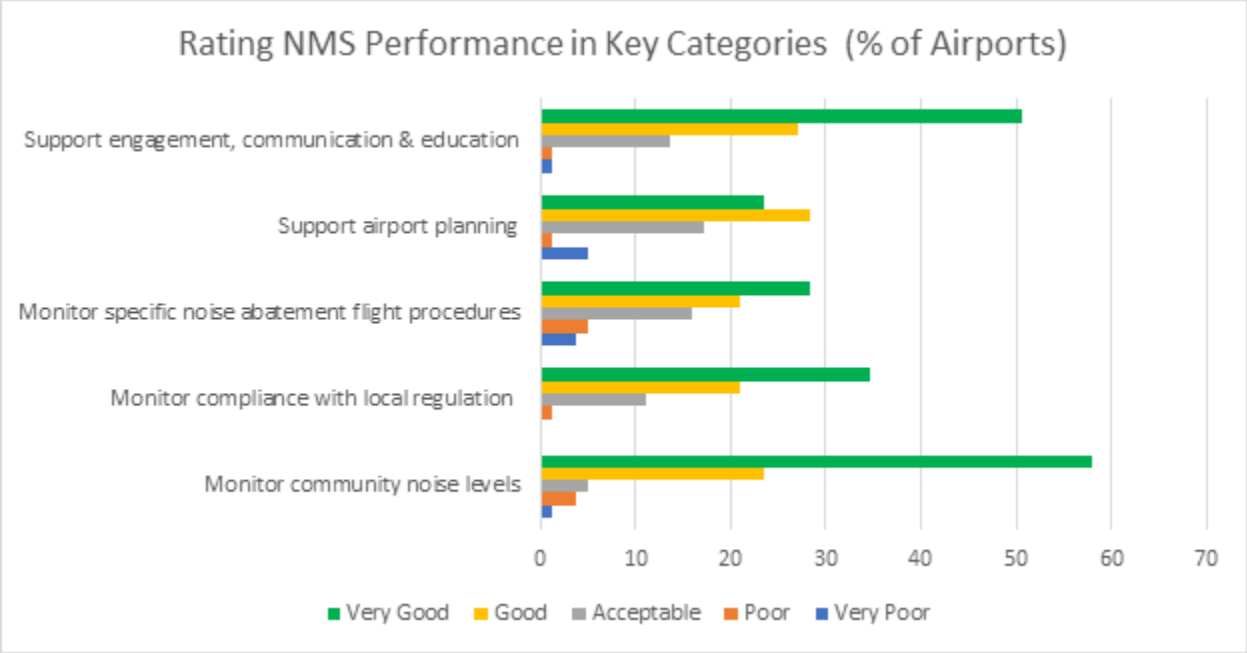


Figure 15 – Rating NMS Performance in Key Categories

Respondents provide information on additional functions of their airport's NMS, these include:

- To provide information such as, runway utilization, DNL monitoring values and noise complaints, for monthly reports.
- Displaying flight track data
- Responding to, and following up on noise complaints
- Supporting city planning
- Calculate ROT, taxing time and airspace delays
- Sharing data with non-community stakeholders (e.g., Air Navigation Service Provider)

Respondents then rated their NMS's performance of these additional functions. Table 1 outlines the ratings provided.

Table 1 – Respondent Ratings of NMS Performance

Function	**Average Rating**	**Number of airports this function was attributed**
Provides information such as, runway utilization, DNL monitoring values and noise complaints, for monthly reports	Good	4
Displaying flight track data	Good	3
Responding to, and following up on noise complaints	Good	2

Supporting city planning	Good	1
Calculate ROT, taxing time and airspace delays	Good	1
Sharing data with non-community stakeholders (e.g., Air Navigation Service Provider)	Good to Very Good	2

The majority of airports (51-72%) use their NMS to coordinate with external stakeholders including the general public, regulators, and airlines. While 14% of airports use their NMS for internal coordination. Twenty (20) respondents provided information on additional stakeholders they coordinate with using NMS data. These stakeholders include:

- Politicians
- Air Navigation Service Providers
- Community roundtables
- Local government
- Airport advisory commission

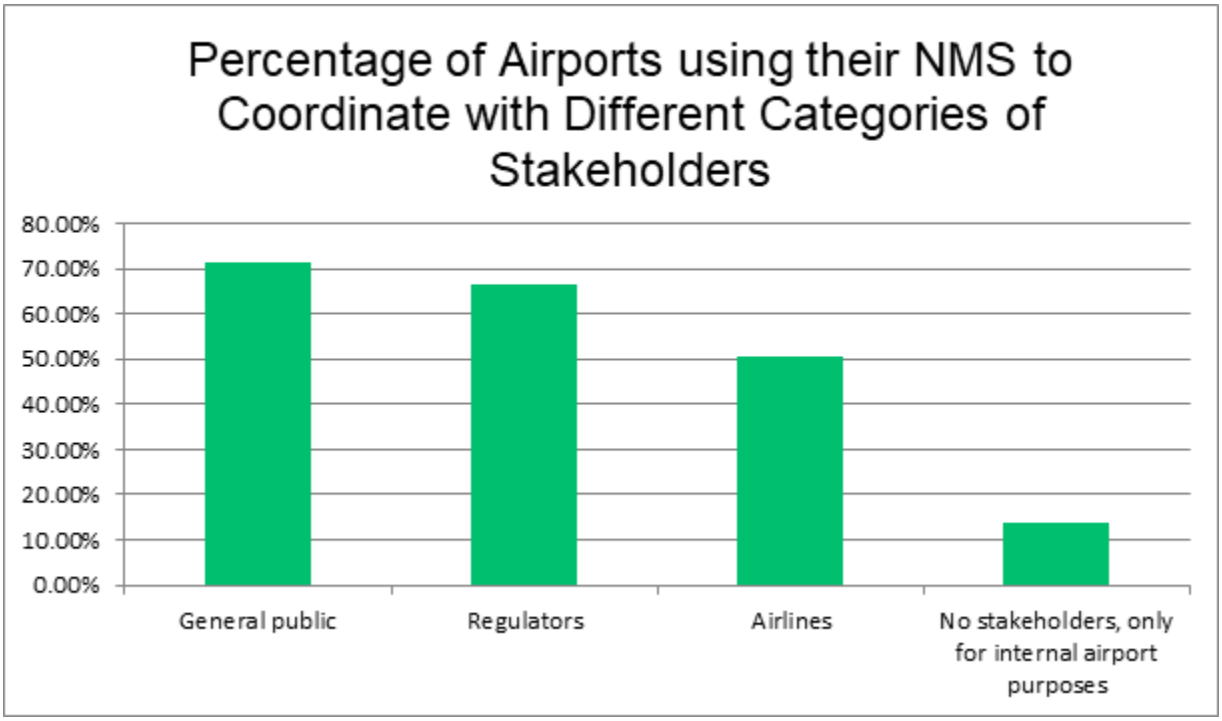


Figure 16 – Percentage of Airports using their NMS to Coordinate with Different Categories of Stakeholders

Seventy (70) of respondents provided information on what they see as the challenges to implementing an NMS at their airports. Some of the most commonly cited challenges include:

- Requires human resources, particularly personnel who are technically capable and trained in using the NMS.

- Expense to operate and maintain the NMS.
- Finding locations that are suitable for monitors including considerations such as electrical supply, land ownership, potential for damage or theft.
- Need to educate the community so that they can understand the outputs.
- Need to validate the data produced before it can be used.

Forty-six (46) of the respondents elaborated on how they have overcome these challenges. Solutions include:

- Hiring experienced personnel and providing training to those personnel using the NMS
- More regular coordination with the NMS provider
- Conducting daily checks of the NMS and datasets
- Educating the community where NMS monitors are located and incorporating security measures to protect the monitors.
- Simplifying and automating processes such as QA/QC
- Using AI to reduce labor and improve accuracy
- Outsourcing the operation and maintenance

Forty-one (41) respondents provided examples where operating an NMS had a negative impact on community engagement. The most frequently noted included the operation of an NMS and disclosure of data from the NMS leading to community confusion, particularly over the difference between a single event metric and cumulative metrics. Examples also noted community confusion over monitored noise dated versus modelled noise contours.

Another common theme within the examples is the use of an NMS resulting in a lack of trust by the community. Particularly in situations where the data can be obtained by the public before it is validated and it appears inaccurate.

Finally, many examples cited unreasonable expectations by the community and use of the data for malicious reasons such as political gain or litigation against the airport as examples of an NMS having a negative impact on the community.

Sixty-nine (69) respondents provided examples of how they effectively or efficiently utilize NMS in their airports' overall noise management program. Some examples include:

- Validating and responding to noise complaints
- Tracking pilot adherence to noise abatement departure procedures and voluntary noise procedures
- Generating reports to use for internal and external coordination
- Displaying flight paths and noise monitoring results at public workshops and meetings
- Engaging with airlines and ranking airline noise performance
- Comparing data from year over year to demonstrate noise has not increased over time
- Used in conjunction with Automatic Terminal Information Services to determine future runway operations (from a few minutes to tens of minutes)
- Identifying noise events greater than 94 dBA LMax. These aircraft then must implement an aircraft change program.

