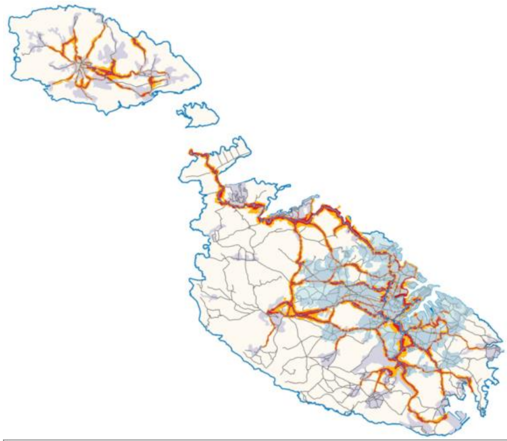
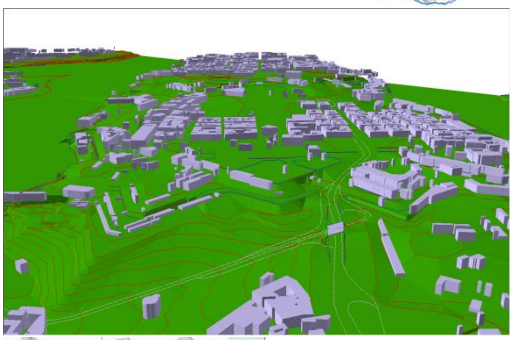
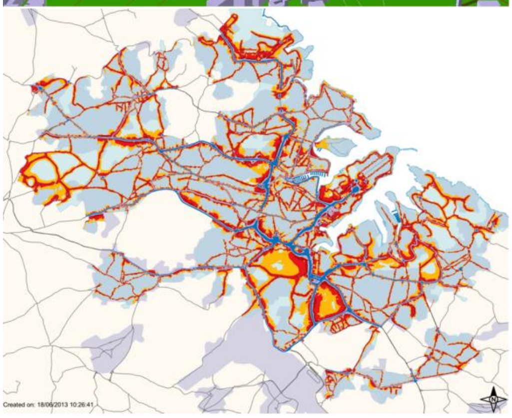
Final Report on

Measurement Methodology and Test Implementation for the Field Validation of the Strategic Noise Maps







For

Environment and Resources Authority

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December 2024

Report for

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Executive Summary

EC Directive 2002/49/EC relating to the assessment and management of environmental noise, commonly referred to as the Environmental Noise Directive (END), was established to pursue the Community objective to protect against the effects of environmental noise. The Directive is transposed separately in each Member state of the EU into local legislation. In Malta, the END is transposed by the *"Assessment and Management of Environmental Noise Regulations, 2004"*, L.N. 193 of 2004 (Regulations).

The underlying principles are:

- Monitoring the environmental problem;
- Informing and consulting the public;
- Addressing local noise issues; and
- Developing a long-term strategy.

And to that end three stages are set out:

- Undertake strategic noise mapping to determine exposure to environmental noise; this monitors the environmental problem by observing and collecting data;
- Ensure information on environmental noise and its effects is made available to the public; this is in line with the principle of the Aarhus Convention; and
- Adopt action plans, based upon the noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

Strategic noise mapping is required at 5 yearly intervals; the Regulations require the third round of maps to be reported to the EC by the end of December 2017, and the fourth round prepared by the end of June 2022. The Regulations require the Environment and Resources Authority to produce strategic noise maps for the main sources of environmental noise, i.e. major roads, major airports and agglomerations with a population of more than 100,000 persons.

Verification Process

This final report sets out the process developed, and implemented at five test sites, for verification of the strategic noise maps for road and aircraft noise sources, using real-time sound level monitoring or measurement results.

The overall verification process uses a noise measurement campaign based on real-time sound level monitoring to capture sound levels adjacent to road, industry and aircraft sources, and noise calculations for each of the measured situations as a means of undertaking verification of noise models developed for strategic noise mapping of Malta.

In order to develop robust models for the comparison study, it was necessary to capture simultaneous datasets for the dynamic behaviour of the noise sources (e.g. traffic flow, speed and %HGV for roads) and propagation conditions. The strategic noise maps developed previously were then used as the basis for a series of small models for the specific location around each of the measurement sites. Different versions of these models were then produced for each of the modelled situations, each representing a specific combination of meteo class and emission window, which include the captured dynamic source data and the meteo conditions actually experienced during the noise measurement campaign. These different model versions were described as meta-models of the original strategic noise model for the measurement location. This approach minimises the sources of uncertainty when comparing the modelled to measured situations.

The datasets containing the results of the noise measurement campaign were then analysed into stratified sets of results, with a view to creating a set of measurement periods where each set of results are consistent by time period, weather conditions and source emissions. This approach is in line with the IMAGINE WP1 final report and concepts in ISO 1996-2:2017.

A series of meta-models were developed within the noise calculation software for each of the sets of favourable measurement results. For each meta-model the baseline strategic noise map in the vicinity of the measurement locations was adapted to include the dynamic data captured alongside the noise measurement campaign. In order to ensure the noise calculation model aligns with the measured situation closely.

The next stage was to determine the level differences between the measured and calculated noise levels for each of the situation windows analysed. The level differences were presented in terms of average difference for all the studied scenarios for each location.

Test Implementation

To this end a noise campaign was undertaken in line with ISO 1996-2:2017 and ISO 20906 at the selected measurement locations. Measurement locations were selected with a view to minimising unwanted noise source, as the main objective of this campaign was to obtain the real contribution of the studied noise sources (roads or aircraft noise) at the measurement location.

Long-term measurements of up to two weeks continuous monitoring were undertaken at locations exposed to road and aircraft sources in order to verify the emission models used within the strategic noise mapping. Long-term measurements of to two weeks continuous monitoring were also undertaken at a number of noise sensitive premises to verify the receiver results of the strategic noise mapping.

During the measurement campaign, data was also captured on various dynamic aspects of the noise source and propagation conditions for use in the later comparison with the noise models. Data such as traffic flow, speed and % HGV for roads, aircraft overflights and meteorological conditions were monitored alongside the noise levels.

The measurement results have been analysed into stratified sets of results, determined by time period, weather conditions and source emissions. This approach is in line with the IMAGINE WP1 final report, and concepts in ISO 1996 and ISO 20906.

The stratified measurement results have been compared with noise calculation results based upon the strategic noise maps and the dynamic data captured during the noise measurement surveys.

Conclusions

This verification report sets out the background, discussion and methodology to verify the strategic noise maps for road traffic and aircraft. Long-term measurements of up to two weeks continuous monitoring were undertaken at locations exposed to road and aircraft sources and at a number of noise sensitive premises.

The analysis of the results and the comparison with the calculation results obtained from the strategic noise maps were undertaken in line with the approach within IMAGINE WP1 final report in order to present an assessment of the measured levels to compare with calculated levels for the monitored scenarios.

The stratified measurement results were then compared with noise calculation results based upon the strategic noise maps and the dynamic data captured during the noise measurement surveys. Any comparison between noise level measurements and calculated strategic noise mapping results can only provide a general indication of the level of confidence for the specific measurement locations, and even then, only if an uncertainty assessment is undertaken for each.

The results of the locations used for the test implementation show that all studied cases for roads at source exhibit level differences within a range of ±6.5 dBA compared to the measured noise levels. Similarly, the results for the locations exposed to aircraft noise, and for noise within a quiet area, have determined that the studied case shows a level difference within a range of ±6.5 dBA and ±13.1 dBA, respectively, in relation to the measured noise levels.

In the majority of cases, the average level differences are within the coverage of the 95% CI of the measured noise levels, and may therefore be considered as equivalent results. Overall, this represents an acceptable level of agreement between the strategic noise mapping and the measured noise levels. In two cases the level difference at the noise sensitive receptors falls outside the coverage area of the 95% CI of the measured noise levels, in both cases this is due to significant development of the road infrastructure in the intervening time between the basis of the strategic noise model and the field measurements. Following the test implementation, the methodology has been adapted to provide guidance where similar situations may arise in the future.

The results appeared to indicate a systematic bias in the overprediction of road traffic noise emissions when using the NMPB ’96 methodology. It is recommended that additional studies are undertaken with a view to establishing road surface correction factors for typical road pavements in Malta for use within the new common noise assessment methodology set out in Annex II of the END (CNOSSOS-EU), in order to help improve the correlation between calculated and measured noise levels and improve the overall accuracy of the strategic noise mapping.

Contents

1 Introduction

Directive 2002/49/EC, commonly referred to as the Environmental Noise Directive (END), requires Member States to undertake strategic noise mapping within major agglomerations, in the vicinity of major road and rail transport corridors and around major airports.

The aim of the Directive is:

> *"to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise".*

The underlying principles are[1]:

- Monitoring the environmental problem;
- Informing and consulting the public;
- Addressing local noise issues; and
- Developing a long-term EU strategy.

And to that end three stages are set out:

- Undertake strategic noise mapping to determine exposure to environmental noise; this monitors the environmental problem by observing and collecting data;
- Ensure information on environmental noise and its effects is made available to the public; this is in line with the principle of the Aarhus Convention[2]; and
- Adopt action plans, based upon the noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

The Directive does not set any limit value, nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the Member States and competent authorities, in the case of Malta this would be the Ministry for the Environment, Energy and Regeneration of the Grand Harbour (MEER) and Environment and Resources Authority (ERA).

The information on the results of the Strategic Noise Mapping assessment, and the proposal set out within the Action Plans, are reported to the EC to provide evidence to support the development of long-term EU strategy. This may include objectives to reduce the number of people affected and provides a framework for developing existing Community policy on noise reduction from sources.

The Directive defines noise mapping, strategic noise maps and action plans as:

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[1] *European Commission, The Directive on Environmental Noise*. Available from: http://ec.europa.eu/environment/noise/directive_en.htm [Accessed March 2019]

[2] Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters. Available from: https://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf [Accessed March 2019]

- 'noise mapping' shall mean the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, the number of people affected in a certain area, or the number of dwellings exposed to certain values of a noise indicator in a certain area;
- 'strategic noise map' shall mean a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area;
- 'action plans' shall mean plans designed to manage noise issues and effects, including noise reduction if necessary.

The END requires Member States to produce strategic noise maps for the main sources of environmental noise, i.e. major roads, major railways, major airports and agglomerations with a population of more than 100,000 persons.

The Directive is transposed separately in each Member state of the EU into local legislation. In Malta, the END is transposed by the *"Assessment and Management of Environmental Noise Regulations, 2004"*, L.N. 193 of 2004 (Regulations). The Regulations were made by the Minister for Rural Affairs and the Environment under the Environmental Protection Act, 2001 (CAP. 435), subsequently amended in 2005. Following the passing of CAP 504, *Environment and Development Planning Act*, 2010, the regulations were subsequently renumbered as Subsidiary Legislation 504.63 of 2007, *Assessment and Management of Environmental Noise Regulations*, 2004.

The Regulations state that the designated competent authority for the making of strategic noise maps, the publication of information on environmental noise, and the drawing up on action plans, is the Malta Environment and Planning Authority (MEPA)[3]. The Minister responsible for the environment retains the power to designate other bodies or persons as the competent authority for different provisions and different purposes of the Regulations.

Responsibility for the environment now resides with the Ministry for the Environment, Energy and Regeneration of the Grand Harbour (MEER). The Environment & Resources Authority (ERA) was established following the passing of CAP 549 *Environment Protection Act*, 2016, and has been designated as the competent authority under the environmental noise regulations.

Mapping is required at 5 yearly intervals, with the first round of maps reported at the end of 2007, and the second round were reported at the end of 2012 in respect of the 2011 calendar year.

Article 7(5) of the END states that:

> *"The strategic noise maps shall be reviewed, and revised, if necessary, at least every 5 years…"*

Resulting information based upon the maps e.g. population exposure, coverage statistics and quality information are to be supplied to the European Commission (EC) using the recommended reporting templates developed by the European Environment Agency (EEA) and published on the EIONET Reportnet 3.0.

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[3] Article 4

1.1 Approach

The approach set out below was developed from the Consultants experience during Round 1, Round 2 and Round 3 of the Directive implementations, and our understanding of the current situation with regards to the requirements of the stakeholders and ERA.

The approach proposed sets out to deliver the main objectives of the project, which were:

1. Develop a methodology for validation of strategic noise mapping results through field survey measurements of noise;
2. Train ERA personnel on the methodology developed;
3. Test implementation of the methodology at six locations exposed to noise, as identified by the R3 strategic noise maps;
4. Report on the methodology developed and the results from the six test locations.

The approach has provided ERA with a robust methodology for long term monitoring of environmental noise based upon current standards and best practice, and a methodology for comparison of measurement results with calculated results derived from the strategic noise mapping.

The approach has included training of ERA personnel and extensive support to ERA personnel during implementation of the methodology at six locations, which helped to tune the methodology to the practicalities of the situation, the ERA equipment and the ongoing requirements of ERA.

The methodology for validation of strategic noise mapping results is set out in the following sections of this report, and was used as the basis for the training of ERA personnel delivered under the project.

2 Background

2.1 *Overview of Verification*

Prior to discussing the verification of strategic noise maps, it is first considered relevant to present a number of references considered relevant to the subsequent discussion and proposed approach.

2.1.1 ISO 9001:2005

ISO 9001: 2005 defines verification:

> *"Verification is a process. It uses objective evidence to confirm that specified requirements have been met. Whenever specified requirements have been met, a verified status is achieved.*
>
> *In the context of this standard, the term verification is used in at least two different situations: design and development and purchasing. Design and development verifications use objective evidence to confirm that design and development outputs meet specified input requirements. Similarly, objective evidence must be used to verify or confirm that purchased products meet specified purchasing requirements.*
>
> *There are many ways to verify that requirements have been met. For example, you could do tests, perform demonstrations, carry out alternative calculations, compare a new design specification with a proven design specification, or you could inspect documents before you issue them."*

2.1.2 ISO 14064-3:2006

ISO 14064-3:2006 defines verification as follows:

> *"Systematic, independent and documented process for the evaluation of a greenhouse gas assertion against agreed verification criteria."*

With verification criteria defined as:

> *"Policy, procedure or requirement used as a reference against which evidence is compared."*

2.1.3 WG-AEN GPGv2

Section 2.03 of the WG-AEN Good Practice Guide v2 discusses the role of noise measurement as follows:

> ***Issue***
>
> *In Annex II (1) it is stated that (for the purpose of strategic noise mapping) values of Lden and Lnight can be determined either by computation or by measurement (at the assessment positions) and that for prediction, only computation is applicable.*
>
> ***Discussion***
>
> *To carry out the strategic noise mapping required by the END by measurement is problematic as it is generally impractical to measure at a sufficient number of*

positions for a sufficiently long period of time to be representative of an average year over the large areas involved with sufficient degree of resolution. Also, the results so obtained cannot be used to predict the effects of proposed action plans (see also section 2.02).

However, noise measurements may be used to validate noise maps at selected sites, boost public confidence in these maps, help develop detailed action plans and to show the real effects of action plans once they are implemented.

Noise measurements may also be needed to determine emission levels or base levels to be extrapolated by calculation, for example, from industrial processes.