- Preventing encroachment of residential buildings near airports

Seventy-seven (77) of respondents provided input on what they see as the benefits of an NMS. Some examples include:

- Providing transparency to the public and stakeholders
- Gaining public trust
- Reporting of noise infringements
- Useful maps and comparison between current and historical aircraft noise
- Ability to compare noise modelling and actual noise emissions (both for certified aircraft and for the airport environment)
- Providing real-time and ongoing data
- Providing data that is used when considering noise reduction measures
- Providing data which can be used for environmental analyses

Correlation Analysis

There are five NMS functionalities that respondents were asked to rate how their NMS performs between ‘very good’, ‘good’, ‘adequate’, ‘poor’, and ‘very poor’. The responses were split into two groups for all five functionalities, these groups are:

- ‘Very Good’ and ‘Good’
- ‘Adequate’, ‘Poor’ and ‘Very Poor’

These groups were then compared to the frequency of NMS calibration to determine if there is a connection between the NMS that perform well to the frequency the NMS is calibrated. See figure 17.

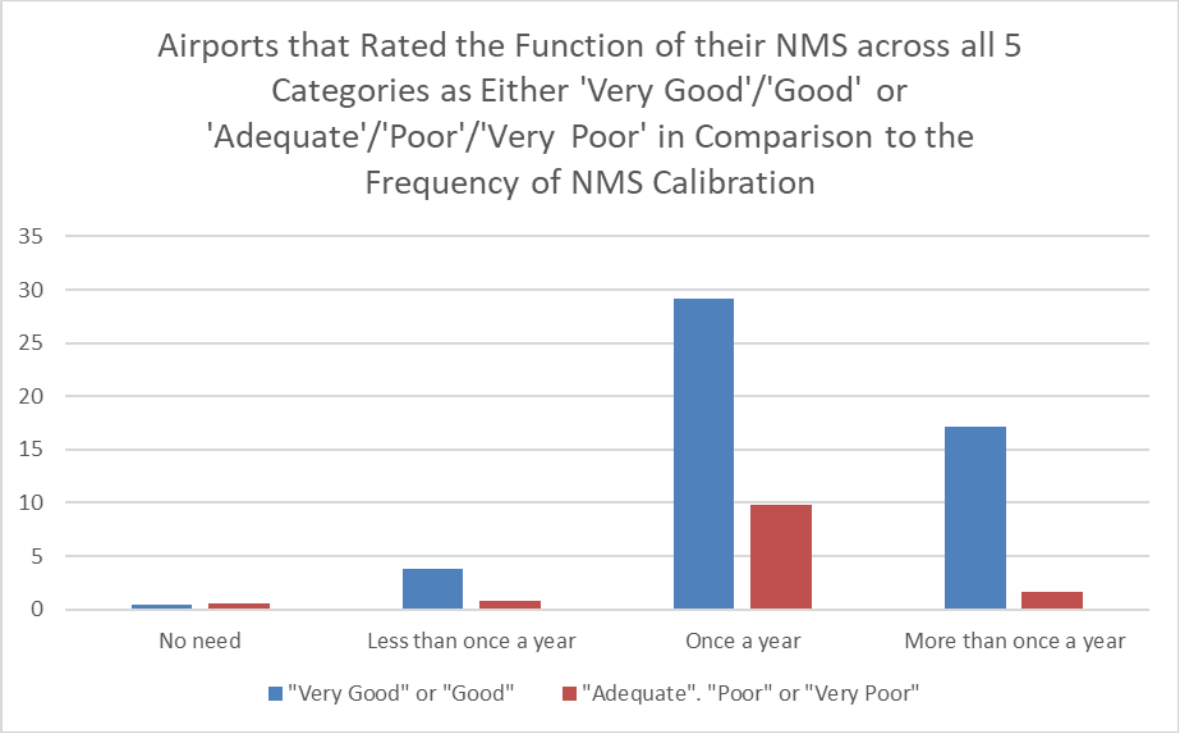


Figure 17 – Airports that Rated the Function of their NMS Across all 5 Categories as either 'Very Good'/ 'Good' or 'Adequate' / 'Poor' / 'Very Poor' in Comparison to the Frequency of NMS Calibration

The airports that have 'very good'/'good' functioning NMS also have a higher rate of calibrating their NMS once a year or more than once a year than those that have less successfully functioning NMS. This supports a good practice of calibrating the NMS at least once a year.

As shown in Figure 19 higher percentage of airports that implemented an NMS due to litigation are 'neither satisfied no dissatisfied', 'dissatisfied' or 'very dissatisfied' with their NMS. This indicates a good practice may be to proactively implement an NMS rather than as a result of litigation.

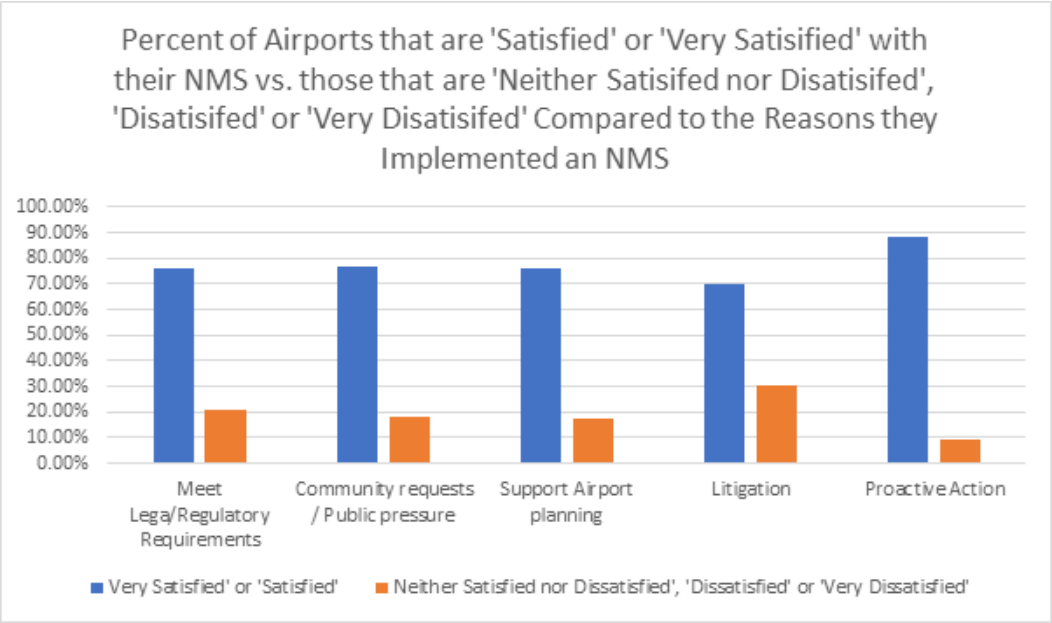


Figure 19 – Percent of Airports that are ‘Satisfied’ or ‘Very Satisfied’ with their NMS vs, those that are ‘Neither Satisfied nor Dissatisfied’, ‘Dissatisfied’, or ‘Very Dissatisfied’ Compared to the Reasons they Implemented an NMS

In general airports that use a public website are ‘very satisfied’ or ‘satisfied’ with their NMS.

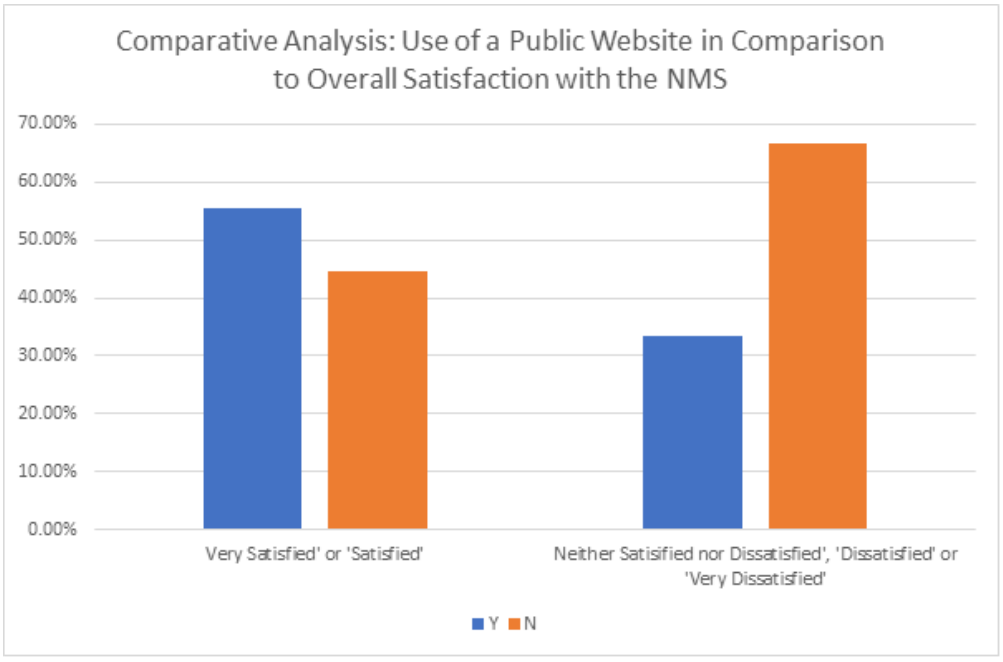


Figure 20 – Comparative Analysis: Use of a Public Website in Comparison to Overall Satisfaction with an NMS

As shown in Figure 21 below airport personnel are more highly satisfied with the function of the NMS the longer it has been in operation.