WG-AEN's Recommendations

WG-AEN recommends that wherever possible strategic noise mapping should generally be carried out by computation. However, it is recognised that noise measurement has many supplementary roles to play in the effective implementation of the END.

2.1.4 IMAGINE WP1 Final Report

Deliverable 8 from the IMAGINE project was *"Guidelines and good practice on strategic noise mapping"*, IMA01-TR22112006-ARPAT12, Section 6.4 discusses quality assurance by measurement:

Direct measurement can be employed to support the credibility of calculations, to validate calculations in well-defined situations and to assess situations not properly covered, or believed not to be properly covered, by the available prediction model and, generally, to ensure the quality of noise mapping project. However, due to the effort necessary to achieve accurate results, measurements are not suitable for large scale assessment.

In order to perform measurement validation, WP3 described an operational procedure [IMAGINE Report IMA32TR-040510-SP08 "Determination of Lden and Lnight using measurements"] that can be used to determine Lden and Lnight, as defined by the European directive 2002/49/EC. Indeed, such a result is usually not attainable by direct measurement; the measurement results often have to be combined with some calculations in order to correct for "reference" operating or propagation conditions differing from those during the actual measurement. In each case the long-term equivalent sound pressure level is calculated by taking into account the frequency of occurrence of the different sources operating and sound propagation conditions. According to the proposed method, the measurement uncertainty has to be determined and reported in each case.

The indicators introduced by the END pose new difficulties in direct measurement of noise levels. WP3 addressed those issues with some hints on how to treat separation of different noise sources and separation between incident and façade reflected sound.

Most of the power of the test methods relies on their flexibility to adapt to different situation; even in cases where direct measurement is not feasible, test methods combine measurements and calculations to deliver a reliable evaluation of the real noise at the assessment location. Test methods provide no specific requirement on *accuracy but let the user determine the measurement effort in consideration of the requested uncertainty level.*

Noise levels indicators Lden and Lnight determined by means of measurements are directly comparable with noise levels obtained by numerical models. When both the measured and the calculated noise levels are accompanied by uncertainty specifications, statistical analysis of significance can be applied. This provides an objective criterion for evaluating the quality of the calculated noise map; i.e. the conformance of the calculated noise levels to the expected degree of accuracy.

2.2 Discussion on Verification of Strategic Noise Maps

Since the END was proclaimed, there has been extensive discussion regarding subjects such as "methods", "software packages", "validation" and "verification". Before discussing any approach to verification of the strategic noise mapping process, it is important to distinguish between different noise prediction methods, and the software packages that implement the methods, and the results obtained during measurements.

In most studies, the term "method" refers to the set of calculation algorithms that describe the source emission or propagation of sound, and the term "software package" refers to the computer software that implements the methods. It is not uncommon for some prediction methods to be implemented in several software packages, and for some software packages to implement several methods. The term "validation" can be defined as an accuracy-test of noise prediction methods and/or the software implementations of them, while the "verification" of the strategic noise maps can be defined as a test for whether the delivered strategic noise maps meet the requirements of the user or any defined quality criteria. It is important to recall that, due to the above definitions, during verification of the strategic noise maps the whole mapping process is under assessment.

Most popular approaches to the verification of strategic noise maps are so called "short-term" studies that are usually conducted in a small number of areas. The number of such areas are in most cases dependent upon various factors (sources interaction, population density, terrain morphology etc..), and there are attempts to representatively distribute measurement locations across the large territory that has been mapped.

Noise levels are usually measured using type 1 sound level meters with an outdoor microphone kit, placed at a height of 4m above the underlying terrain. Noise levels should normally be measured in accordance with:

- ISO 1996-1:2016 Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures;
- ISO 1996-2:2017 Acoustics -- Description, measurement and assessment of environmental noise -- Part 2: Determination of environmental noise levels.

As a basis for comparison, the noise calculation model should include all the details necessary to undertake an assessment of the noise emission and propagation present during the measurement period. These aspects include topographical information, relative heights of the buildings and obstacles, distances between the sources and receivers, relative aspects to any other obstacles.

In the case of verification of the strategic road traffic noise maps, it is necessary to collect information about traffic data to within ±15%. It would also be required to use traffic measurement instruments for measuring volume, flow, speed and composition of traffic. The German method, for example, strictly recommends not conducting road traffic noise measurements during weekends, school and public holidays, or between 00:00 and 04:00 hours.

In order to verify the status of the upwind or downwind conditions it is necessary to perform the noise measurements at the same time as measuring the air temperature, relative humidity, wind speed and direction, at two different heights (0.5 and 10 m). The average wind direction shall be in the interval ± 60 degrees around the normal from the road through to the microphone position. The effective source-receiver distance shall be determined along the bi-sector of the angle between the average wind speed vector and the normal from the road to the microphone position; see Figure 2.1.

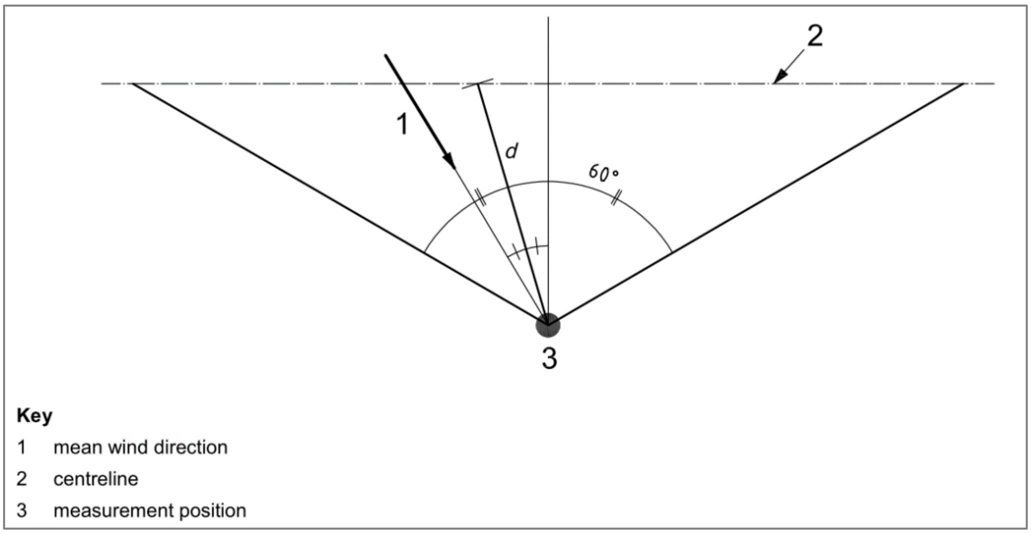

Figure 2.1: Favourable propagation conditions from a road and the effective source-receiver distance, d

Due to the requirement to synchronise the noise measurements with meteorological data collection detailed steps are required to ensure the time clocks on the various measurement devices are aligned, or alternatively a centralised computer system could be used. In order to estimate the annual average situation, the results should then be stratified into sets, such as periods with different wind conditions, taking care to include separate results when the wind was blowing from the road to the receiver from those when it was blowing from the receiver to the road. At the end of each measurement interval, the ISO 1996 standard recommends that certain information needs to be recorded and reported:

a) time, day and place for measurements;
b) instrumentation and its calibration;
c) measured and, if relevant, corrected sound pressure levels (L_{eqT}, L_E, L_{max}), A-weighted and, optionally, in frequency bands;
d) measured N percent exceedance level ($L_{N,T}$) including the base on which it is calculated (sampling rate and other parameters);
e) estimate of the measurement uncertainty together with the coverage probability, typically the 95 % confidence interval is used;
f) information on residual sound pressure levels during the measurements;
g) time intervals for the measurements;

h) thorough description of the measurement site, including ground cover and condition, and locations, including height above ground, of microphone and source;
i) description of the operating conditions, including number of vehicles/aircraft pass-bys specified for each suitable category;
j) description of the meteorological conditions, including wind speed, wind direction, cloud cover, temperature, barometric pressure, humidity and presence of precipitation and location of wind and temperature sensors;
k) method(s) used to extrapolate the measured values to other conditions.

Using the models developed for the strategic noise mapping as a basis, and the data captured during the measurement campaign, it is then possible to compare the measured noise levels with those produced by the noise model. The actual situation during the measurement campaign should be used and the uncertainty in both the measured and calculated levels should be estimated.

The uncertainty in the measured results may be assessed using the approaches set out in the relevant ISO standards, whilst the uncertainty of the calculated noise models is more difficult to determine as this area is not yet sufficiently investigated to provide suitable uncertainty factors for each step in an approach in line with the Guide to the Expression of Uncertainty in Measurement (GUM), 1995.

The diagram of uncertainty, Figure 2.2 below, illustrates that the uncertainty in the calculated noise levels is a combination of a number of different sources of uncertainty, including:

- Noise calculation methodology;
- Input data quality and sensitivity of the methodology to those uncertainties;
- Implementation of the noise calculation method into the software; and
- User defined calculation settings in the software.

At present the best approach is to undertake the calculations using the static model data from the strategic noise maps, and the dynamic model data captured during the monitoring campaign, as a basis for comparison. This is in line with the recommendation of the IMAGINE WP1 report, and also the Defra research on uncertainty, NANR93, as illustrated in Figure 2.2 below.

Strategic noise mapping under the END, and the Maltese Regulations, aims to give a representation of noise across the area being mapped, expressed as an annual average situation to help form the basis of a long-term exposure to noise. It does not aim to represent a worst-case scenario, as typically used for environmental impact assessments (EIA), or for a specific day or specific weather condition. For this reason, as discussed within the IMAGINE Report, it is not practical to undertake annual real time noise level measurements of the situation represented within the strategic noise maps of the annual average situation.

Any comparison between noise level measurements and calculated strategic noise mapping results can only provide a general indication of the level of confidence for the specific measurement locations, and even then, only if each is assessed in terms of uncertainty.

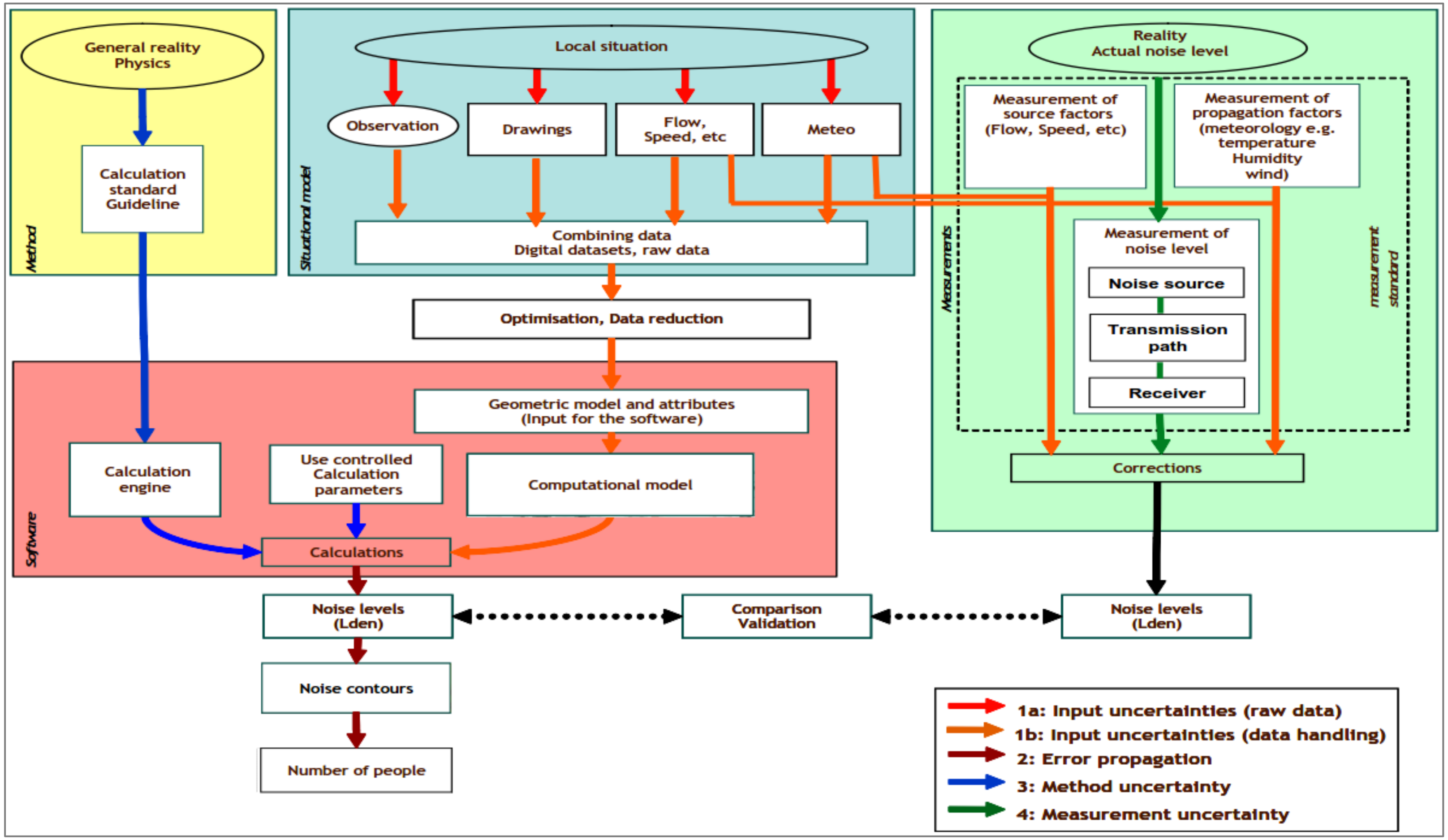

Figure 2.2: How different types of uncertainties are inter-related to each other (NANR93)

3 Measurement Locations

The first stage of the process is to identify suitable measurement locations, which may be used as the basis of the verification process. The following provides an overview of the proposed approach to identify measurement sites, and an overview of the field measurement campaigns to be undertaken.

3.1 Road Traffic Noise Source

For verification of the road traffic noise emission model, XPS 31-133 Interim, as implemented in the software used for the strategic noise mapping, real time noise measurements will be undertaken at locations alongside mapped sections of the road network as follows:

- Measurement locations are selected near to real time traffic counting device, or where a real time traffic counter may be installed for the duration of the measurements, to undertake continuous real time noise and meteorological measurements for 7 days:
- Sound level measurements will be in octave bands from at least 63 Hz to 8 kHz;
- These will be analysed into average 1-week L_{day}, $L_{evening}$ and L_{night} period data, and where necessary stratified into different weather-related sets;
- Extraneous noise will be removed from the measured data, as discussed within the IMAGINE report;
- Actual traffic count data logged during the noise measurement period will be collected using real time traffic counters and the data analysed into 30-minute datasets coinciding with the measurement data; and
- The measurement locations will be modelled in the noise mapping software using the actual meteo and traffic count data collected during the measurement program.

The dominant sound source at the selected sites should be road traffic noise from the road for which traffic counting is being undertaken. Extraneous and residual sound from other sources should be 10 dB(A) below the noise from the road of interest. The measurement site should have an unscreened view of the road being measured, and be clear of any near vertical reflecting surfaces by at least 5m.

The precise locations will be confirmed after a number of possible suitable locations have been identified by ERA and the Consultants.

3.2 Industry Noise Source

For verification of the industry noise emission model used for the strategic noise mapping, real time noise measurements according to ISO 1996 will be undertaken at locations alongside the mapped industrial noise sources as follows:

- Locations around the perimeter of each modelled area noise source are selected to undertake real time noise and meteorological measurements in line with the approach set out within ISO 1996:
  - Sound level measurements will be in octave bands from at least 63 Hz to 8 kHz;
  - These will be analysed into average L_{day}, $L_{evening}$ and L_{night} period data, and where necessary stratified into different weather-related sets;
  - Extraneous noise will be removed from the measured data, as discussed within the IMAGINE report.

The dominant noise source at the selected measurement sites should be industrial noise from the area source of interest. Extraneous and background noise from other sources should be 10 dB(A) below the noise from the industry source of interest. The measurement site should have an unscreened view of the industrial area being measured, and be clear of any near vertical reflecting surfaces by at least 5m.

The precise locations will be selected after the industry sources are confirmed with the beneficiaries, and suitable locations have been identified.

3.3 Aircraft Noise Source

For verification of the aircraft noise emission model, ECAC Doc. 29, used for the strategic noise mapping, real time noise measurements will be undertaken at locations alongside operational mapped sections of Malta international airport as follows:

- Continuous real time noise measurements are undertaken at locations alongside operational flight paths, along with continuous real time meteorological measurements, for 3 days:
  - Sound level measurements will be in octave bands from at least 63 Hz to 8 kHz;
  - These will be analysed into average 3 day L_{day}, $L_{evening}$ and L_{night} period data, and where necessary stratified into different weather related sets;
  - Extraneous noise will be removed from the measured data, as discussed within the IMAGINE report;
  - Noise measurement data will be used to identify the aircraft overflights, and cross referenced against the actual flight data from MIA/MATS in order to identify the aircraft type for each overflight;
  - The measurement location will be modelled in the noise mapping software using the actual meteo and aircraft movement data collected during the measurement program.

The dominant noise source at the selected sites should be aircraft noise from the specific flight path being measured. Extraneous and background noise from other sources should be 10 dB(A) below the overflight noise levels from the aircraft of interest. The measurement sites should have an unscreened view of the aircraft being measured, and be clear of any near vertical reflecting surfaces by at least 5m.

The precise locations will be confirmed after a number of possible suitable locations have been identified by ERA and the Consultants.

3.4 Noise Exposure at Sensitive Buildings

For verification of the calculated strategic noise mapping results at noise sensitive buildings, real time noise measurements are undertaken at the most exposed facades of noise sensitive buildings exposed to road, railway, industry and aircraft noise:

- Measurements are undertaken at the most exposed facades of noise sensitive buildings exposed to road traffic noise, industry noise and aircraft noise in the vicinity of the measurement locations used for the respective source noise level measurements. On the basis of the microphone position (free field, semi free field, microphone on façade), appropriate corrections will be applied.

- Locations are selected to undertake continuous real time noise and meteorological measurements for 7 days for road noise, and 3 days for industry and aircraft noise:
    - Sound level measurements will be in octave bands from at least 63 Hz to 8 kHz;
    - These will be analysed into average 3 day L_{day}, $L_{evening}$ and L_{night} period data and where necessary stratified into different weather related sets;
    - Extraneous noise will be removed from the measured data, as discussed within the IMAGINE report;
    - Actual traffic count data during the noise measurement period will be collected from the real-time traffic counters, or MIA/MATS for the airport;
    - Actual noise emission measurements of the industry sources will be undertaken during the noise measurement period;
    - The measurement locations will be modelled in the noise mapping software using the actual meteo and road traffic count data collected during the measurement program.

The dominant noise source at the selected sites should be road traffic, industry or aircraft noise, from the relevant source for which data is available during the measurement period. Extraneous and background noise from other sources should be 10 dB(A) below the noise from the sources of interest during a measurement event. The measurement sites should have an unscreened view of the source being measured, and be clear of any near vertical reflecting surfaces by at least 5m, other than the receptor point's self-facade.

The precise locations will be confirmed after a number of possible suitable locations have been identified by ERA and the Consultants.

4 Methodology

Set out below is an overview of the methodology developed to undertake the verification procedure. It includes the approach to be used for the noise measurement campaign, the development of the noise calculation models and the verification process. The outputs of the measurement campaign and noise modelling are to be compared within the verification procedure using statistical analysis alongside an assessment of uncertainty.

4.1 Verification process

The overall verification process uses a noise measurement campaign based on real-time sound level monitoring to capture sound levels adjacent to road, industry and aircraft sources, and noise calculations for each of the measured situations as a means of undertaking verification of noise models developed for strategic noise mapping of Malta. The workflow of the overall verification process is summarised in Figure 4.1 below.

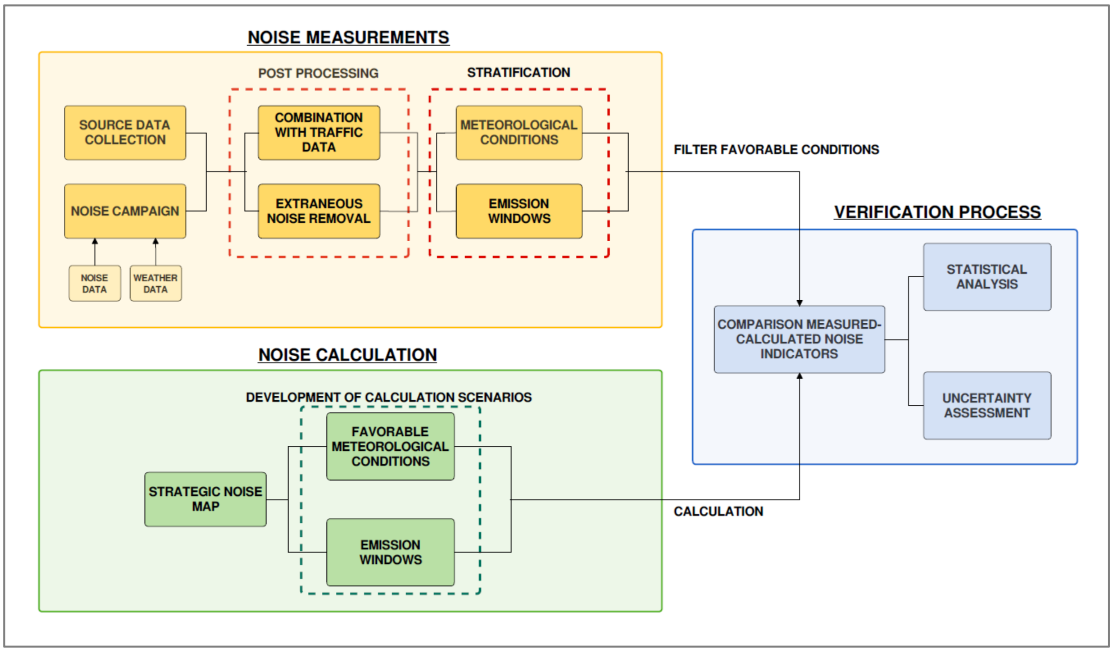

Figure 4.1: Overview of verification process

The measurement campaign includes simultaneous collection of noise level measurements, dynamic noise source data and meteorological conditions. The noise level measurements are undertaken in line with ISO 1996-2:2017 at each of the selected locations adjacent to the noise sources or near the receiver locations. The main objective of this campaign is to obtain the real contribution of the specific noise sources under investigation (roads, industry or aircraft noise) whilst attempting to minimise the influence of extraneous ambient noise.

In order to develop robust models for the comparison study, it is necessary to capture simultaneous datasets for the dynamic behaviour of the noise sources (e.g. traffic flow, speed and % HGV for roads) and propagation conditions. The strategic noise map developed previously is then used as the basis for a series of small models for the specific location around each of the measurement sites. Different versions of these models were then produced for each of the modelled situations, each representing a specific combination of meteo class and emission window, which include the captured dynamic source data and the meteo conditions actually experienced during the noise measurement campaign. These different model versions were described as meta-models of the original strategic noise model for the measurement location. This approach minimises the sources of uncertainty when comparing the modelled to measured situations.

The datasets containing the results of the noise measurement campaign are then analysed into stratified sets of results, with a view to creating a set of measurement periods where each set of results are consistent by time period, weather conditions and source emissions. This approach is in line with the IMAGINE WP1 final report and concepts in ISO 1996-2:2017.

Each of the 30-minute measurement periods are to be assigned to one of four meteorological windows, in line with ISO 1996-2, namely:

- M1 – Unfavourable
- M2 – Neutral
- M3 – Favourable
- M4 – Very favourable

Within each meteorological class, the measurement periods are then grouped together to collect a set with consistent source emissions, typically using a 2 dB-wide emission window. Figure 4.2 shows a typical outcome of this stratification process for one of the measurement locations, with results grouped into meteo classes and emission windows.

AG01_ROAD_L18_NSC01 - Leq_{30min} (dBA)				
Emission windows	Meteo classes			
	M1	M2	M3	M4
E1	51,3	--	--	45,7
E2	52,5	--	--	47,9
E3	53,1	--	--	50,0
E4	53,7	--	--	52,8
E5	55,6	58,4	--	55,4
E6	57,1	56,9	--	56,6
E7	61,9	62,7	--	--

Figure 4.2: Example of stratification of measurement data

As the noise calculations methods used within the models generally have an underlying presumption of favourable propagation, the measurement results obtained under favourable conditions (M3/M4 classes) are selected as the basis of the comparison. For example, the six entries under the M4 meteo class in Figure 4.2 would become six scenarios used for the basis of the comparison between measured and calculated results.

A series of meta-models are developed within the noise calculation software for each of the sets of favourable measurement results, e.g. the six examples under M4 in Figure 4.2. For each meta-model the baseline strategic noise map in the vicinity of the measurement locations is adapted to include the dynamic data captured alongside the noise measurement campaign. In order to ensure the noise calculation model aligns with the measured situation closely, the following steps are advised where possible:

- The configuration of the software is modified to calculate the noise levels under favourable conditions of propagation (measurements situation);

- The noise model is aligned with the reality of the measurement situation where possible, including confirming that road surface type, buildings, barriers, ground absorption etc which are present during the measurements are correctly included within the model;
    - Where any differences are found between the strategic noise models and the situation identified through the field surveys, it is recommended that the noise models are updated within the calculation model used for the verification work in order to more closely align with the real-world situation.
- The measured and calculated noise levels should include reflections in a similar manner, either including the influence of reflections in both cases or considering only incident noise. Consideration should be given at each location as to whether corrections are to be applied to the results at each measurement location, or whether the configuration of the noise prediction software needs to be changed;
- The location of each receiver within the noise model is confirmed to be at the same location as the sound level meter, including the distance to reflectors and the main noise sources;
- The dynamic parameters of each noise source are adapted in each meta-model to match the values captured during each defined emission window in order to establish each of the scenarios for the comparison; and
- Any known variations between the monitored situation and the modelled scenario are noted and reported as part of the discussion on the outcome of the verification process.

As discussed in Section 2 above, any comparison between noise level measurements and calculated strategic noise mapping results can only provide a general indication of the level of confidence for the specific measurement locations, and even then, only if each is assessed in terms of uncertainty assessment.

4.2 Noise calculation model

Under the European Environmental Noise Directive 2002/49/EC (END) and the Maltese Regulations the method of assessment to be used for road and railways traffic noise, industrial noise and aircraft noise sources are set out. The methods of assessment to be used are:

- **Roads:** EC Recommended Interim Method
    - The adapted version of French national computation method to be used as described within the following documents:
        - 'NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB)', referred to in 'Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Officiel du 10 mai 1995, Article 6';
        - French standard 'XPS 31-133', plus;
        - Commission Recommended Adaptations from 2003/613/EC; and
        - The source noise levels used within the calculations should be derived via a methodology in line with the WG-AEN GPGv2.
- **Industry:** EC Recommended Interim Method
    - ISO 9613 Interim is described within the following documents:

  - ISO 9613-2: 'Acoustics — Abatement of sound propagation outdoors, Part 2: General method of calculation', plus;
  - Commission Recommended Adaptations from 2003/613/EC; and
  - The source noise levels used within the calculations should be derived via a methodology in line with the WG-AEN GPGv2 Toolkit 10.

- **Aircraft:** The method of assessment including the recommended adaptations is referred to as ECAC Doc 29 Interim.

  - ECAC.CEAC Doc. 29 'Report on Standard Method of Computing Noise Contours Around Civil Airports', 1997. Of the different approaches to the modelling of flight paths, the segmentation technique referred to in section 7.5 of ECAC.CEAC Doc. 29 will be used. Which should be used in accordance with the adaptations set out in:
    - Commission Recommendation 2003/613/EC of 6 August 2003, which acknowledges the revision of Doc. 29 and suggests using the updated Doc. 29 after release by ECAC, provided this is "appropriate and considered necessary".

The time periods used in the computation of noise calculation were as follows for railways, industry and aircraft noise:

- Day Time – 07.00 to 19.00
- Evening Time – 19.00 to 23.00
- Night Time – 23.00 to 07.00

The configuration of road traffic and industry noise models are to be adapted to represent the noise influence of roads for intervals of 30 minutes.

The strategic noise models only represent the main roads/industrial plants or aircraft operations within the study area on the basis that they are the primary contributors to the environmental noise at the measurement positions. This criterion is consistent with the requirement for low background noise levels during the selection of the measurement locations.

The different emission conditions are implemented in the noise models by means of a series of meta-models where different variants were produced with the source emission (roads, industry and aircraft) changed according to the data captured during the measurement window, as follows:

- **Road traffic noise:** for each meta-model the road traffic source input data and meteorological data is edited to match the data captured during each measurement window being modelled;
- **Aircraft noise:** The meta-models are established by defining the aircraft types, number of aircraft overflights and routes in use during the on-site measurements.

4.3 *Verification process*

The next stage is to determine the level differences between the measured and calculated noise levels for each of the situation windows analysed. The level differences are presented in terms of average difference for all the studied scenarios for each location, according to the following expression:

$$Level\ difference\ [D_j] = \frac{\sum_{i=1}^{n}(L_{Aeq,calculated,i} - L_{Aeq,measured,i})}{n}$$

Where:

- D_j is the average difference between measured and calculated values for location j.
- $L_{Aeq,calculated,i}$ is the calculated noise level for the scenario i of location j.
- $L_{Aeq,measured,i}$ is the measured noise level for the scenario i of location j.
- n is the total number of evaluated scenarios for location j.

All average level differences are calculated considering equally the noise indicators for day, evening and night periods (arithmetic average of these values). Positive values of D parameter represent an overestimation, i.e. the calculated level is higher than the measured level, whilst negative values represent an underestimation, i.e. the calculated level is lower than the measured level.

4.4 *Measurement Uncertainty*

Any measured value (noise indicator in this case) should be expressed along with the associated uncertainty of the applied methodology of measurement with a chosen coverage probability. Standard ISO 1996-2:2017 describes the uncertainty of sound pressure level measurements which are dependent on the sound source and the measurement time interval, the weather conditions, the distance from the source and the measurement method and instrumentation. The verification results are to be expressed as L ± 2U (L is the measured value; U is the combined standard uncertainty considering a coverage probability of 95% by convention). This means that the real value would be within the range [L – 2U, L + 2U] with a 95% confidence interval (CI).