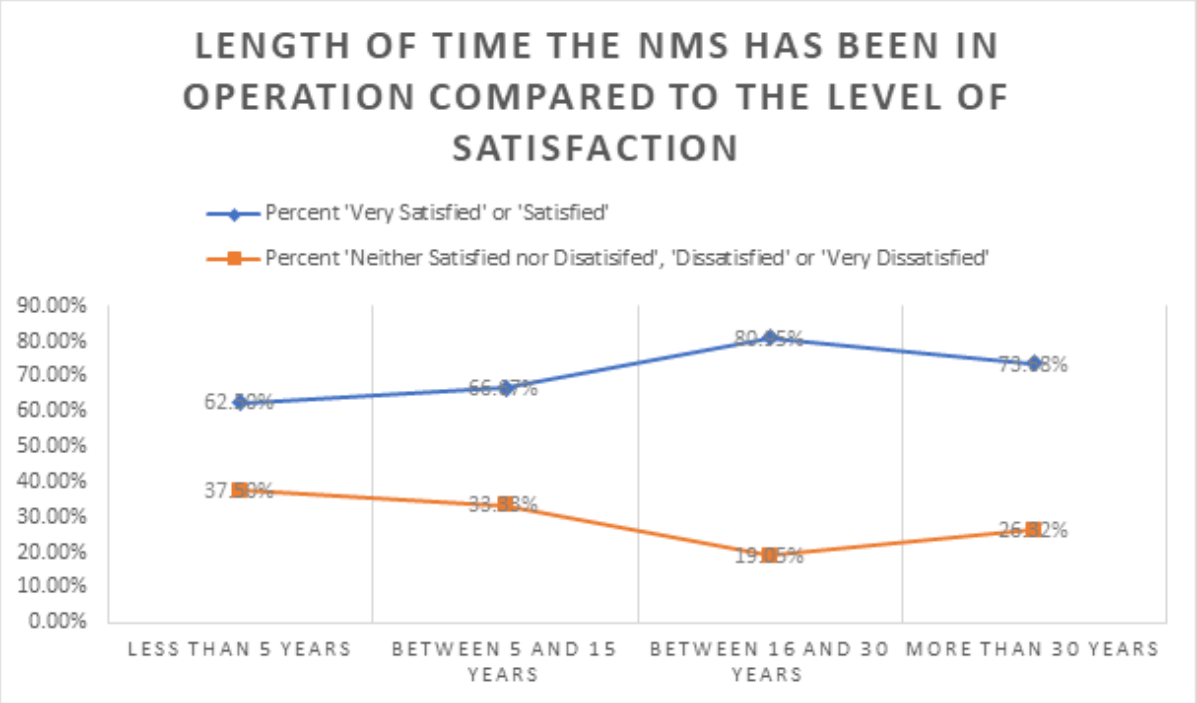


Figure 21 – Length of Time the NMS has been in Operation Compared to the Level of Satisfaction

Figure 22 below compares the number of NMS professionals employed by the airport in comparison to the level of satisfaction with the NMS. Airports that employ more NMS professionals whether they be permanent or part-time employees or a combination of both have higher rates of satisfaction with their NMS.

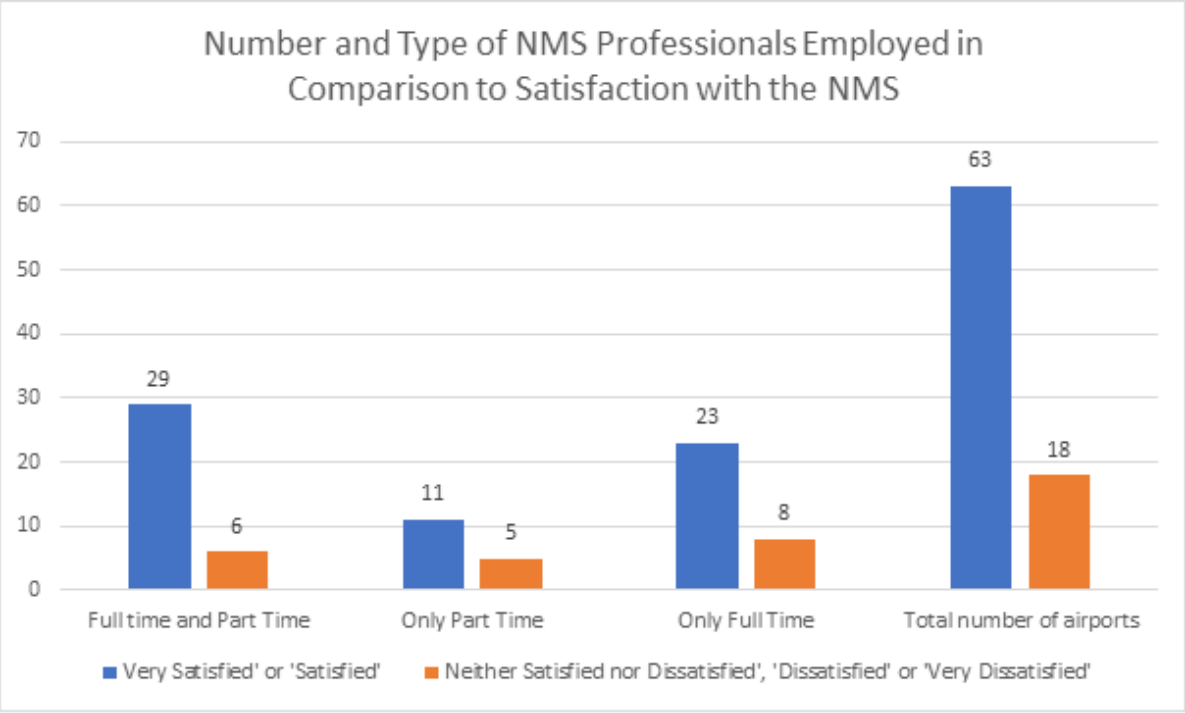


Figure 22 – Number and type of NMS professionals employed compared to NMS Satisfaction

APPENDIX C – AIRPORT USE CASES

The sections below provide a summary of the six airports use cases.

Frankfurt International Airport (EDDF)

The first aircraft noise measuring stations were set up in the 1960s along some of the approach and departure routes of Frankfurt Airport. The reason for this was the increase in aircraft noise pollution due to the increasing use of civil jet aircraft. The measurement results were passed on to the responsible authorities and to a newly founded Aircraft Noise Abatement Commission.

Following the example of the procedure at Frankfurt Airport, the obligation to measure aircraft noise and to set up aircraft noise commissions was regulated in the national Air Traffic Act. This requires aircraft noise monitoring systems to be installed and aircraft noise commissions set up at all German airports with scheduled civil flights.

The system in Frankfurt currently comprises 29 stationary aircraft noise measurement stations. The measurement results continue to be transmitted to the responsible authorities and the Aircraft Noise Commission, as well as to the general public via the Internet.
In addition to recording and transmitting aircraft noise measurements, the Frankfurt International Airport also uses NMS data for noise related landing and take of charges.

NMS Data is published monthly via the internet with a noise report document. The report framework and its contents are regulated in a German standard (DIN 45643 edition 2011). Metrics published are Lday, Lnight, Lden noise metrics as well as the numbers and intensity of single aircraft noise events at daytime and nighttime per month.

The NMS helps to make aircraft noise pollution around Frankfurt International Airport transparent and to support objective dialogue with the communities surrounding the airport.. Alongside the measurements, Frankfurt International Airport also conducts annual aircraft noise calculations, the results of which are also published on the Internet.

Tokyo International Airport (RJTT)

The NMS at Tokyo International Airport is utilized to comply with regulations, report to the public and support community response to noise, and correlate flight tracking data with noise measurements. Published information includes measurement locations, the number of noise occurrences, and the Lden and LASmax noise metrics. Also provided is

information about aircraft tracks including videos, Decision on what data to publish is based on environmental standards and noise prevention laws, with support from relevant local governments and the Civil Aviation Bureau.

NMS data and information dissemination allow both residents and airport management to understand noise exposure situations in each region as well as the associated noise reduction measures. Airport representatives indicate the NMS is operating effectively and does not require modification.

Athens International Airport (LGAV)

Athens International Airport (ATH) “Eleftherios Venizelos” located near Athens, the capital of Greece, has been operating permanent NMS for more than 20 years, since the beginning of its operations, in line with the requirements of its Environmental Permit. The NMS continuously monitors aircraft noise in the broader area of the airport, while a connection with the ANSP's radar enables correlation of the noise levels with specific flights.