If the 95% CI of the measured levels, for each type of measurement situation, is applied to the average level difference determined for the same situation, it may be concluded that the calculated noise levels are all within the 95% CI of the measured noise levels for each situation, as illustrated by the example data in in Figure 4.3 below.

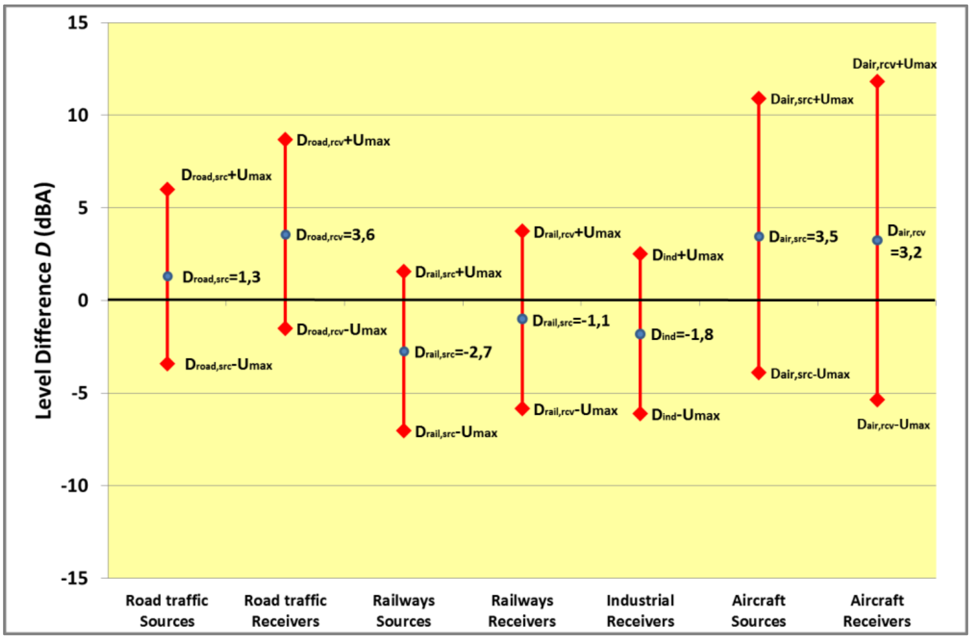

Figure 4.3: Example of the overall level difference from a verification process for road, railways and industry noise considering 95% of coverage probability

4.5 *Calculation Method Uncertainty*

WG-AEN GPGv2 considers model uncertainty as a combination of the ability of the calculation methodology to replicate the real-world situation and the ability of the noise calculation software to completely and unambiguously implement the methodology without additional uncertainty being introduced.

The adapted EC recommended Interim Methods set out within Annex II of the END are engineering methods developed during the 1980s and 1990s ahead of the development of the END. These engineering methods provide a simplified version of real-world sound propagation in order to provide a solution which may be applied to the majority of reasonably simple situations without undue complexity. By their nature they do not provide a full analytical solution for all possible real-world situations, and as such some discussion about potential conflicts with the monitored locations is considered appropriate.

4.5.1 Road traffic noise calculations

The adapted version of French national computation method applied to the calculation of road traffic noise presents some limitations when the speed of the traffic flow is very low, and the emitted sound power of the vehicles depends on the load of the engine. Although the method incorporates some additional corrections for the lower speed range (lower than 60-70 km/h), all speeds below 20 km/h are set to 20 km/h. For this reason, the calculated noise levels will become inconsistent with the measured values exposed to congested roads. If possible, this situation should be avoided during site selection, however if it occurs during the measurement campaign the effects should be identified and either removed from the analysis, or the additional uncertainty estimated.

4.5.2 Aircraft noise calculations

The noise calculation model used for the aircraft movements at MIA is completely aligned with the requirements of the ECAC Doc 29; 3rd Edition, however as an engineering method it has intrinsic limitations taking into account non-flat or urban areas, and the different ground reflections and diffractions they introduce. This implies that calculated noise levels in non-flat, hard ground or urban areas are to be treated with caution and may possibly result in high level differences.

The documentation for the ECAC Doc 29; 3rd Edition calculation method "emphasises" some possible differences in measured and predicted values with the main causes being ground cover effects, lateral attenuation and lateral screening. Apart from the aircraft flight profiles, ground surface and atmospheric conditions, local factors including topography and ground cover may have significant effects upon contours in certain circumstances and may sometimes warrant special treatment. Although it is normally disregarded, the built environment around an airport will also influence the amount of noise received locally, especially from aircraft on runways. Theoretically, receiver height above the surface has an influence on lateral attenuation; however over soft ground in real non-uniform atmospheres, the effect on event levels is small. Lateral attenuation significantly affects sound propagating at acute angles to the ground surface. It is largely caused by interference between directly radiated sound and reflection from the ground surface - which depends on the angle of sound incidence, ground properties and receiver height. As the geometry of sound reflection is influenced by refractions caused by wind and temperature variations, it means that attenuation is difficult to model theoretically.

Lateral attenuation is a reflection effect, due to interference between directly radiated sound and that which reflects from the surface. It depends on the nature of the surface and can cause significant reductions in observed sound levels at low elevation angles. It is also very strongly affected by sound refraction, both steady and unsteady, caused by wind and temperature gradients and turbulence, which are themselves attributable to the presence of the surface. The mechanism of surface reflection is well understood and, for uniform atmospheric and surface conditions, it can be described theoretically with some precision. However, atmospheric and surface non-uniformities - which are not amenable to simple theoretical analysis - have a profound effect on the reflection effect, tending to 'spread' it to higher elevation angles; thus the theory is of limited applicability.

5 Scope of Verification Plan

Verification of the strategic noise maps developed for roads and aircraft was to be undertaken using real-time sound level monitoring or measurement results. In addition, the noise calculation model was to be validated for a low noise exposure level, through real-time sound level monitoring in a quiet area.

An overview of the scope of the Verification Plan is described and includes the locations used for the noise measurements, previously selected by ERA with support from the Consultants. Complete and detailed description of the measurement locations is included in the Appendices of this report.

5.1 Road Traffic Noise Source

For verification of the road traffic noise emission model, XPS 31-133 Interim, as implemented within the software used for the strategic noise mapping, real time noise measurements were undertaken at locations alongside mapped sections of the road network as follows:

- Measurements were undertaken along major roads in the Malta noise agglomeration and the major road network across Malta;
- Four sites were selected, at each location real time traffic counting and continuous real time noise and meteorological measurements were undertaken for at least one week; At each location the measurements were undertaken in the vicinity of the road under study (source location). At two locations, for Location Codes 1 and 3, measurements were also undertaken at a distance away from the source to assess exposure at the facades of noise sensitive buildings most exposed to road traffic noise (receiver location).
- The environmental noise was evaluated at four meters above local ground.

The locations were identified and selected by ERA with support from the Consultants and are identified in Figure 5.1 and Table 5.1 below.

Table 5.1: Identification of road traffic noise locations

Location Code	Place	Coordinates (E/N) WGS 84
1	Triq Għar Dalam, Birżebbuġa	35.836485, 14.528402
2	Rue D'Argens, Gżira	35.904751, 14.492737
3	Marsa-Ħamrun Bypass, Ħamrun	35.882810, 14.481400
4	Triq Ix-Xatt, Msida	35.895833, 14.489910

Figure 5.1: Road traffic noise measurement locations

5.2 *Noise within Quiet Areas*

For verification of the low noise levels calculated within the noise calculation model, real time noise measurements were undertaken. The assessment took into account the noise propagation standard, which is incorporated in the modelling software, XPS 31-133 Interim, as follows:

- Continuous real time noise measurements were undertaken for seven days in a quiet area where noise from road traffic is very low.
- The environmental noise was evaluated at four meters above local ground.
- The chosen location is also a potential candidate location for the designation of a quiet area within the agglomeration in view of its amenities, being an open green space within a public garden.

The location was identified and selected by ERA in consultation with the Consultants and is identified in Figure 5.2 and Table 5.2 below.

Table 5.2: Identification of the potential quiet area location

Location Code	Place	Coordinates (E/N) WGS 84
5	Il-Park ta' San Klement, Triq il-Kunsill tal-Ewropa, Żabbar	35.878336, 14.528883

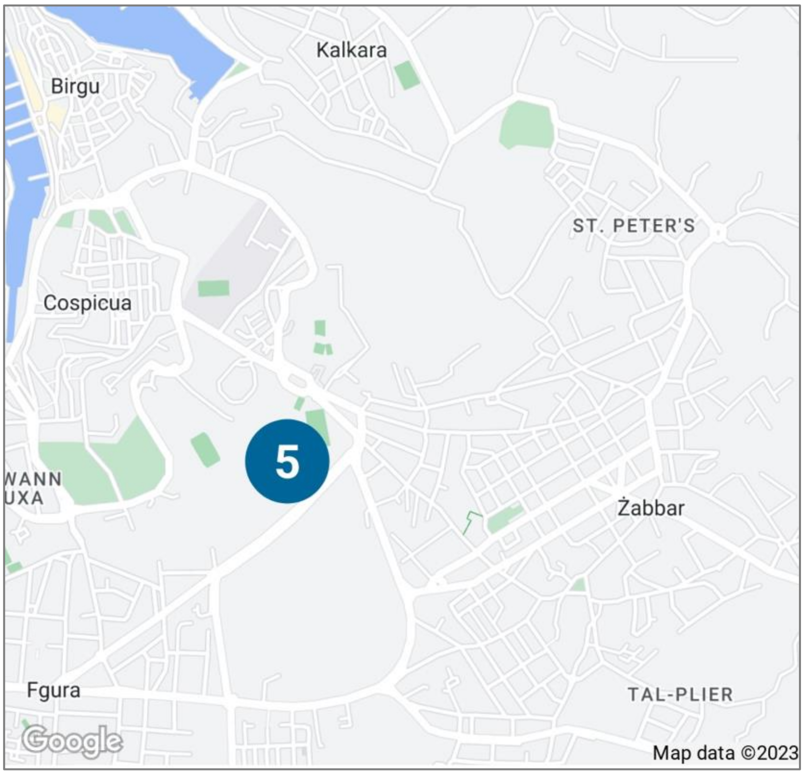

Figure 5.2: Location of the potential quiet area

5.3 Aircraft Noise Source

For verification of the aircraft noise calculation model, ECAC Doc. 29, as implemented within the software used for the strategic noise mapping, real time noise measurements were undertaken at a location alongside Malta International Airport as follows:

- Continuous real time noise measurements were undertaken for 10 days at one location exposed to operational flight paths, alongside continuous real time meteorological measurements;
- Noise measurement data was used to identify the aircraft overflights, and cross referenced against the actual flight data from MIA/MATS flight log data in order to identify the aircraft type for each overflight; and
- The environmental noise was evaluated at four meters above local ground.

The location was identified and selected by ERA in consultation with the Consultants and is identified in Figure 5.3 and Table 5.3 below.

Table 5.3: Location of Aircraft noise location alongside Malta International Airport

Location Code	Place	Coordinates (E/N) WGS 84
6	Triq Wied in-Noqor, Ħal Farruġ	35.864276, 14.476791

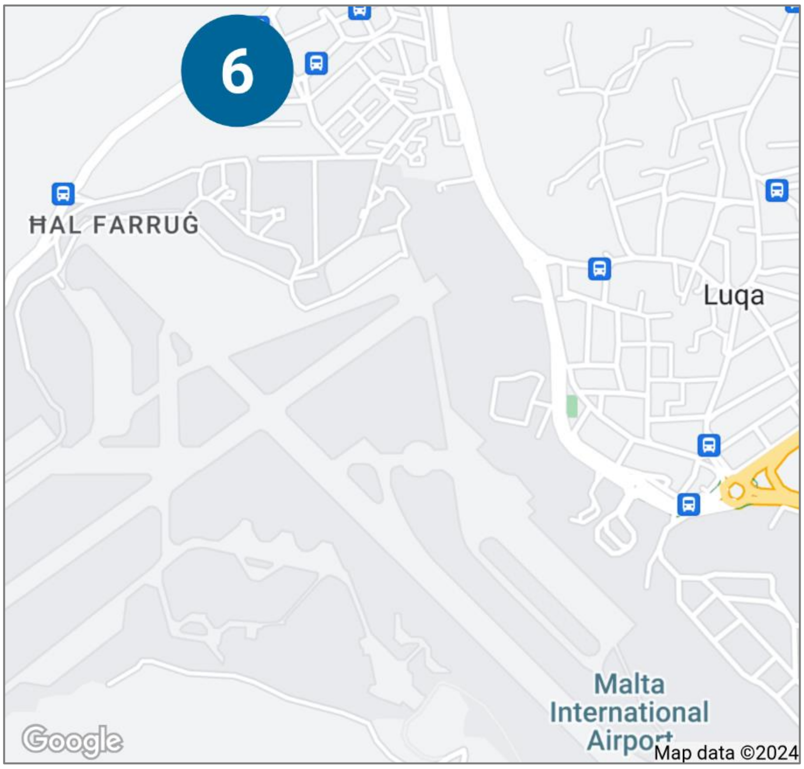

Figure 5.3: Identification of Aircraft noise location

6 Results

6.1 Verification process

Set out below is a summary of the results of the verification process, specifying the level differences between the measured and calculated noise levels for each of the situations analysed. The level differences are presented in terms of average difference for all the studied scenarios for each location, according to the following expression:

$$Level\ difference\ [D_j] = \frac{\sum_{i=1}^{n}(L_{Aeq,calculated,i} - L_{Aeq,measured,i})}{n}$$

Where:

- D_j is the average difference between measured and calculated values for location j.
- $L_{Aeq,calculated,i}$ is the calculated noise level for the scenario i of location j.
- $L_{Aeq,measured,i}$ is the measured noise level for the scenario i of location j.
- n is the total number of evaluated scenarios for location j.

All average level differences were calculated considering equally the noise indicators for day, evening and night periods (arithmetic average of these values). Positive values of D parameter represent an overestimation, i.e. the calculated level is higher than the measured level, whilst negative values represent an underestimation, i.e. the calculated level is lower than the measured level.

Below are set out a summary of the results of the verification process for each type of noise source (road and airport), and noise levels within the quiet area, alongside the assessed measurement uncertainty for each associated measurement in order to provide an indication of the representativeness of the level difference. The complete results of the noise measurement campaign, and noise calculations of each scenario, are included in Appendix 4 and 5 of this report.

6.2 Road traffic noise results

Here the level difference is shown for each road traffic noise measurement location, along with the range of measurement uncertainty, calculated according to ISO 1996-2:2017 recommendations based upon the $L_{Aeq\ 30min}$ scenarios.

Table 6.1: Level difference between calculated and measured noise level for road traffic noise

Site No. & Name	Microphone Location	Level Difference *D* (dBA)	Measurement Uncertainty[1] U (dBA)
1 - Birżebbuġa	Source	4.9	4.2 - 4.9
	Receiver	8.5	4.2 - 5.0
2 - Gzira	Source	4.2	4.3 - 5.6
3 – Marsa-Hamrun Bypass	Source	4.1	4.1 - 4.4
	Receiver (School)	8.7	4.2 - 4.9
	Receiver (Field)	8.0	4.2 - 5.8
4 - Msida	Source	4.4	4.2 - 5.2

[1] Uncertainty of the measurement calculated according to ISO 1996-2:2017. More details in Appendix 3

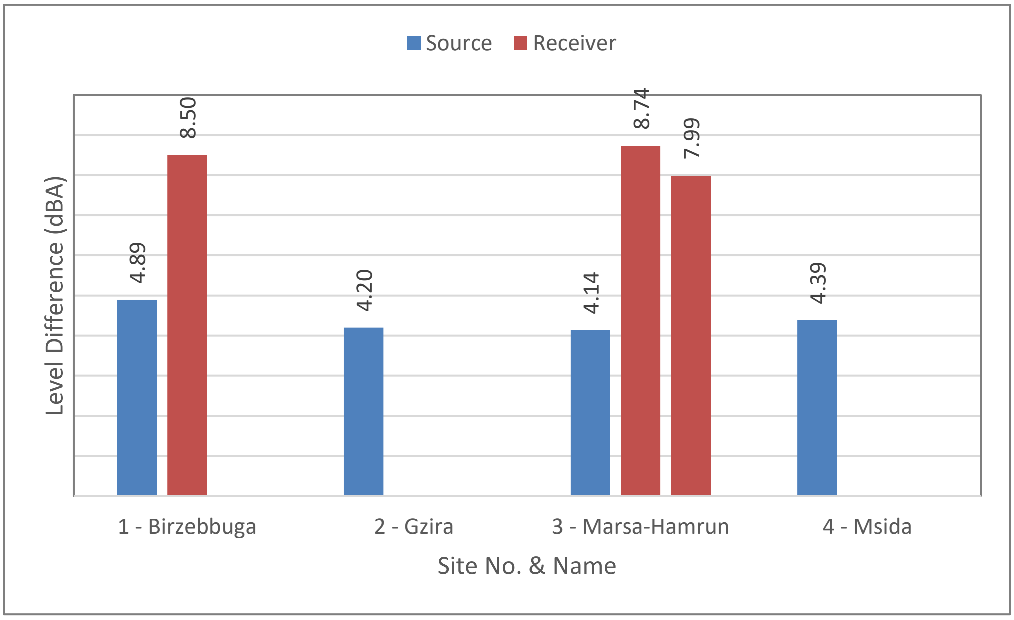

Figure 6.1: Level difference between calculated and measured noise level for road traffic noise

Overall, the calculated noise levels tend to overestimate the measured levels across all locations. The highest-level differences were found at the receptor locations (1 – Birżebbuġa and 3 - Marsa-Hamrun Bypass). This can be attributed to the propagation calculation in the model and might be related to the complex topography near to the position of the microphone, and the distance away from the source. Furthermore, the presence of buildings and the recent widening of the Marsa-Hamrun Bypass road were not featured in the road network layer considered for the modelling exercise, and so the calculations do not accurately represent the specific features of each location.

At the source locations, the highest-level differences were found at the Birżebbuġa and Msida locations, where there is usually pulsating (touch and go) or slow moving traffic. Although the light vehicles in the noise model were modelled as pulsed non-differentiated flows, this has still resulted in a marginal overestimation. The road traffic data for the Msida location contained errors in the individual vehicle hit data. To address this, an average speed calculation was performed, providing approximate speed values for light vehicles and heavy goods vehicles during the day, evening, and night.

6.3 Noise Levels within Quiet Area results

The level difference at the quiet area measurement location is presented here, with an estimated measurement uncertainty of 0.5 dBA due to the use of a Class 1 sound level meter, in accordance with ISO 1996-2:2017. When comparing the road agglomeration point map to the measured noise levels, the calculated noise levels seem to be overestimated as can be seen in Table 6.2 and Figure 6.2.

Table 6.2: Level difference between calculated and measured noise level for the quiet area

Site No. & Name	Microphone Location	Assessment period	Level Difference *D* / dBA	Averaged Level Difference *D* / dBA	Measurement Uncertainty U / dBA
5 – San Klement	Receiver	Day	13.1	8.5	0.5
		Evening	5.8		
		Night	6.8		

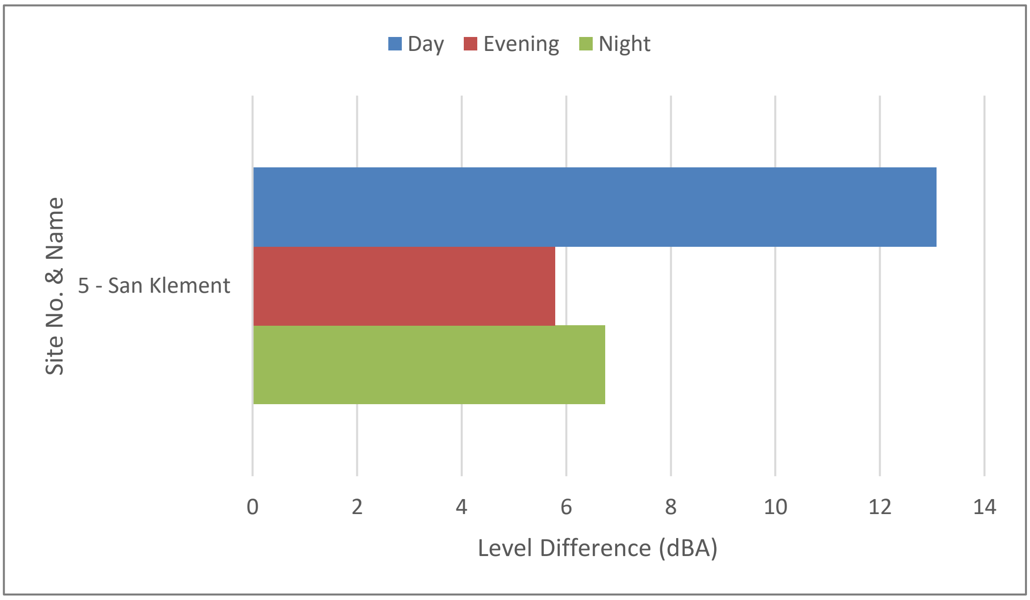

Figure 6.2: Level difference between calculated and measured noise level for the quiet area

6.4 Aircraft noise results

Aircraft noise level results have been evaluated from one measurement location for each of the assessment periods (day, evening and night). On the basis of the calculated measured values, a level difference for each assessment period has been calculated. According to the recommendations from the ISO 1996 and ISO 20906 standards measurement uncertainty may arise due to the following factors:

- Measurement instrumentation;
  - According to the IEC 61672-1:2002, the Type 1 real time sound levels meters used for the measurement campaign introduce an uncertainty of 1 dBA;
- Operation of the noise sources;
  - This was calculated for the aircraft operations from three consecutive assessment periods during measurement exercise;
- Ground and propagation effects;
  - This had the most influence on the overall uncertainty, and was estimated in accordance with ISO 20906:2009; Annex B; Table B.1 for the group of aircraft

A320 and Boeing 737-400 which made up over 60 % of operations during measurement exercise;

- Correction for residual noise.

Table 6.3: Level difference between calculated and measured noise level for air traffic noise

Site No. & Name	Assessment period	Level Difference *D* / dBA	Average Level Difference *D* / dBA	Measurement Uncertainty U / dBA
6 – Hal Farrug	Day	2.0	3.1	4.1
	Evening	6.5		4.2
	Night	1.0		4.4

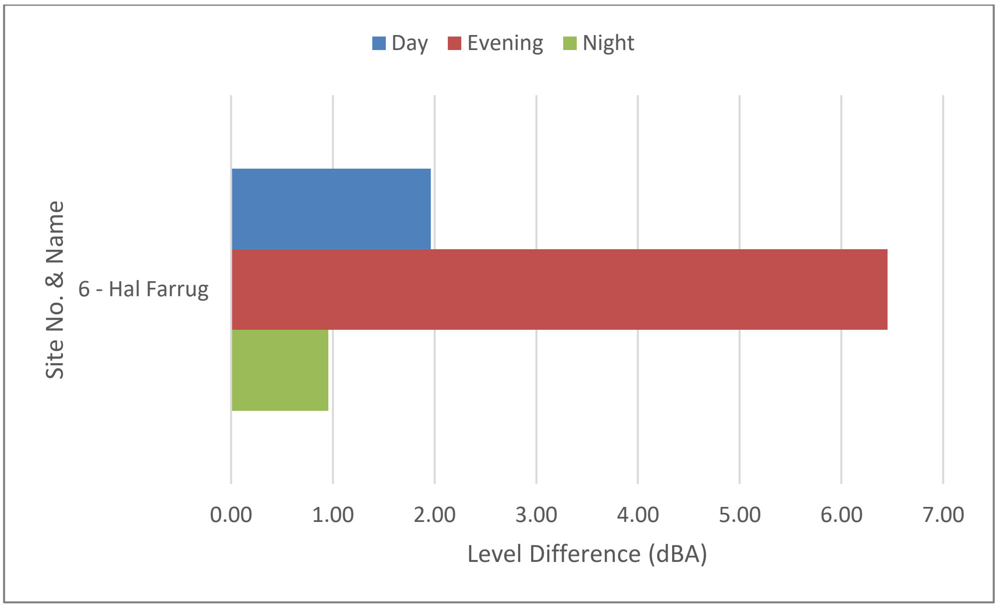

Figure 6.3: Level difference between calculated and measured noise level for air traffic noise

For the situation where the source is close to the ground, e.g. for an aircraft on a runway, the measured sound levels at Hal Farrug were heavily influenced by propagation close to the ground, especially during night. The night, and day period calculated results are generally within good agreement with the measured levels, within 2.0 dBA, while the evening period movements have a larger difference, up to 6.5 dBA. The difference in the evening period may be due to changes in propagation conditions, or the type and number of flight movements.

7 Summary and Discussion

7.1 *Summary*

The stratified measurement results have been compared with noise calculation results based upon the strategic noise maps and the dynamic data captured during the noise measurement surveys.

The analysis of the results and the comparison with the calculation results obtained from the strategic noise maps were undertaken in line with the approach within IMAGINE WP1 final report in order to present an assessment of the measured levels to compare with calculated levels for the monitored scenarios.

Any comparison between noise level measurements and calculated strategic noise mapping results can only provide a general indication of the level of confidence for the specific measurement locations, and even then only when viewed alongside and uncertainty assessment.

Based upon the results presented in Section 6 above it is possible to average the results for each noise source across all the measurement locations to provide a summary of the average level difference, as presented in Table 7.1 below.

Table 7.1: Average level differences for road, quiet area and aircraft noise

Classification	Location	Average Level Difference *D* (dBA)
Road	Source	4.4
	Receiver	8.4
Quiet Area	Receiver	8.5
Aircraft	-	3.1

The results presented suggest that the average level differences obtained vary between noise sources, and may be summarised as:

- **Road traffic noise:** On average the calculated levels overestimate the measured levels near to the roads by approximately 4.4 dBA, and approximately 8.4dBA further from the roads at the receiver locations;
- **Noise Levels within Quiet Area:** On average the calculated levels overestimate the measured levels further from the roads at the receiver locations within a quiet area by approximately 8.5 dBA.
- **Aircraft noise:** On average the calculated levels overestimate the measured levels near to the airport by approximately 3.1 dBA.

In order to provide a general indication level of confidence for the strategic noise maps, it is relevant to discuss a number of factors which may influence the uncertainties associated with the analysis undertaken within the verification process.

7.2 *Measurement Uncertainty*

Any measured value (noise indicator in this case) should be expressed along with the associated uncertainty of the applied methodology of measurement with a chosen coverage probability; often the 95% confidence interval (CI) is used. Standard ISO 1996-2:2017 describes the uncertainty of sound pressure level measurements which are dependent on the sound source and the measurement time interval, the weather conditions, the distance from the source and the measurement method and instrumentation (see Appendix 4 for more details). In this report, the results are expressed as L ± 2U (L is the measured value; U is the combined standard uncertainty considering a coverage probability of 95% confidence interval by convention). This means that the real value would be within the range [L-2U, L+2U] with a 95% confidence interval (CI).

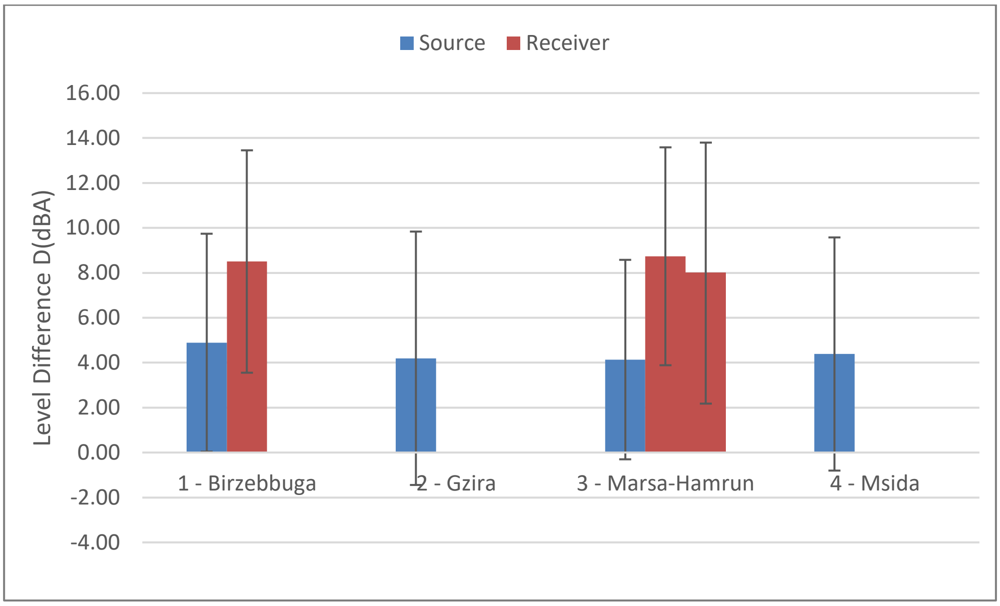

Figure 7.1: Overall level difference of verification process for road within a considering 95% of coverage confidence interval

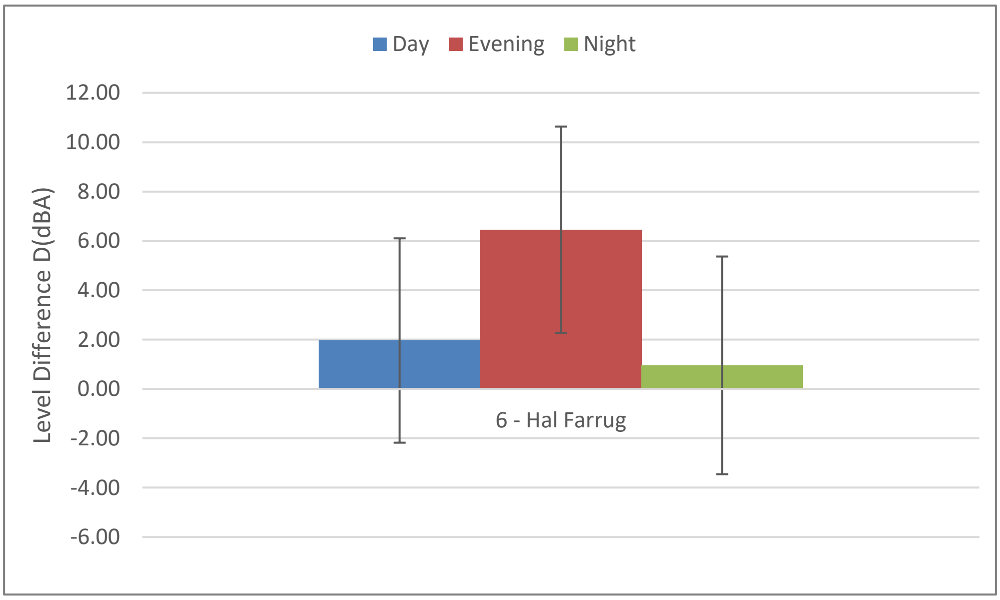

Figure 7.2: Overall level difference of verification process for aircraft noise within a considering 95% of coverage confidence interval

If the 95% CI of the measured levels, for each type of measurement situation, is applied to the average level difference determined for the same situation, it may be concluded that the calculated noise levels are all within the 95% CI of the measured noise levels for each situation, as illustrated in Figure 7.1 and Figure 7.2.