NOMOS The monitoring system NMS is composed of a network of ten (10) permanent Noise Monitoring Terminals (NMTs) installed in the main residential areas around the airport located underneath flight paths, a mobile station for periodic ad hoc noise monitoring cases, and a central unit with software for the collection, processing and storage of data. It is directly connected with the Hellenic Aviation Service Provider's radar system to obtain data about aircraft flight paths, the Airport Operation Data Base (AODB) for data about the flight plan, as well as a connection with AIA's Air Quality Monitoring Network for meteorological data. An automatic correlation of noise levels with particular aircraft movements based on an advanced algorithm that among other parameters takes into consideration the minimum distance of the aircraft flight path from each station is accomplished with the NMS.

The measurement data are used to evaluate the impact of aircraft movements upon noise levels in the vicinity of the airport, monitoring of compliance with the Noise Abatement Procedures in effect at the airport, investigation of public complaints, and planning in general. The system provides a large number of indicators for the description of the acoustic environment (Lday, Levening, Lnight, Lden, Lmax, etc.).

AIA has created a special line of communication for the community, a telephone line called "We Listen" where concerned citizens can call for information and can also register their complaints. The telephone line operates on a 24-hour basis. The public may also submit noise related comments through a form on AIA's website or to a dedicated email address. Furthermore, AIA provides local residents with a web-based application

WebTrak (https://webtrak.emsbk.com/ath1) which presents aircraft flight track data together with noise levels in the vicinity of the airport. It is an add-in module of the existing NMS.

Denver International Airport (KDEN)

The Denver International Airport Noise Abatement Office has maintained and utilized a NMS since the airport opened in 1995. Inputs to Denver International Airport's system include U.S. Federal Aviation Administration (FAA) radar and operations data, noise event data from 26 Remote Monitoring Terminals, and noise complaint data. A web portal enabling the public to view air traffic and investigate and register noise complaints is included. Aside from typical functions, the system also feeds radar and operations data to a noise model that generates noise contours surrounding the airport, as well as Leq values at a number of more distant discrete locations.

Denver International Airport's NMS is unique in that in addition to being installed to perform typical noise monitoring and analysis functions, it was specifically designed to meet the requirements of an intergovernmental agreement (IGA) with the county surrounding the airport. This agreement, the 1988 Denver/Adams County Intergovernmental Agreement on a New Airport, specifies noise limits with which Denver International Airport must comply, as well as financial penalties for instances of non-compliance.

The IGA noise limits consist of two components: 1) The annual DNL 65 dBA noise contour surrounding the airport, and 2) Annual Leq limits at 101 individual geographic grid points spread across three areas designated as noise sensitive, to the northwest, west, and southwest of the airport. The airport must ensure that the annual average noise generated by operations (total operations, not individual flights) does not create an annual DNL 65 dBA contour that extends beyond the boundaries of the projected contour contained in the 1989 Final Environmental Impact Statement (FEIS) for the airport, and that noise at the grid points does not exceed the designated annual Leq limit at any of them by more than 2 dBA. Any violation of either the contour DNL limit or the grid point Leq limits that is not remedied can require Denver International Airport to pay Adams County $500,000 per violation, per year that it continues to be in violation.

Adding to the challenge that the IGA presents is the fact that the Leq limits at the grid points are unusually low compared to background levels and to levels that most airports consider acceptable. Most of the 101 grid point dB limits are in the 30s and 40s, with the lowest limit being 31.4 dB and the highest limits in the low 50s. Because of the extreme difficulty of accurately discriminating between aircraft noise and background sources at these low levels, the airport uses a noise model, rather than data from the remote noise

monitors, to calculate and report IGA noise compliance, though it continues to investigate methods to improve noise event discrimination.

Aside from the analytical and public relations benefits that an NMS typically provides, DEN's system is the centrepiece of a noise compliance framework that was and still is the linchpin in Denver's ability to acquire the site that airport occupies. The noise assurances contained in the IGA were a prerequisite for Adams County to agree to allow Denver to annex a portion of Adams County land to build the airport. The Denver International Airport literally couldn't exist without its NMS.

Sao Paulo / Congonhas Airport (SBSP)

Sao Paulo / Congonhas Airport is a domestic airport located 10 km from the center of Sao Paulo Brazil, and is the second busiest airport in the country. In 2011, the National Civil Aviation Agency (ANAC) published RBAC 161 - Aerodrome Noise Zoning Plans - PZR in which it regulates the development of noise contours and provides guidelines for noise emission management. RBAC 161 has continued to evolve since it's inception, ntegrating a systemic and holistic view involving various stakeholders to mitigate the impact of noise.

Aena Brazil, which operates the aerodrome, implements a three-part strategy to meet the legal and regulatory requirements. This strategy includes a technical working group, continuous noise monitoring, and a noise management commission.

Currently the Sao Pauolo / Congonhas Airport conducts continuous noise monitoring, with 3 stations installed outside the airport property, 2 inside the noise contours, 1 in each direction of each runway heading, and another outside the contour, at a point where the highest current level of complaints is concentrated. NMS data is used to verify the adherence between the real operations to the established routes, identify any errors in the simulations, and record history for trend evaluation.

Aéroport de Paris-Charles de Gaulle (LFPG)

The RMBA (Réseau de Mesure du Bruit des Avions - Aircraft Noise Measurement Network) operated by the ADP Group comprises 40 stations spread over several Paris airports. This monitoring mission is entrusted to the ADP Group under Decree 2005-828 of 20/07/2005. It is therefore a regulatory mission. The Group's Laboratory Acoustics Unit,

which is responsible for this task, has COFRAC (French Accreditation Committee) accreditation for this activity.

The first fixed stations in this network were installed in the 90s, and the network has expanded year on year, until the last station installed in 2022. At CDG, 25 stations measure noise continuously. The sound level meters used are CUBE models, supplied by ACOEM.

The raw data is first processed to distinguish aircraft noise from the rest of the noise environment using an internal detection/recognition method, then correlated with radar data provided by DGAC (French civil aviation).

The raw data in LAeq,1s (unprocessed) can be viewed using the VITRAIL tool, available at https://vitrail.entrevoisins.org/vitrail/, at the same time as the trajectory tracking.

The processed data (event coding + correlation) provides a number of indicators, presented in monthly reports, available at https://entrevoisins.groupeadp.fr/donnees/mesure-du-bruit/bilans/.
The monthly energy indicators calculated by station are essentially LAeq and LDEN. Noise exposure levels provide daily ambient and event LAeq for the month.

Statistics are produced per station on the correlated LAmax and provide the LAmax indicators by type of movement and aircraft type, as well as the NA (Number Above).

APPENDIX D – SUMMARY OF LITERATURE REVIEW

Today airports use noise monitoring systems (NMS) for several purposes, namely: to collect, manage, analyse, and communicate data such as noise measurements, aircraft flight tracks and flight procedures, aircraft identification, aircraft noise complaints, and weather. The number of tasks and their content depends on the legal requirements around managing the airport's noise exposure and the legal requirements related to installation of an NMS. The literature review indicated that legal requirements are still the main driver leading to an airport authority to operate an NMS and report on noise exposure to responsible boards including non-governmental and the surrounding communities.

The literature review indicates that aircraft noise is a problem for citizens. Residents living close to airports are subject to noise exposure from air traffic. The impact from this exposure is dependent of how the air traffic is organized and on how the residential areas are protected from noise. It also relates to how this exposure is assessed including its measurements and how it is communicated with the communities to allow for a better understanding of real environmental conditions where they live.

NMS can be used by airports efficiently and effectively in combination with the ICAO Balanced Approach (BA)[1] - to support the management of noise exposure and assessing its impact at airports, in coordination with airport authorities and neighbouring communities, and other stakeholders involved in noise management in the region. ICAO Annex 16[2] describes the purposes of noise monitoring as the following: 'monitoring compliance with and checking the effectiveness of such noise abatement requirements as may have been established for aircraft in flight or on the ground'. C.R.Bragdon[3] included the NMS in a list of the operational airport noise control strategies among the noise abatement profiles and flight tracks, preferential runways and others used to minimize aircraft noise from the flights over noise-sensitive areas. The main reason for this is thatthe NMS serve a variety of purposes such as assessing alternative flight procedures for noise control, assisting in the investigation of specific public inquiries and complaints, and assisting in addressing land use planning and noise-impact issues. Locations of any aircraft noise monitoring sites are utilized for data acquisition and refinement procedures[4].

Under the ICAO umbrella there are two broad classes of systems required by standards, in particular by Annex 16, vol. 1 Aircraft Noise[2], and currently in use for aircraft noise measurements. First is the aircraft noise certification system, which is capable of precise measurement and evaluation of single aircraft flyovers for the purpose of determining compliance with ICAO Annex 16 noise certification requirements. Such certification procedures require accurate knowledge of aircraft position and detailed analysis of acoustical flyover signatures. Second is the aircraft noise monitoring system, which is normally used at an air facility for purposes related to abatement of community noise exposure. Such systems vary widely in their capabilities, but most operate continuously and use a single-number rating of aircraft flyover noise in calculating various exposure measures.

The components and subsystems used for monitoring and certification systems are similar in many respects. The wide range of system complexity in each class often allows an overlap in capabilities of the equipment used. This similarity between the measurement systems may explain the reason why the still single vision of the ICAO on Aircraft Noise Monitoring Systems is presented in ICAO Annex 16 'Environment Protection', vol. 1 "Aviation Noise' at a specific Part III. "Noise Measurement for Monitoring Purposes".

A fundamental part of the BA, as defined by the ICAO Assembly, is the identification of the noise problem at the airport. To determine the presence of a noise problem to be solved at a specific airport, it is necessary to assess the change in the noise environment at this airport and the surrounding housing development. To the extent that a noise problem is identified, it should be evaluated in order to determine what measure or measures can reduce its severity or completely eliminate it. When starting the assessment, the authorized body must have the means of measuring, forecasting and comparing the levels of current and future noise exposure. NMS should be the main objective mean for these purposes[2].

ICAO CAEP carried out the survey on the NMS usage in airports[18] during the 5th working cycle aiming to collect details of the NMS in airports such as their capabilities, data stored, technical support, etc. At the end 1990s not all systems were similar in their complexity and realized functionalities (Figure 1). For example, around 92% of airports with NMS responded positively to "noise monitor data transferred to a central processor", which means approximately one in ten systems was operated with a simplified NMS platform, with few noise measurement stations. And only half the respondents in the survey reported use of the meteorological data system to support the NMS[18].

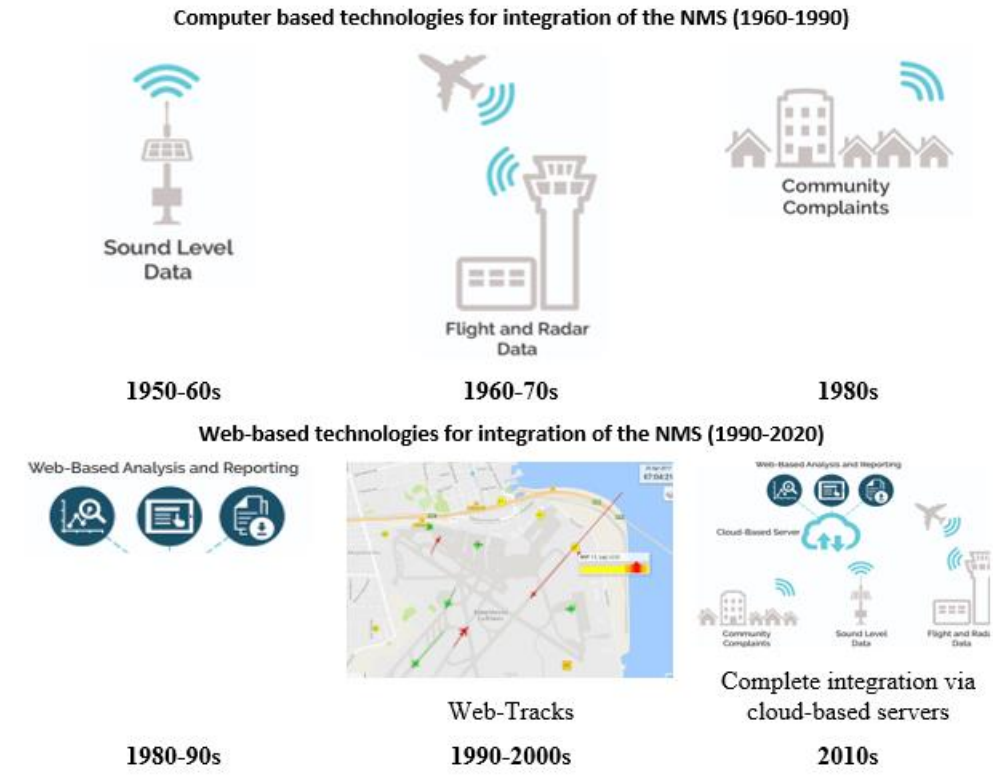


Figure 1. Accomplished road map of the development of NMS

Earlier system generations often comprised noise monitoring alone[14]. Many of the capabilities of modern monitoring systems have only become feasible with the advances which have been made in the speed and storage capacities of computer systems. The key element in 2nd generation systems is radar tracking information recorded from the air traffic computer system. The time correlated tracking information can be combined with the aircraft noise level information to identify a specific aircraft associated with each noise event. Track density, while not an indication of noise levels in itself, by showing the frequency a particular flight path is used, can help communities understand the impacts of a change, as in Figure 2. If possible, the map should show the full width of a flight path, so that it is clear that aircraft can be expected anywhere within a wide corridor, not just along a tightly defined line[19].

During last few decades, the ICAO expanded the management process for environmental protection in airports by including "people issues", meaning the inclusion of community engagement for aviation environmental management[20]. Engagement creates opportunities to deliver improved understanding by all partners and stakeholders of the process. Environmental matters usually dominate community engagement and often it is the impact of aircraft noise that is the issue of most concern. Thanks to Internet technologies the airport noise portals are used to provide public reporting of information on noise levels at NMS terminals[21], air traffic movements, runway use, and flight paths, and complaints summaries and statistics. It also includes summaries of noise improvement investigations and their outcomes for communities.

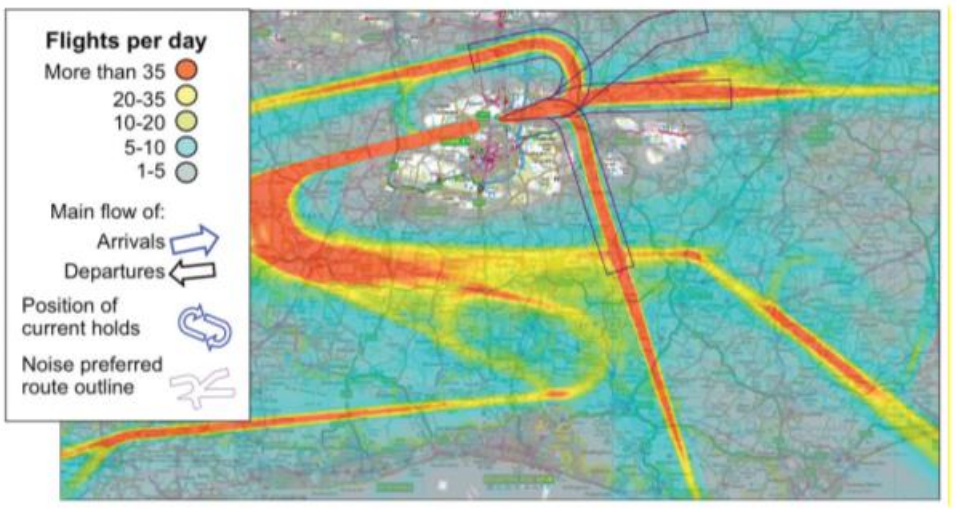


Figure 2 – Typical track density plot [19] *(Source: NATS, Gatwick Airport Runway 08 Operations)*

Reasons for noise measurement in airports

The literature review indicates that noise monitoring continues to be one of the most important procedures in noise management around airports, since noise pollution is a serious problem for the surrounding communities[22]. The demand for such systems is predicted to increase because of the growth of aviation and the proximity of communities to airports, which may result in potential land-use incompatibility around the airports[10]. Monitoring system typically operates 24 hours a day, seven days a week, collecting data from every aircraft flying to and from the airport throughout the year. It is a routine long-term noise monitoring system at a specific location where a noise monitor is installed, which is of interest to evaluate the aircraft noise level for several noise management reasons around the airport. Monitoring locations can be very stable and can be used for decades. Short-term noise monitors can be deployed for a limited period, usually a few months, usually to monitor during the heaviest air traffic and its noise exposure at a location.

For the long-term noise monitoring the fixed noise monitoring terminals (NMT) are used and for the short-term noise monitoring the mobile (or portable) NMT ,is used. These two types of monitoring terminals are similar except of time of the operation for monitoring purpose. The number of fixed and mobile NMT as part of any NMS depends on noise management program at the airport which must define the requirements for the noise monitoring program as a whole and for every NMT in particular. Usually the higher frequency of air traffic at an airport produces spatially larger noise exposure and an increased need for supervising the larger number of NMT. CAEP5 defined that the percentage of fixed NMT increased proportionally with the increase in annual aircraft movements[18].

The number and location of the monitoring terminals is important depending upon the specific role they are to play[22]. They are combined by central station of the system, its efficiency is defined by the software and data bases included into the central station for assessment of current, previous

(historical) and future (forecasted) scenarios of air traffic and its exposure/impact of environment. Such systems can be used to collect the information which[15]:

- ✓ enables assessment of the effects of operational and administrative procedures for noise control and compliance with these procedures and/or assess alternative flight procedures for noise control (the tool of objective assessment of efficiency of the proposed operational and administrative procedures for noise control in the vicinity of the airport);
- ✓ assists in the planning of airspace usage issues;
- ✓ increases public confidence that airport related noise is being monitored to protect the public interest;
- ✓ enables validation of noise forecasts and forecasting techniques and their methodologies over an extended period of time (collection of data for noise contouring, system noise exposure forecasting and contouring with compiled data);
- ✓ assists relevant authorities in land-use planning for developments and noise impact on areas in the vicinity of an airport;
- ✓ enables assessment of a Quota Count system (special mitigation procedure which defines a number of flights of the aircraft of specific types during a specific period of the day), among other possible noise mitigation measures; and

indicates official concern for airport noise by its jurisdiction and its governing bodies and enables provision of reports to, and responses to questions from, government, parliament, industry organizations, airport owners, community groups and individuals.