These graphs illustrate that the average noise level differences between calculated and measured levels are all within the interval ± 9 dBA. All the average level differences are within the coverage of the measured 95% CI, and may therefore be considered as equivalent results.

7.3 Input Data Uncertainty

The estimation of the uncertainty of the input data used for the noise calculation is not included within the scope of the Verification Plan, mainly due to lack of information on the uncertainty associated with the data sampling methods, however it will have an influence over the results of the strategic noise map verification due to the error propagation of the input data uncertainty into uncertainty of the calculated levels. As examples of the potential for input data uncertainty to influence the outcome of the process a number of aspects are discussed below.

7.3.1 Traffic Speed

The strategic noise maps were modelled on the basis of speed limits, as real speed data was generally not available, which were in the region of 50 km/h throughout most of roads within the agglomeration. Table 7.2 shows the ranges of average speeds of vehicles measured at the different sites.

Table 7.2: Range of average speeds of vehicles measured at the different sites

Site Name	Range of Average Speed (km/h)
1 – Birzebbuga	33.5 – 45.0
2 – Gzira	23.2 – 28.6
3 - Marsa-Hamrun	15.0 – 24.7
4 - Msida	36.8 – 40.3

Given that the measurements were carried out alongside busy roads, the sum of average speed for each emission window was calculated for light and heavy vehicles from the individual pass-by traffic data, however the average speed had quite low values due to slow moving traffic in such arterial roads.

The low speed posed an issue due to the way that the French road traffic noise prediction model NMPB-96 deals with speeds below 60 to 70 km/h where at such speeds the effect of the propulsion noise is attributed by the type of traffic flow selected which can have a very large influence of the emission level at low speeds, where for light vehicles this can vary by around 10dB at low speeds depending on the type of traffic flow selected while for heavy vehicles emissions can vary by more than 10dB. This resulted in greater uncertainty, as the type of traffic flow selected has a great influence on the emission from the road, as well as the road surface correction, as shown in Figure 7.3

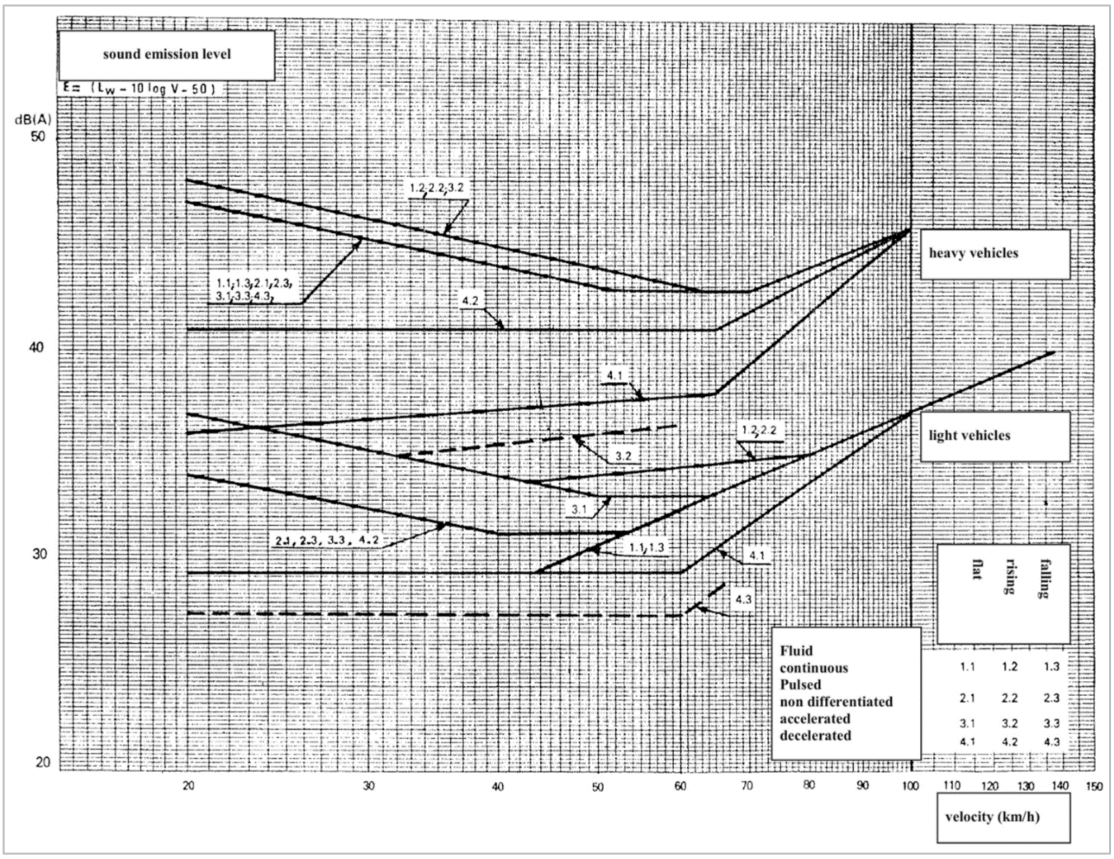

Figure 7.3: Sound emission levels from NMPB '96 methodology with speed

This may also be compounded by a potential for NMPB '96 to overpredict noise from low speed traffic, as illustrated in Figure 7.4 from the AR-INTERIM-CM report "Road traffic noise – Noise emission: databases", 2003, by Wölfel Meßsysteme on the interim methods, where it is compared with other European calculation methods RLS90, RVS and TemaNord.

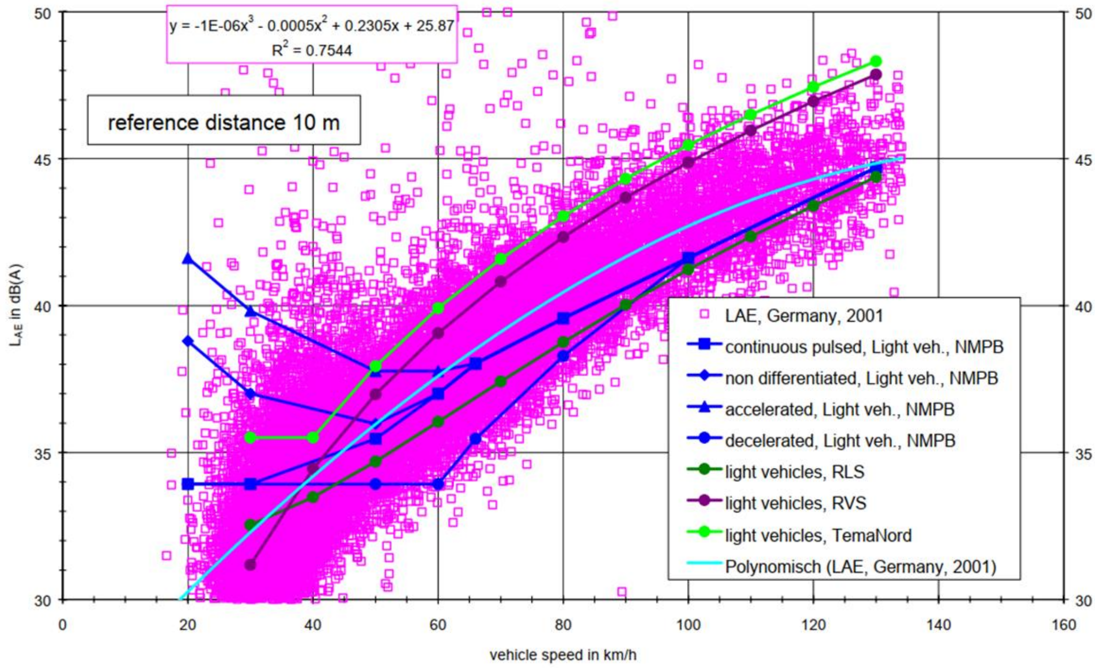

Figure 2

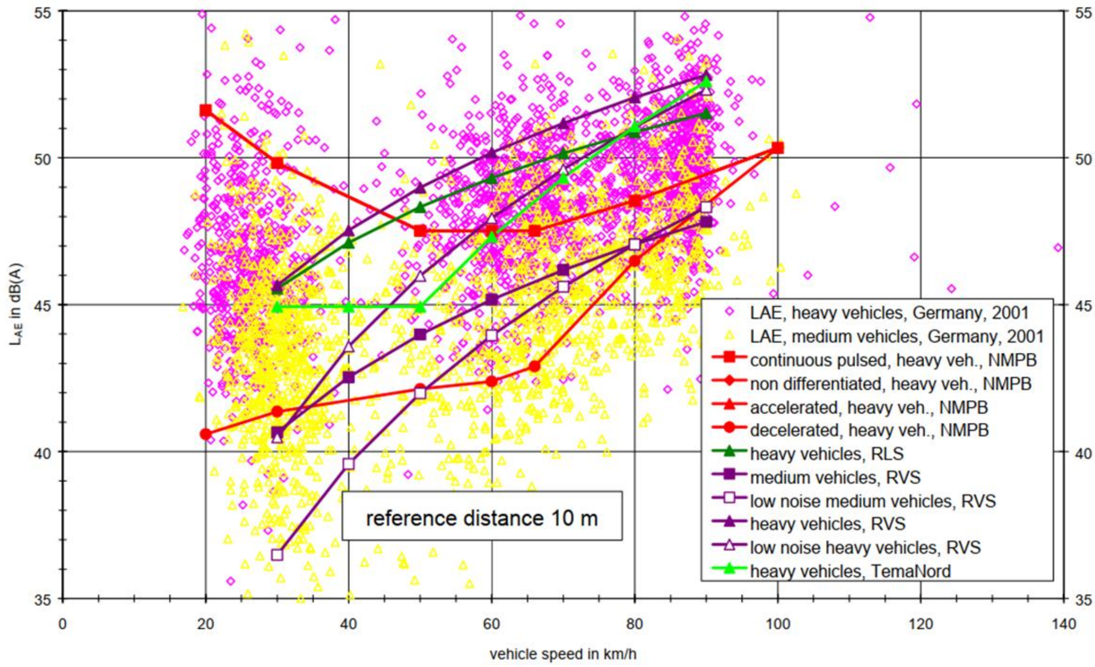

Figure 3

Figure 7.4: Comparison of NMPB sound emission levels with RLS90, RVS and TemaNord (after Wölfel Meßsysteme)

7.3.2 Traffic Flow Type

In view of the rather low speeds encountered during the monitoring exercises, the selection of the type of traffic flow became the most critical individual aspect of the emission calculation for the NMPB '96 method, as illustrated in Figure 7.3 above, with even more effect than the road surface type. Indeed, at average speeds below 40 km/h the model calculates much higher noise levels than those measured or predicted by other models, and presents a systematic over prediction of the noise for "continuous pulsed" traffic flow type.

The emission levels from Guide du Bruit 1980, the basis of emission in NMPB '96 become very different below approximately 60 km/h, and is split into four different emission levels dependent of the type of traffic flow. The consultant's previous experience in other similar exercises has shown a large divergence between measured and calculated noise levels if the incorrect traffic flow is utilised when modelling. The type of traffic flow selected gives an approximate average level of emission so that the uncertainty area of the emission level is considerably accurate in view of the lack of knowledge on flow type obtained from the traffic data. This translated to the "pulsed non-differentiated" flow on flat roads, according to French Standard XPS31-133. This describes a pulsed, continuous flow of vehicles where the average speed remains stable and consistent over an extended period. This flow type corresponds to major roads close to saturation, or connecting roads with numerous crossings, car parks, pedestrian crossings, or junctions to residential areas.

The systematic nature of the error introduced by the calculation methodology not aligning with the noise emission from the roads at low speeds can be confirmed by the fact that for the four measurement locations close to the road traffic source, the level difference ranges from 4.1 to 4.9 dBA, while the level differences at the noise sensitive premises and in the quiet area are all between 8.0 and 8.7 dBA. If this systematic over prediction could be addressed, such as via a change in road surface type, or even an overall adjustment, it would have the knock on effect that the measurement locations close to the noise sensitive premises, or in the quiet area, would then have an overprediction of around 4 dBA, rather than 8 dBA as reported.

To prevent this methodological change in emissions at low speeds from occurring again, it will be considered in future site selection processes. Although this aspect is not included in CNOSSOS-EU, the model does have a minimum speed of 20 km/h and also accounts for corrections to emissions within 100 meters of traffic light-controlled junctions and roundabouts. Therefore, measurement locations alongside very low speed roads, or within these 100-meter zones should be avoided if possible.

7.3.3 Road Surface Type

The basis road traffic noise emission levels used for NMPS '96 interim are derived in accordance with the French national standard XPS 31-133. The correction for the type of road surface is a basic overall dBA correction, as shown in Table 7.3 below.

Without any detailed information on the road surface types assumed within XPS 31-133, or in use within Malta, the road surface was selected as "smooth asphalt" as a default in all cases. It is not know whether this assumed smooth asphalt has a noise emission equivalent to Maltese road surfaces, but, for example, if stone chip sizes in Malta are typically smaller than those used in France in the 1980s it could be expected that Maltese road surfaces may be lower in noise emission than the model calculates. This may in part contribute to the systematic over prediction discussed above.

With the change in calculation method to CNOSSOS-EU, the database includes 13 road surface types which are derived from pavements typically used in the Netherlands. The road surface corrections are given in octave bands, with respect to the notional reference surface, and are summarised as approximate overall dBA changes in Table 7.4.

Table 7.3: Road surface corrections in XPS 31-133[4]

Road Surface Categories	Noise Level Correction, dB(A)	
	v < 80 km/h	v > 80km/h
Porous Surface	-1	-3
Smooth Asphalt	0	
Cement, Concrete and Corrugated Asphalt	2	
Paving Stones	4	
Own Defined	-	

Table 7.4: Road surface types for which correction factors are given in CNOSSOS-EU[5]

Description	Valid speed range [km/h]		Approximate correction [dB(A)]
in brackets: upper layer chipping size	**min**	**max**	
reference surface	-	-	0.0
1-layer porous asphalt concrete (11-16 mm)	50	130	-2.0
2-layer porous asphalt concrete (8 mm)	50	130	-4.8
2-layer porous asphalt concrete (5 mm)	80	130	-6.0
stone mastic asphalt (5 mm)	40	80	-1.1
stone mastic asphalt (8 mm)	40	80	-0.5
brushed concrete	70	120	+1.2
optimised brushed concrete	70	80	-0.3
fine broomed concrete	70	120	+1.9
chip seal / surface dressing	50	130	+1.9
paving blocks (herringbone)	30	60	+2.8
paving blocks (not herringbone)	30	60	+6.2
quiet paving blocks	30	60	+0.8
thin layer porous asphalt (8 mm)	40	130	-2.5
thin layer porous asphalt (5 mm)	40	130	-3.8

It can be seen from Table 7.4 that the selection of road surface type within CNOSSOS-EU can have up to 12.2 dBA effect on the total emission from the road traffic. The default assumption to use the reference surface minimises possible error, as it is in the centre of the range, however it

[4] *Research Project NANR 93: WG-AEN's Good Practice Guide And The Implications For Acoustic Accuracy, Final Report: Error Propagation Testing of XPS 31-133*, Hepworth Acoustics, May 2005

[5] *Determination of road surface correction factors for CNOSSOS-EU in Ireland*, S.J. Shilton et al., Inter-Noise 2023, Chiba, Japan, 20-23 August 2023

would not provide any understanding of accuracy, without undertaking a similar validation exercise with measurements alongside a number of different roads with similar, and different, road surfaces in order to understand the correlation between the CNOSSOS-EU road traffic noise emission model, and the situation experienced on Maltese roads.

7.3.4 Site Location

Considerations were made in accordance with Sections 3.1 and 3.3 for road traffic and aircraft noise, respectively. For road traffic noise, care was taken to ensure that the primary sound source at the selected sites was traffic from the road where monitoring was conducted. Any extraneous or residual noise from other sources was required to be at least 10 dB(A) lower than the road noise. Additionally, the measurement site needed an unobstructed view of the road, with no near-vertical reflective surfaces within 5 meters. For aircraft noise, the dominant sound source had to originate from aircraft following the specific flight path under observation. Any background or extraneous noise was similarly required to be at least 10 dB(A) below the noise from the aircraft. The measurement sites also needed a clear view of the aircraft and to be free of nearby vertical reflective surfaces within 5 meters.

Microphone locations were accurately mapped using coordinates to ensure correct placement during the measurement process.

7.3.5 Aircraft movements

Aircraft movements for the same time period considered for the noise modelling were obtained from Malta International Airport, and Malta Air Traffic Services, to determine each landing and take-off and considerations were made to the runway used for each flight as well as the flight path taken. Aircraft flying over the monitoring location were considered and each movement was matched to the respective time period during the measurements. The measurements included a lot of other noise sources which were not aircraft noise. However, these extraneous noise events such as birdsong around dawn, car horns and other events which are not aircraft overflights were removed from the data analysis. Furthermore, it was noted that noise levels relating to aircraft movements captured during the night time period particularly between 06:00 and 07:00am were considerably higher than the rest of the night. It was concluded that data gathered during this time period appears to be an outlier and was removed from the data analysis since the increase in noise level was attributed to traffic present during the early morning peak hour which was captured during the same aircraft movements and have led to a higher contribution in the noise measurements.

7.4 Model Uncertainty

The test implementation of the validation process was undertaken using the noise calculation models developed for the Round 3 strategic noise mapping, which was designed to represent the situation in 2016. The field measurement studies were undertaken during 2022, which had the potential for aspects of the site geometry changing between the baseline models for the strategic noise mapping, and the reality during the field measurements.

Following the comparison of the measured and calculated noise levels, further site visits were undertaken and they identified that at two locations there had been changes in reality which unfortunately did not align with the situation during the field measurements. For the Marsa-Hamrun Bypass location, the road had been widened and resurfaced between the strategic noise mapping exercise and the field survey work. In Birżebbuġa, the street layout remained unchanged, however the field monitoring location was on a small hill, at a higher altitude than the road where the noise source was located.

The verification process outlined above in Section 4.1 above includes the following steps to be taken when setting up the meta-models for calculation:

- The noise model is aligned with the reality of the measurement situation where possible, including confirming that buildings, barriers, ground absorption etc which are present during the measurements are correctly included within the model;
- The measured and calculated noise levels should include reflections in a similar manner, either including the influence of reflections in both cases or considering only incident noise. Consideration should be given at each location as to whether corrections are to be applied to the results at each measurement location, or whether the configuration of the noise prediction software needs to be changed;
- The location of each receiver within the noise model is confirmed to be at the same location as the sound level meter, including the distance to reflectors and the main noise sources;
- The dynamic parameters of each noise source are adapted in each meta-model to match the values captured during each defined emission window in order to establish each of the scenarios for the comparison; and
- Any known variations between the monitored situation and the modelled scenario are noted and reported as part of the discussion on the outcome of the verification process.

The situation in Birżebbuġa may seem like a small change between the model and the reality, however changes in distance, screen and ground effects can be quite significant, even at short distances. For the Marsa-Hamrun Bypass case, ideally the changes to the local situation would have been identified during the field survey, and these changes noted and fed back into the modelling exercise. Given the changes identified, it would have been preferred to revise the strategic noise model in this area to more closely replicate the revised road geometry, and surrounding landscape, and the change in road surface.

The validation process has now been slightly amended in Section 4.1 to more clearly outline the process of aligning the calculation models with the situation found during the field surveys.

7.5 Calculation Method Uncertainty

WG-AEN GPGv2 considers model uncertainty as a combination of the ability of the calculation methodology to replicate the real-world situation, and the ability of the noise calculation software to completely and unambiguously implement the methodology without additional uncertainty being introduced.

The adapted EC recommended Interim Methods set out within Annex II of the END in 2002 are engineering methods developed during the 1980s and 1990s ahead of the development of the END. These engineering methods provide a simplified version of real-world sound propagation in order to provide a solution which may be applied to the majority of reasonably simple situations without undue complexity. By their nature they do not provide a full analytical solution for all possible real-world situations, and as such some discussion about potential conflicts with the monitored locations is considered appropriate.

7.5.1 Road traffic noise calculations

The adapted version of French national computation method applied to the calculation of road traffic noise presents some limitations when the speed of the traffic flow is very low, and the emitted sound power of the vehicles depends on the load of the engine. Although the method incorporates some additional corrections for the lower speed range (lower than 60-70 km/h), all speeds below 20 km/h are set to 20 km/h. For this reason, the calculated noise levels will become inconsistent with the measured values exposed to congested roads. This situation was found to be quite common at locations 2-Rue, D'Argens, Gzira and 3 – Marsa-Hamrun Bypass, and it may be an influencing factor in the level differences identified.

The results of the comparison between measured and calculated levels shows what appears to be systematic bias in the results, both near to the source (where the model has overpredicted by between 4.1 to 4.9 dBA), and further away at the noise sensitive locations and in the quiet area (where the model has overpredicted by between 8.0 and 8.7 dBA.

While the modelled mean traffic speed has been based on the measured levels, there remains uncertainty regarding the flow type and the road surface correction, as discussed above in Sections 7.3.2 and 7.3.3 respectively.

Both these aspects may be contributing the systematic over prediction shown from the comparison of measured and calculated levels. If this systematic over prediction could be addressed, such as via a change in road surface type, or even an overall adjustment, it would have the knock-on effect that the measurement locations close to the noise sensitive premises, or in the quiet area, would then have an overprediction of around 4 dBA, rather than 8 dBA as reported.

7.5.2 Aircraft noise calculations

The documentation for the ECAC Doc 29; 2nd Edition calculation method (Vol. 1, page 14) "emphasises" some possible differences in measured and predicted values with the main causes being ground cover effects, lateral attenuation and lateral screening. Apart from the aircraft flight profiles, ground surface and atmospheric conditions, local factors including topography and ground cover may have significant effects upon contours in certain circumstances and may sometimes warrant special treatment.

Theoretically, receiver height above the surface has an influence on lateral attenuation; however over soft ground in real non-uniform atmospheres, the effect on event levels is small. Lateral attenuation significantly affects sound propagating at acute angles to the ground surface. It is largely caused by interference between directly radiated sound and reflection from the ground surface - which depends on the angle of sound incidence, ground properties and receiver height. As the geometry of sound reflection is influenced by refractions caused by wind and temperature variations, it means that attenuation is difficult to model theoretically.

Lateral attenuation is a reflection effect, due to interference between directly radiated sound and that which reflects from the surface. It depends on the nature of the surface and can cause significant reductions in observed sound levels at low elevation angles. It is also very strongly affected by sound refraction, both steady and unsteady, caused by wind and temperature gradients and turbulence, which are themselves attributable to the presence of the surface. The mechanism of surface reflection is well understood and, for uniform atmospheric and surface conditions, it can be described theoretically with some precision. However, atmospheric and surface non-uniformities - which are not amenable to simple theoretical analysis - have a profound effect on the reflection effect, tending to 'spread' it to higher elevation angles; thus the theory is of limited applicability.

The noise calculation model used for the aircraft movements at MIA is completely aligned with the requirements of the ECAC Doc 29; 2nd Edition. The methodology is currently up to the 4th Edition, and there have been significant changes to how lateral attenuation from the aircraft are calculated since the 2nd Edition.

This may in part help to account for the difference between the measured and calculated levels, but does not explain the increased difference in the evening period, compared to the day and night periods. The evening period may be affected by greater variation in aircraft type, and may have had a lower proportion of the most common aircraft, with fewer movements over fewer hours, but may also be exposed to changes in meteo conditions during the evening period as the sun sets and the temperature changes across the 4 hour evening period with real-world changes in meteo conditions occurring which may not have been replicated within the calculation model.

8 Summary and Conclusions

Directive 2002/49/EC, commonly referred to as the Environmental Noise Directive (END), requires Member States to collect information on long term noise exposure due to road, rail, aircraft and industrial noise sources through the use of strategic noise mapping. The Directive is transposed separately in each Member state of the EU into local legislation. In Malta, the END is transposed by the *"Assessment and Management of Environmental Noise Regulations, 2004"*, L.N. 193 of 2004 (Regulations). The monitoring of environmental noise is undertaken with the aid of 3D noise assessment models and noise mapping software for the production of strategic noise maps.

A verification methodology was developed to form the basis of a training workshop that was conducted for ERA personnel prior to the initiation of this exercise and used to assist with the field measurements and verification at the six locations.

This report sets out the background, discussion and methodology for verification of the strategic noise maps for road traffic, industry and aircraft. Long-term measurements of up to two weeks continuous monitoring were undertaken at locations exposed to road and aircraft sources in order to verify the emission models used within the strategic noise mapping. Long-term measurements of up to two weeks continuous monitoring were also undertaken at a number of noise sensitive premises, and another site at a quiet area, to verify the receiver results of the strategic noise mapping.

The measurement results were analysed into stratified sets of results, determined by time period, weather conditions and source emissions. This approach is in line with the IMAGINE WP1 final report and concepts in ISO 1996. The stratified measurement results were then compared with noise calculation results based upon the strategic noise maps, and the dynamic data captured during the noise measurement surveys.

The analysis of the results and the comparison with the calculation results obtained from the strategic noise maps were undertaken in line with the approach within IMAGINE WP1 final report in order to present an assessment of the measured levels to compare with calculated levels for the monitored scenarios. The comparison between noise level measurements and calculated strategic noise mapping results can only provide a general indication of the level of confidence for the specific measurement locations, and even then, only if an uncertainty assessment is undertaken for each.

The results presented suggest that the average level differences obtained vary between noise sources, and may be summarised as:

- **Road traffic noise:** On average the calculated levels overestimate the measured levels near to the roads by approximately 4.4 dBA, and approximately 8.4 dBA further from the roads at the receiver locations;

- **Aircraft noise:** On average the calculated levels overestimate the measured levels near to the airport by approximately 3.1 dBA;

- **Noise within Quiet Area:** On average the calculated levels overestimate the measured levels further from the roads at the receiver locations within a quiet area by approximately 8.5 dBA.

The Verification Report of Strategic Noise Maps for roads has concluded that all studied cases for roads at source exhibit level differences within a range of ±6.5 dBA compared to the measured noise levels. Similarly, the Verification Report of Strategic Noise Maps for airport noise and for noise within quiet area has determined that the studied case shows a level difference within a range of ±6.5 dBA and ±13.1 dBA, respectively, in relation to the measured noise levels.

In all cases, the average level differences are within the coverage of the 95% CI of the measured noise levels, and may therefore be considered as equivalent results. Overall, this represents an acceptable level of agreement between the strategic noise mapping and the measured noise levels.

The measurement locations, and noise calculation methods, were reviewed in order to try to identify any underlying reasons for difference between the measured and calculated levels, particularly where difference appeared consistent between measurement sites, or situations, indicating a systematic bias.

8.1 Recommendations

Further to the overall results of the verification process, a number of recommendations may be made for consideration in future studies:

- As a means of validating annual average L_{den} and L_{night} noise level results calculated from strategic noise mapping, the verification process based upon ISO 1996 and IMAGINE WP1 has been shown to provide a suitable approach to the comparison of measured and calculated noise levels based upon stratified measurement results and a series of meta-models used for the basis of the comparison. It is recommended that any future verification of noise mapping projects should follow a similar approach as it is much more focussed and efficient than measurement of many tens of locations alongside noise sources;

- The source noise levels alongside roads generally showed a consistent overprediction of around 4.5 dBA when compared to the measured levels, this is thought to be due to two potential factors, the way that NMPB ’96 calculated sound emission from low speed roads, and the correction for road surface type. It is recommended that additional studies are undertaken with a view to establishing road surface correction factors for typical road pavements in Malta for use within the new common noise assessment methodology set out in Annex II of the END (CNOSSOS-EU), in order to help improve the correlation between calculated and measured noise levels and improve the overall accuracy of the strategic noise mapping.

- The validation process has now been amended in Section 4.1 to more clearly outline the process of aligning the calculation models with the situation found during the field surveys, with the text revised as follows:

    - The noise model is aligned with the reality of the measurement situation where possible, including confirming that road surface type, buildings, barriers, ground absorption etc which are present during the measurements are correctly included within the model;

- Where any differences are found between the strategic noise models and the situation identified through the field surveys, it is recommended that the noise models are updated within the calculation model used for the verification work in order to more closely align with the real-world situation.