Airport noise monitoring programs have been established for a variety of reasons. The main reason is not defined simply by the measurement of the noise level. In most cases noise monitoring is not undertaken to determine compliance with aircraft noise regulations because of the absence of national regulations specifying an aircraft noise limit within the community. For any specific location of the monitoring the reasons are different usually and defined by noise management program objectives. Airports must analyse the advantages and disadvantages of establishing a monitoring program before proceeding. Because of the growth of air transportation and the lesser proximity of the communities to airports due to attractiveness of the growing aviation business, which may result in potential land-use incompatibility inside the airport noise zones, the demand for NMS is predicted to increase[10].

CAEP/5 review found that the NMS may be installed for reasons such as[18]:

- ✓ enforcement of regulations on noise levels and flight tracks for individual aircraft;
- ✓ gathering data to assess the effectiveness of noise abatement procedures;

- ✓ collection of data for noise contouring, and validation of noise contouring methodologies;
- ✓ assessing the impact of aircraft noise on surrounding communities, and evaluation of land use policies; andfor public relations purposes.

Based on the experience of systems already installed at airports for decades after the CAEP/5 review, collective purposes of establishing a noise monitoring program today are to[18]:

- ✓ Assess alternative flight procedures for noise control;
- ✓ Assist in the investigation of specific public inquiries and complaints;
- ✓ Instil public confidence that airport-related noise is being monitored to protect the public's interest;
- ✓ Validate noise modelling efforts at the airport over an extended period of time (e.g., 1 year);
- ✓ Assist in addressing land-use planning and noise-impact issues;
- ✓ Indicate official concern for airport noise by the jurisdiction and its governing body;
- ✓ Detect unusual flight events;
- ✓ Educate airplane pilots, airlines, the airport proprietor, and the public about airport noise and its characteristics;
- ✓ Obtain valid statistical data using an objective and scientific resource;
- ✓ Apply research tools to assist the airport in performing certain tasks, as required or mandated;
- ✓ Assess compliance with some voluntary or mandatory noise level, established by a governmental entity.

Early-generation noise monitoring systems often included only noise measurements[14]. A notable disadvantage of such an arrangement is in the reduced reliability of the attribution of a noise event to an aircraft in air traffic. Today many of the systems enable noise data to be identified with an individual aircraft operation. The identification method appears to be primarily through the correlation of noise events with flight schedule data, or with radar flight track data, or with flight Automatic Dependent Surveillance–Broadcast (ADS–B) data, etc[23]. The ability to correlate the two types of data – noise and flight path (Figure 3) – makes the system much more useful[14]. Sometimes even the flight path data itself is enough to show why the public's response to aircraft noise is defined as annoying[24].

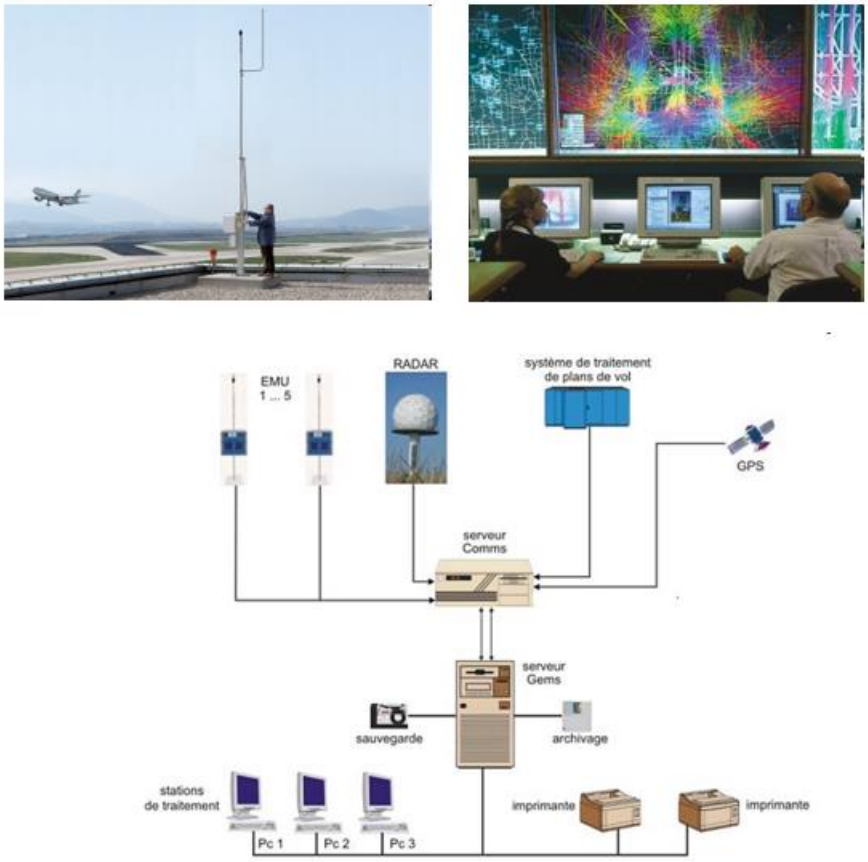


Figure 3 – Complex of the NMS with Flight Traffic

The system must have a connection with a source of weather information[15]. It is necessary for both noise data interpretation and flight track analysis. The information commonly recorded includes wind speed, wind direction, temperature and relative humidity. Generally the meteorological data is recorded at either one of the NMT monitoring sites or from the airport meteorological station.

To assess the number of people annoyed by noise it can be necessary to provide a subsystem of complaints and messages from the residents living close to airports and flight routes[15]. People are driven to complain when some nuisance factor (or stressor) in the environment gives rise to annoyance and when this stressor reaches a threshold of tolerance. In this context the stressor is an aircraft noise, which is described by exposure metrics usually.

The ability to correlate these types of data – noise, flight traffic (fleet of the aircraft and flight paths in their use), state of the environment and reactions to noise from the population – makes the system much more useful and widen the list of tasks to be solved in monitoring the noise for its effective management[15].

The monitoring of aircraft noise levels in community areas is an important component of managing airport noise. Although noise monitoring has no direct noise reduction, it can be an integral

component of noise management and community engagement[17]. NMS allows airport staff to disseminate a variety of information related to aircraft operations and related noise through an airport's complaint handling process and community outreach programs. Airports may share NMS information as part of a complaint investigation and response process, a special report for an individual or group, or upon request. Additionally, airports may prepare periodic reports and announcements relative to topics such as noise abatement procedure or operational agreement compliance, runway use, run-ups, complaint statistics, and noise levels at monitors. These reports and announcements can be shared in printed format during public meetings, in electronic format as e-mails, and posted on the airport's website and social media platforms. NMS vendors also provide online resources to share information with the public. Online NMS data include near-live flight tracking, flight replay, address locator, and noise levels at noise monitors.

Noise communication to the public may be considered one of the instruments to manage the reaction of exposed to noise population[21,28]. From this point of view bringing information closer to the public becomes of the highest importance – the reported information, which is overly technical, should be customized for different users' profiles, so that they can understand the information provided by the NMS. Commonly used noise prediction indexes do not satisfy the general public's expectations, as, on some occasions, they seem to mask the real pollution (physical phenomenon) under mathematical operations.

Four main ways of reporting measurements of aircraft noise were identified by the research – online platforms, reporting of noise monitor data, bespoke noise reports for a given community and noise contours. The study[29] showed that these indicators, when used in regulations, have the serious drawback of being too technical for non-experts and not meeting the expectations of the citizens. Residents do not understand these metrics nor do they rely on them. Some airports use complementary indicators that give information that can be more easily understood by non-experts. The "Number Above", "Time Above", "Person-Events Index" and "Average Individual Exposure" indicators are the most used nowadays[21].

Many airports facilitate various levels of public access to NMS data as part of their community outreach. While some airports allow limited or no public access to NMS information, many permit the public to follow and review operations in the vicinity of their homes. Airports with comprehensive community outreach programs develop robust public websites or portals that offer community engagement solutions that provide self-investigation, education, and reporting tools, which have improved trust and transparency between airports and their surrounding communities.

Few questions are still need for the answers: How to communicate with community, what are the tools are available for that? How to organize close proactive and collaborative communication and community engagement? Standards for communication tools – are they necessary also (similar to technical requirements for NMS installations in technical standards ISO 20906)?

Definition of the NMS

The literature review indicates that it is now generally accepted that the noise levels, as like any other kind of environmental pollution, generated by any significant activity in society should be monitored and be published for public awareness of the potential adverse effects which may be generated by that activity. It is important that the results of noise in particular and of overall environmental monitoring are archived so that long-term trends in noise and pollution levels can be checked and published. On a more detailed level, the information can demonstrate the changing nature of aircraft noise (along with air pollution, crash risk, electro-magnetic fields) exposure around an airport.

Monitoring systems in general involve a system of continued observation, measurement, forecasting and evaluation for defined purposes and is the basic tool for that underpins responsible environmental management[22]. In general case the purposes of monitoring are described elsewhere as: 1) to assess the current status of the resource to be managed or to help determine the priorities for management, 2) to determine if the desired management strategies were followed and produced the desired consequences, and 3) to provide a greater understanding of the system being managed. Noise monitoring to be undertaken usually in the local community on the assumption that aircraft noise will exceed what is considered 'acceptable' or legally permissible level, and in this connection, it is necessary to refer to the legislative controls on aircraft noise.

According to a special ICAO CAEP Work Programme, an airport noise monitoring effort should[15]:

(a) compile data on methods used to describe aircraft noise exposure and applications of the data;

(b) determine the contribution (general and/or specific by type, route, airlines, etc.) of aircraft to the overall noise exposure;

(c) collect data on the characteristics of airports with noise and/or flight path monitoring systems;

(d) collect details of airport noise monitoring systems such as capabilities, data stored, technical support;

(e) compare calculated and monitored noise levels for a suitable sample of airports;

(f) compare measured noise levels with certificated noise levels for a range of aircraft types and operating conditions;

(g) examine changes in measured noise exposure over a representative time period; and

(h) update advisory documents on methodologies and applications of noise contouring and monitoring, supplemented, for environmental noise management, by the elements of expert and decision-making systems.

Standards for noise monitoring installations

One of the most important issues in NMS is the correct detection and marking of aircraft sound events through their measurement profiles, as this influences the results. In the case of airport noise measurements, the presence of a quite detailed structure of standards does not seem to guarantee a user-independent interpretation of the phenomena and not of the results. Most of the factors that can affect the uncertainty of the results are dealt with in ISO 20906[11]: measuring instrumentation, residual sound, emission at the source, ground effect, etc. The standard also describes some of the possibilities for minimizing or avoiding the influence of these factors. Figure 4 shows the aircraft events identification schema as defined in ISO 20906. The monitor records the A-weighted sound level for every 1-s interval, in terms of equivalent sound level (LAeq,1s) or sound pressure level with time weighting SLOW (LAS). The recorded time history, Lp(t) is used for the detection of noise events.

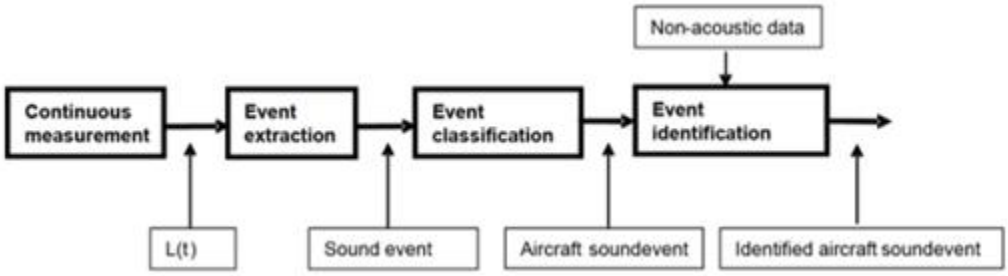


Figure 4 – Terms used for data processing by NMS in accordance with ISO 20906

A number of international and national standards exist (for example, ISO-1996, SAE ARP4721[12] and ISO 20906[11]) and provide engineering methods that can be applied to monitoring aircraft noise and operations in the vicinity of airports using either attended or unattended monitoring systems, as well as methods for validation of measurement results from permanent systems.

The ISO 3891-1978 was the first International Standard[25] and provided a procedure for describing the noise heard on the ground from aircraft operations. It also provided the specifications for the four steps to be followed for the purpose of describing the noise from a single aircraft operation which included data acquisition, data processing, data normalization, and data reporting. These specifications are given for two levels of sophistication of measurement: those requiring spectral analysis as a function of time, and those requiring only frequency weighting. The Standard recommended the calculation procedures for assessment of the perceived noise levels, including EPNL, as determined by subjective experiment on a fundamental psycho-acoustical basis, - similar with certification procedures described by ICAO Annex 16[2].

Two main applications of the measurements were distinguished by this Standard[25]: a) requiring the characterization of single events, such as for measurement of the noise from an individual

aircraft against specified requirements or for monitoring at an airport; and b) requiring the determination of noise exposure for a succession of events. Specific purposes for which these methods might be used were also discussed, including certification, monitoring of noise levels and of noise exposure, and land-use planning.

The literature review indicates that where possible, noise monitors should be installed to conform with guidance provided in ISO 20906 and SAE-ARP-4721. The international standard ISO 20906[11] defines requirements for reliable measurements. It describes a threshold system of sound event recognition in a complex sound situation with multiple aircraft and other sound sources. A much more complex and sophisticated system may be needed to separate the aircraft sound events from each other and from other sound sources. Such methods, which may include radar location of sources, the addition of flight information systems, directional microphones, and other methods such as distribution of specific and residual sound or pattern recognition, are not described in the ISO 20906.

For political reasons it is often necessary to install monitors in acoustically unsuitable places. Monitors installed in areas with usually low aircraft sound may act as a kind of protection: those monitors have to prove that there is normally only low aircraft sound and hence no measured aircraft events, –except in the case of extraordinary circumstances when an aircraft flies close by. Such monitors may be politically necessary. Their function is covered by this International Standard only for the case of the extraordinary events, i.e. the measurable events.

The guidance in SAE-ARP-4721[12] Part 1 is intended for application to airport noise-monitoring systems that are designed and installed (or refurbished). Part 1 also provides methods for analysing data from temporary noise monitoring. The methods and information in Part 2 may be used for any permanent monitoring system.

The primary topics addressed in SAE-ARP-4721[12], Part 2 are identified in six subsections. Sections 2 and 3 give references and definitions of the airport noise-monitoring systems. Section 4 ‘Post-Installation Screening Tests’ identifies tests that may be conducted immediately after a system has been installed and is operational. These tests use only data directly from the system and should efficiently identify any major short-comings, such as missing significant numbers of operations, or missing or erroneous aircraft noise event data. These tests may also be run at any time that some major portion or type of system reported data is in question. Section ‘System Validation for Special Studies’ provides more rigorous and time-consuming methods for quantifying a permanent system’s capabilities when special needs require detailed, quantitative analysis of system data. It describes metrics, tests and calculations that can be used to determine how well the system is: (1) capturing all aircraft flight tracking information, (2) matching captured tracks to runways, aircraft types and flights, (3) capturing aircraft noise events, (4) matching those events with correct tracks, runways and aircraft, (5) measuring aircraft sound levels, and (6) properly locating aircraft flight tracks. Section 6 ‘Data Analysis and Reporting’ suggests what

general steps can be taken to improve system operation and how measured data should be reported to provide sufficient information so that reviewers can easily judge data quality.

The technical requirements from the standards do not focus on identifying the the successful and efficient operation and maintenance of the NMS. The requirements for the conditions of monitoring terminals placement provide the accuracy and reliability of the measurements at a specific location. The number of terminals, their measurement performances and location are defined by the airport authority without any requirement for the efficiency of NMS operation in the airport.

Best national experience of NMS usage for aircraft noise management

US experience

The Airport Cooperative Research Program (ACRP) recently published a "Primer and Framework for Considering an Airport Noise and Operations Monitoring System"[10]. This report fills the specific need of providing a methodology to assist airports and other stakeholders in deciding whether an NMS is appropriate for their situation. It does not address good practices in implementing an NMS, and certain portions of its content are US-centric.

The total number of airports in the United States (including all 50 states and the territories) that have installed NMS was 89. Virtower (a Vendor of the NMS in USA) provided an additional 40 systems that do tracking and operations monitoring without noise monitoring, confirming the importance of flight track keeping itself[24]. All of the systems were minicomputer-based systems, usually running on UNIX operating systems. Flight track data were transferred manually from FAA air traffic control to the airport via tape reels, making public portals and public access to the data non-existent. Since then, NMSs have become highly integrated and provide virtually real-time access to noise and flight track data. By integrating noise data and radar flight track information, NMS is able to determine the contribution of aircraft noise at the noise monitoring terminal sites. It may also be possible to use radar tracking data for air pollution analyses, especially investigation of particulate deposition. A further application of tracking data is analysis of fuel use.

At many airports, the public has direct access to noise and flight data to research and file aircraft noise complaints. The aircraft noise and operations monitoring industry has come a long way in the last 50 years. In the next 50 years, the industry will likely improve exponentially. The future of the noise and operations monitoring industry will focus on two main areas: new software enhancements/concepts and new hardware technology will greatly improve NMS functionality.

New software enhancements will likely include increased use of cloud storage, more use of virtual NMTs, more automation of reports and complaint investigation, and more data analytics and business intelligence tools. New hardware technology will soon include increased use of tablets and other mobile platforms, a better radar data capture rate, air quality/emissions monitoring, more

affordable NMTs, increased use of Automatic Dependent Surveillance-Broadcast (ADS-B) transmitters and less reliance on passive transmitters, and fully live (no delay) public display of data.