Appendix 1: Glossary of Acoustic and Technical Terms

Term	Definition
Agglomeration	Major Continuous Urban Area as set out within the Regulations
Attribute Data	A trait, quality, or property describing a geographical feature, e.g. vehicle flow or building height
CI	Confidence Interval
CNOSSOS-EU	Common Noise Assessment Methods for Europe, as defined in Annex II of the Environmental Noise Directive 2002/49/EC
Data	Data comprises information required to generate the outputs specified, and the results specified
dB	Decibel
EC	European Commission
EEA	European Environment Agency
EIA	Environmental Impact Assessment
END	Environmental Noise Directive (2002/49/EC)
ERA	Environment and Resources Authority
ISO	International Organisation for Standardisation
MEER	Ministry for the Environment, Energy and Regeneration of the Grand Harbour
MEPA	Malta Environment and Planning Authority
Noise Levels	Free-field values of L_{den} L_d, L_e, L_n, and $L_{A10,18h}$ at a height of 4m above local ground level
Noise Level - L_d - Daytime	L_d (or L_{day}) = $L_{Aeq,12h(07:00 \text{ to } 19:00)}$
Noise Level - L_e - Evening	L_e (or $L_{evening}$) = $L_{Aeq,4h(19:00 \text{ to } 23:00)}$
Noise Level - L_n - Night	L_n (or L_{night}) = $L_{Aeq,8h(23:00 \text{ to } 07:00)}$
Noise Level - L_{den} – Day/Evening/Night	A combination of Ld. Le and Ln as follows: L_{den} = 10 * lg 1/24 {12 * 10^((L_{day})/10) + 4 * 10^(($L_{evening}$+5)/10) + 8 * 10^((L_{night}+10)/10)}
Noise Mapping Software	Computer program that calculates required noise levels based on relevant input data
Noise Model	All the input data collated and held within a computer program to enable noise levels to be calculated.
Processing Data	Any form of manipulation, correction, adjustment factoring, correcting, or other adjustment of data to make it fit for purpose. (Includes operations sometimes referred to as 'cleaning' of data)
WG - AEN	Working Group – Assessment of Exposure to Noise

Appendix 2: Bibliography

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2. Assessment and Management of Environmental Noise Regulations, 2004, L.N. 193 of 2004
3. ISO 9001: 2015, Quality management systems -- Fundamentals and vocabulary
4. ISO 14064-3:2006, Greenhouse gases -- Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions
5. European Commission Working Group Assessment of Exposure to Noise (WG-AEN), Position Paper, Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure, Version 2, 2006
6. IMAGINE WP1 Final Report, Guidelines and good practice on strategic noise mapping Deliverable 8 of the IMAGINE project IMA01-TR22112006-ARPAT12
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8. D. Keuhner, Minimising Uncertainties of Long-Term Measurements Using Stratification, I-INCE Symposium Le Mans (France), 27-29 June 2005
9. ISO 1996-1:2016 Acoustics -- Description, measurement and assessment of environmental noise -- Part 1: Basic quantities and assessment procedures
10. ISO 1996-2:2017 Acoustics -- Description, measurement and assessment of environmental noise -- Part 2: Determination of environmental noise levels
11. ISO/IEC Guide 98-3:2008, Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)
12. Technical Regulations for Methods of Measuring Emission, Rail Traffic 21 December 2006, CROW steering group Calculation and Measurement Regulations, translated version from Dutch.

Appendix 3: Equipment Required for Field Measurements

No	DEVICES DESCRIPTION	Type	Required quantity
	SOUND CALIBRATION DEVICES		
1.	Sound calibrator device	Class 1 according to IEC60942	1 per measurement team
	SOUND LEVEL METERS		
2.	Sound level meter (SLM) Type 1	Type 1 according to IEC 61672-1	1 per measurement point at every measurement location
3.	Logging capability software installed on SLM	-	software per SLM
4.	Sound recording software installed on SLM	-	optional
5.	Frequency analysis capability software on SLM	-	optional
	OUTDOOR EQUIPMENT		
6.	Outdoor microphone kit (weather protected microphone case)	-	1 per SLM
7.	Microphone extension cable 10m (to be used with outdoor kit)	-	1 per SLM
8.	Microphone extension cable 30 m (to be used with outdoor kit)	-	1 per SLM
9.	Microphone pole 4m	-	1 per SLM
10.	Microphone pole mount/adapter	-	1 per SLM
11.	Protective case for SLM and external battery	-	1 per SLM
12.	Protective case lock	-	1 per case
13.	External battery	capacity according to SLM power consumption and measurement duration	1 per case
14.	DC power cable	-	1 per case
15.	Set of ropes for fixing microphone pole	-	3 pcs per set for every microphone pole
16.	Set of pegs for fixing microphone pole on soft ground	-	3 pcs per set for every microphone pole
	METEOROLOGICAL DATA EQUIPMENT		
17.	Logging device for meteorological data including sensors for: wind speed and direction, air humidity, air temperature, atmospheric pressure (all to be logged during entire sound measurement duration)	±0,5 K for temperature ±5,0 % for relative humidity ±0,5 hPa for pressure ±0,5 m/s for wind speed ±5°for wind direction	1 set
18.	Meteo mast 10 m with holders and adapters	-	1 set
19.	Set of ropes for fixing meteo mast		3 pcs per set for every mast

No	DEVICES DESCRIPTION	Type	Required quantity
20.	External battery for meteo data logger device	capacity according to system power consumption and measurement duration	1 pc
	TRAFFIC DATA EQUIPMENT		
	Radar Based System		
21.	Radar based traffic data analyser/logger with external sensor/transceiver	-	1 per traffic data acquisition site
22.	Measuring pole for radar system	-	1 per system
23.	Measurement pole/sensor adapter	-	1 per system
24.	Protective case for radar system	-	1 per system
25.	Set of ropes for measuring pole fixation	-	1 per measurement pole
26.	Protective case lock	-	1 per case
27.	External battery	capacity according to system power consumption and measurement duration	1 per case
28.	Transport case for radar system	-	1 per system
	Induction Loop Based System		
29.	Induction loop traffic data sensor/logger and rubber road tubes	-	1 per traffic lane
30.	Protective cover for inductive sensors	-	1 per sensor
31.	Inductive sensor charger	-	1 per sensor
32.	Transport case for inductive sensors	-	1 per sensors set
	MISCELLANEOUS		
33.	Battery chargers for external batteries	-	optional
34.	Laser distance measuring device	-	optional
35.	Reserve set of batteries for calibration device	-	optional
36.	Photo camera for documenting	-	1 per measurement team
37.	Hammer for pegs manipulation	-	1 pc
38.	Laptop PC	-	1 per measuring team
39.	Software for SLM data download and processing	-	1 per laptop PC
40.	Software for meteorological data download and processing	-	1 per laptop PC
41.	Software for traffic data download and processing	-	1 per laptop PC

Appendix 4: Noise Measurement Results

- Example of contents:
  - Scope of noise measurements
    - List of measurement locations
    - Include mapped locations and site photos during measurements
    - Include details of measurement height, distance to source,
  - Measurement campaign
    - Criteria for selection of measurement location
    - Pre-evaluation of residual noise – what else could be heard at the location during attended measurements
    - Instrumentation
      - Sound
      - Meteo
      - traffic
    - Selection of microphone position – free field, façade etc
    - Installation of devices
    - Meteo data measurement
    - Traffic data measurement
    - Clock synchronisation between devices
    - Calibration
    - Checking on measurements
    - Download of data
  - Post-processing
    - Removal of unwanted results
    - Analysis of meteo data
    - Analysis of traffic flow data
    - Level correction for residual noise (if required)
    - Define emission windows
    - Synchronise database of noise levels, meteo and traffic data per emission window, for each measurement location
  - Uncertainty assessment
    - methodology
  - Results
    - Road traffic noise measurement results per location
      - Overall dBA results in table view showing emission windows and meteo classes
      - Average octave band results per emission window for M3 & M4 favourable meteo class, with number of samples, and overall uncertainty
    - Aircraft noise measurement results per location
      - Table of measured noise indicator values for receiver, Ld, Le, Ln, Lden
    - Noise measurement results within Quiet Area per location

Table of measured noise indicator values for receiver, Ld, Le, Ln, LdenAppendix 5: Noise Calculations

- Example of contents:
    - Scope of noise calculations
        - List of measurement locations
    - Methodology
        - Per measurement location, show general approach to:
            - Changes to calc setup eg meteo, temp, humidity etc
            - Addition to model of receiver locations to match measurement points
            - Changes to road surface, and traffic volume, flow type and speed to match assessment scenario
            - Calculation process
    - Results
        - Road traffic noise: Table per measurement location, per emission window
        - Aircraft noise: Table per measurement location, results per time period
        - Noise within Quiet Area: Table per measurement location, results per time period

Appendix 6: Comparison of Results

- Example of contents:
  - Road traffic
    - comparison of results per location
    - example:

Table 1.1: Verification Results at Location XX

Emission window	E1	E2	E3	E4	Average (dBA)
Source location	4,8	4,2	3,8	0,4	3,3
Receiver location	8,1	7,3	6,2	-	7,2

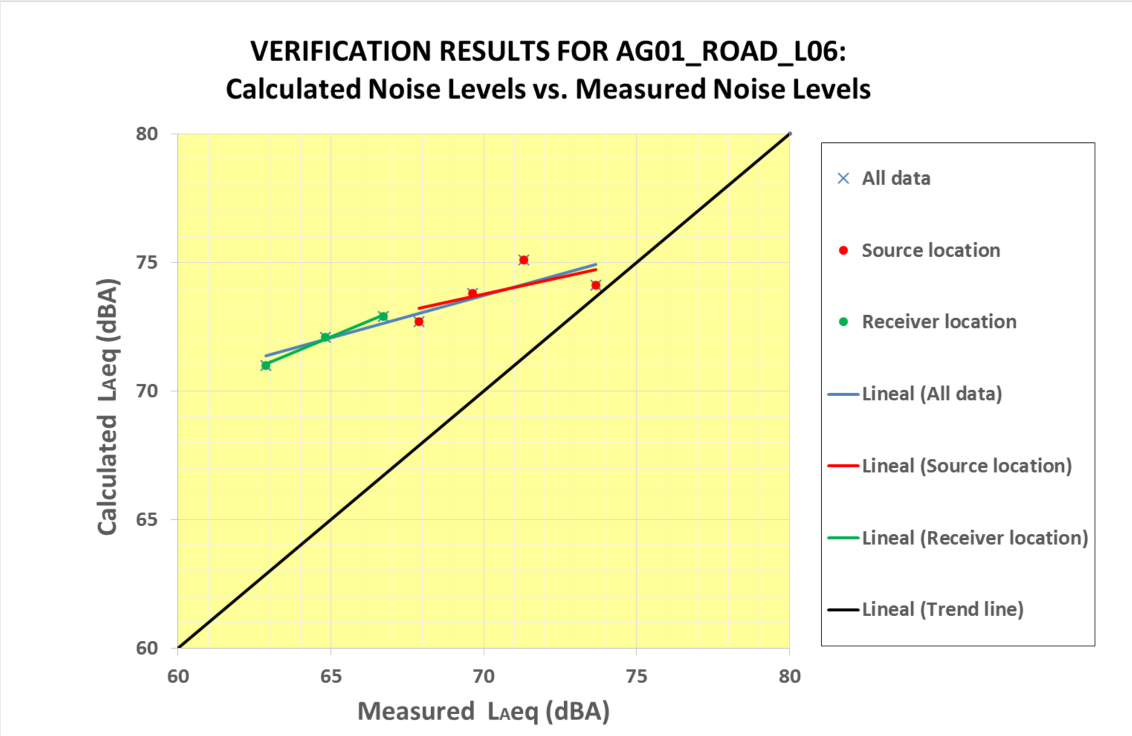

Figure 1.1: Verification Results at Location XX

  - Aircraft noise
    - Comparison of results for all measurement locations
    - Example

Table 4.1: Verification Results at Source Positions

Noise indicator	Source Positions	
	L02_SRC01	L03_SRC01
L_{day} / dB(A)	2,8	4,8
$L_{evening}$ / dB(A)	-0,6	1,3
L_{night} / dB(A)	5,0	6,6
L_{den} / dB(A)	3,8	5,6

Table 4.2: Verification Results at Receiver Position

Noise indicator	Receiver Positions		
	L01_NS01	L04_NS01	L05_NS01
L_{day} / dB(A)	3,4	3,7	-0,2
$L_{evening}$ / dB(A)	1,7	3,1	0,3
L_{night} / dB(A)	6,9	6,7	3,0
L_{den} / dB(A)	5,4	5,8	2,2

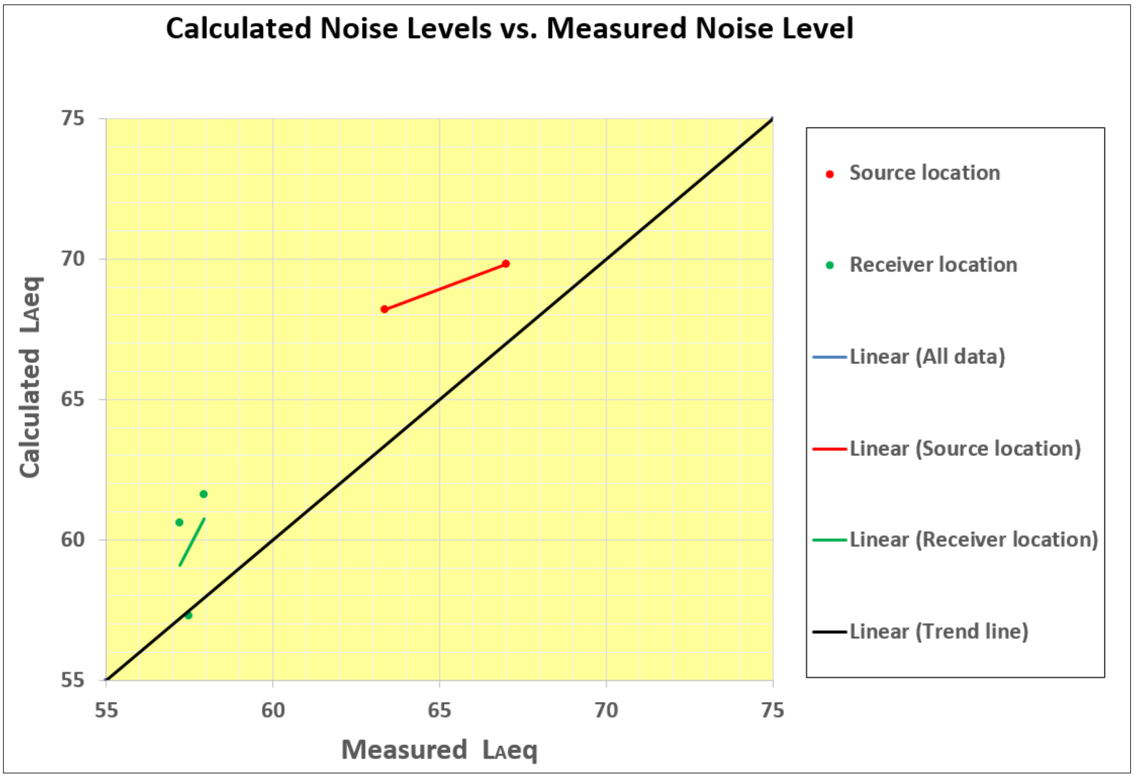

Figure 4.1: Verification Results at Source and Receiver Positions around Airport