The following list presents the many ways that airports can use NMS (that were noted in the Airport Questionnaire survey in the Report[10]):

Monitor flights in general

• Monitor specific noise abatement flight procedures

• Monitor noise abatement runway use

• Monitor noise levels/limits at monitors

• Monitor airspace use

• Monitor aircraft departure and approach profiles

• Monitor community noise levels

• Monitor compliance with agreements/mandates, i.e., community commitments

• Monitor nighttime curfews

• Monitor run-ups

• Monitor taxiing

• Monitor nighttime noise levels

• Support special studies by consultants

• Monitor pavement utilization

• Monitor capacity utilization of departures

• Manage Remain Overnight parking

• Produce and validate airport noise contours

• Educate and communicate with the public

• Investigate noise ordinance/limits violations

• Support airport planning

• Assess fleet mix

• Supplement information to other airport proprietor departments and government agencies

• Investigate incursions

• Analyze performance-based navigation/Metroplex route impacts and compliance

• Cross-check airlines' self-reporting records

• Measure off-airport temporary helistops

• Monitor runway crossings

• Monitor airspace utilization (geofencing)

A wish list of the future for NMSs includes real-time data feeds, better ability to track area navigation (RNAV) and required navigation performance (RNP) procedures, higher quality tools for the public to use in self-service noise complaint monitoring, more accurate noise prediction models, enhanced tools to communicate with the public, better reports for making informed decisions, improved data quality and reduction in data loss from the source, and superior noise-to-flight track correlation rates.

The new frontiers in air transportation include urban air mobility (UAM) and unmanned aerial vehicles (UAVs). Airports will need to consider a fundamental change in aircraft monitoring as the potential exists for many UAMs/UAVs to be flying and possibly creating noise issues well outside the environs of the airport. These are likely to become the fastest-growing sectors in aviation, and airports need to consider how to accommodate these new aircraft in their NMS. UAVs, or "drones," are being used to inspect infrastructure, provide emergency response support, survey agriculture, and deliver supplies and products to customers in urban and rural environments. UAMs are small vehicles used to transport people by air and are used to reduce traffic on congested highways and roads. While aircraft noise levels will become less of an environmental and annoyance issue, visual pollution and privacy issues will become the main concern. It is likely that including UAM/UAV monitoring will be a separate module within existing NMSs or flight tracking systems. The new UAM/UAV aircraft will be required to operate a transponder that will respond to Mode-S interrogation. These new aircraft will have registration/tail numbers and Mode-S codes and will show up in standard registry databases, although the registry may be separated from conventional aircraft. Either way, the new aircraft registries will be able to recognize aircraft ownership through NMS.

UK experience

NLR report Verification of Heathrow Noise and Track Keeping Systems[26] was written on results of the trials conducted in 2010s to test concepts and techniques to examine how Heathrow's airspace to be better managed in the future[27]. These trials were related to the Government's plans to update and modernise UK's airspace and to see if the publicly provided information is plausible. The overall conclusion of the verification study is that there is no indication this reduces the trustworthiness of the information presented.

The information available via Heathrow's NMS as well as via the publicly accessible WebTrak system is based on correct input, is processed in a correct way and is complete. NMS receives radar data from National Air Traffic Services (NATS) Air Traffic Control radars, which provides information of all aircraft movements as a continuous stream about the height of an aircraft above airport elevation, the track it has flown, its ground speed at any particular point and the aircraft's call-sign (Figure 5). NMS also provides noise measurement results for several measurement locations in the vicinity of Heathrow. WebTrak is an online system that allows those affected by aircraft operations at Heathrow to locate their residence and view how aircraft operate in their area. It has been in operation at Heathrow since 2008. Currently the system shows information on the last 12 months of operations, with a 20-minute delay.

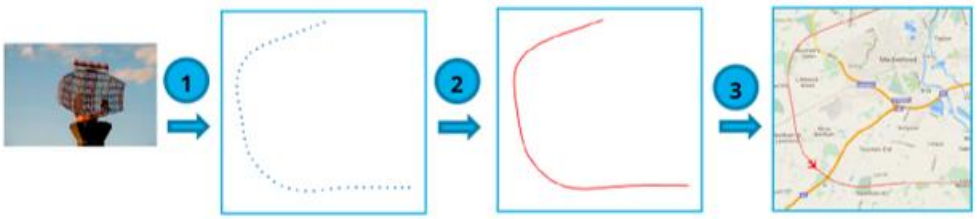


Figure 5 - Processing chain from radar data to presentation

To meet the objectives of the study the following detailed actions were defined:

1. Verification of the NMS and WebTrak systems information in regard of the following aspects (including the Radar transfer to NMS shown in Figure 5):

- The lateral accuracy of the mapping and presentation of flight tracks over the ground
- The vertical accuracy of the flight tracks in relation to height/altitude over the ground
- The capture rate of the data, i.e. are all the flights operating from Heathrow accounted for in the system.

2. Assessment of individual flights to demonstrate the level of accuracy displayed by the NMS and WebTrak systems.

3. Assess whether there has been any historical change in the past 5 years to the NMS or WebTrak systems which may have altered the accuracy of the information.

4. Verification whether the noise models used by Heathrow are compliant with international standards and provide an accurate assessment of the calculated noise climate (Figure 6).

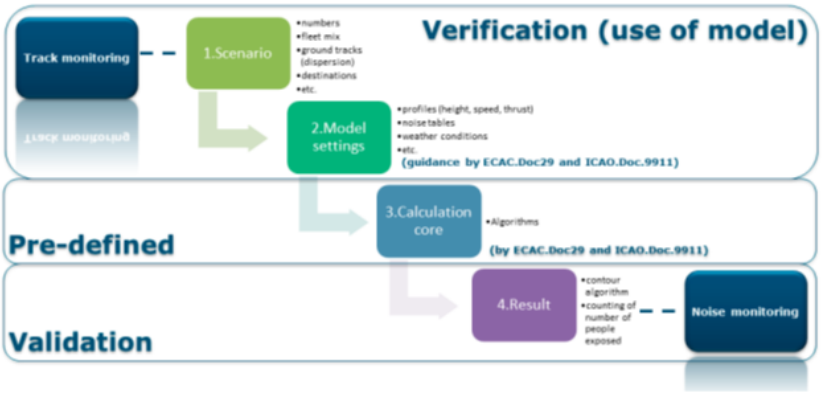


Figure 6 - Schematic flow chart of environmental aircraft noise modelling

On top of the verification with radar data as a reference it was decided to also make a verification using data from an ADS/B source. The aircraft positions in NMS are therefore more in line with the raw NATS radar data. However, this does not mean the ADS/B data is wrong. ADS/B data is derived through other systems having different purposes and different measurement accuracies.
The final step in flight track processing is the presentation of tracks on a topographical background, either in NMS or in WebTrak (Figure 7). No incorrect track presentation is found. The tracks at greater distances from the airport are verified via the positioning of tracks over beacons. Such beacons are used as navigational aids and can be found on charts published in an Aeronautical Information Publication (AIP). As an example, a chart showing the beacon located at Biggin Hill Airport is shown in Figure 8.

Figure 7 - Flight track visualisations on WebTrak background map

Figure 8 - Part of an AIP chart and WebTrak presentation showing the standard arrivals via BIGGIN

The relevant metrics in the context of this reports are the peak levels (LAmax) and the sound exposure levels (SEL). The noise models ANCON2 and INM are internationally accepted models (also by ICAO CAEP to be in accordance with ICAO Doc 9911) and considered to be best practice.

Based on the findings it is concluded that Heathrow's noise climate is assessed adequately, the models are used in a good manner and the results of these models are trustworthy. The main conclusions, per task are elaborated below.

1. Enable community stakeholders to be confident that the aircraft are at the heights and locations that the Heathrow systems indicate:

- NMS uses correct input data
- NMS produces correct flight tracks based on the data it receives
- No incorrect flight track presentation is found.

2. Enable community stakeholders to be confident that all operations from Heathrow are accounted for in the system and have correct flight attributes.

- 100% of the flights are available in NMS
- Not all (but 99.8%) operations were shown in WebTrak. Since the verification was conducted, system changes have been made to improve this.

3. Verify flight characteristics with respect to correct flight type, runway and aircraft type Flight data show correct attributes.

4. Assess whether there has been any historical change in the past 5 years, to the NMS or WebTrak systems, which may have altered the accuracy of the systems.

- Several changes are applied to system functionality as well as input data
- Although all changes are improvements, some of them led to changes in the results.

5. Verify that the noise models used by Heathrow are compliant with international standards and provide an accurate assessment of the noise climate.

The comparison of measured and calculated aircraft noise in the vicinity of Heathrow shows a good match.

Based on this finding and since the noise modelling is within the boundaries of 'best practice' (i.e. use of the models), the assessment of the noise climate of Heathrow by UK-CAA and Anderson Acoustics is considered to be done adequately.

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