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Comparison of measurements of aircraft noise levels and their variability with model results

Matthew Cand[a],
Justin Adcock,
Barry Jobling,
Hoare Lea Acoustics
Glen House, 200-208 Tottenham Court Road, London W1T 7PL

ABSTRACT

Hoare Lea Acoustics were commissioned to predict and assess the impact of different flight patterns associated with a large airport development. As part of a preliminary study for this project, a detailed investigation was commissioned to evaluate the extent to which actual daily and weekly aircraft noise levels around an existing airport differ from long term values derived from computer model predictions. This provided the opportunity to gauge to what extent predictive noise levels can estimate noise levels measured over extended periods, to be used as a context to a wider study. An extensive series of data was recorded for 8 locations in the area surrounding an existing airport for a period of 6 weeks or more in 1 second intervals. Conditions of relatively high temperature and humidity were prevalent during the survey period. Due to the substantial volume of data gathered during the survey process, specialist software was employed to automatically filter and convert the data into meaningful noise ratings. The prediction model used was ECAC Doc 29, as recommended in guidance documents associated with the European Noise Directive. A commercially available software implementation of the model was used to produce calculations over a 2 month period overlapping with the survey. Analysis of the measurement results indicated a strong correlation between the measured and predicted noise levels. This finding supported the use of the chosen aircraft noise prediction methodology to estimate long term upper noise levels arising from aircraft movements.

1. INTRODUCTION

In 2006, Hoare Lea Acoustics (HLA) was commissioned to develop a series of long term noise predictions for an airport development in the Middle East. To complement these predictions, and to provide a “calibration” reference and a context for predictions of aircraft noise in general and under the particular prevailing environmental conditions in the area, HLA first undertook a preliminary study, which will be described in the present paper.

This study consisted of both predictions and measurements at an existing airport in the United Arab Emirates (UAE): Dubai International. Undertaking these measurements and predictions for a given time interval provides the opportunity to gauge the quality with which predictive noise levels can estimate noise levels measured over extended periods. The measurements also provide an indication of the extent to which daily and weekly noise levels within a longer term assessment period will vary.

[a] Email address: matthewcand@hoarelea.com

2. AIRCRAFT NOISE SURVEY

An extensive survey was undertaken to quantify existing levels of noise generated by Dubai International Airport flight operations. The survey comprised 8 measurement positions under the aircraft flight paths, mainly located between the airport boundary and the coastal line at distances of 1 to 5 km from the edge of the airport runway. Sound level meters we set up on roof tops so as to have a clear uninterrupted line of sight to aircraft. The precise location of each was recorded using a Global Positioning System.

The equipment used for the noise monitoring included the following instruments: RION NL-31 and NL-32 and SVAN 939 sound level meter logging systems. The SVAN instrument had full frequency capability, and the NL-32 audio recording capability. Due to concern about overheating, the noise monitoring units were protected from direct sunlight using a layer of insulating foam covered with a reflective surface. The equipment was serviced weekly. It was observed that despite the high temperatures, calibration sensitivity checks indicated a variation of not more than 0.5 dB for all systems.

Noise levels were monitored over a 6 week period during July and August 2006. Each logging instrument was set to record 1 second samples of A-weighted noise levels. Additionally, frequency data and audio recordings were obtained at two locations, both near and far from the airport.

3. DATA ANALYSIS

A. Data filtering

The noise measurement survey resulted in a substantial dataset of 1 second contiguous samples over a 6 week period for 8 time correlated positions, which was reduced as described in this section.

An automated filtering of the data was performed during the post-processing phase to separate aircraft noise events from the background noise and apply corrections where necessary. The first element of the analysis involved filtering of the data to isolate events associated with aircraft pass-by and subsequently remove any periods in which the samples appeared to have been contaminated by extraneous background sound influences. This process took advantage of the characteristic progressive rise and fall in noise level associated with an aircraft event, as depicted below in Figure 1.

Very short, impulsive events (1 second or less) were first eliminated as they were considered to be due to spurious sources. The background noise level, estimated by calculating the L_{A80} for a moving 10 minute window, was in most cases dominated by building services plant noise. Probable aircraft fly-over events were identified by being above a detection threshold (X dB above the background level) for a minimum duration (Y seconds) as represented in Figure 1. For each event, 7 seconds of data was also included before and after the threshold detection: this represents the “shoulder period” and ensures that the whole aircraft noise event is taken into account. The correct identification of aircraft events was confirmed by analysing a sample of identified events with reference to audio samples recordings.

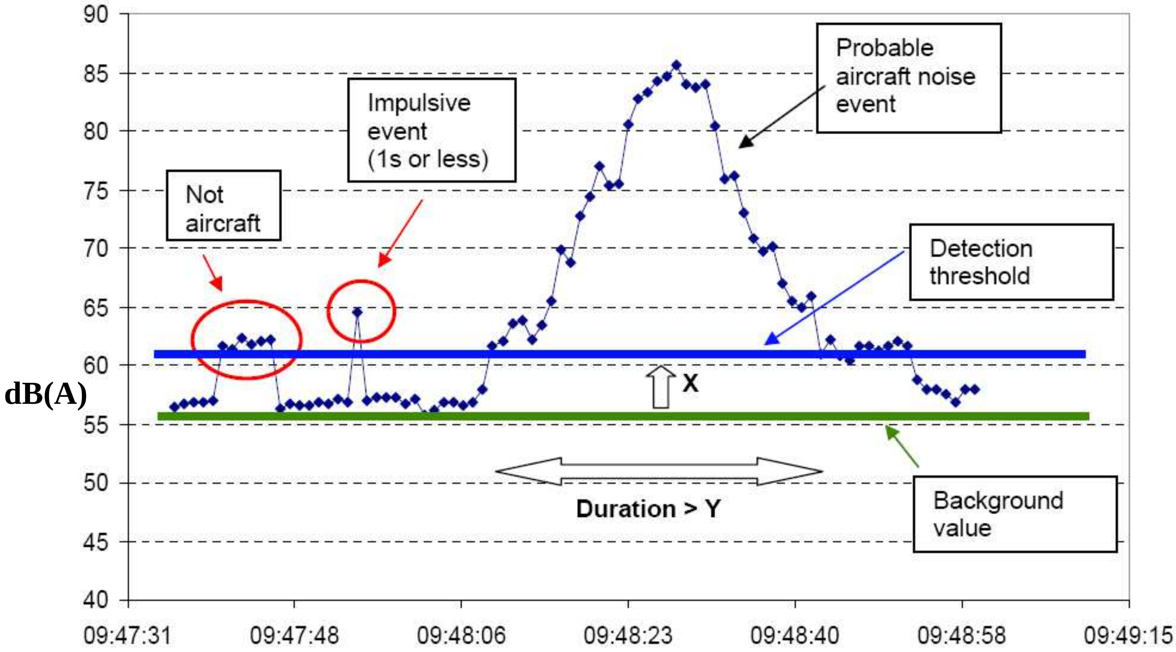

Figure 1: Typical measured aircraft event and depiction of the filtering procedure

Values of X and Y were adjusted for each site, but X=5dB and Y=7s were found to be adequate in most cases. For several sites, the more distant ones where noise levels were lower, the detection threshold was lowered: X=3dB; Y was also reduced to 5s. It was observed that even if occasional spurious noise contributions were then included within the dataset, there was minimal effect on the overall results as aircraft noise levels were dominant and controlling the energy averaged levels: less than 0.5 dB change was observed, typically.

It was also found that background noise did not greatly affect the overall derived long term aircraft noise levels. Subtracting the background level from all the calculated parameters lead to no more than 0.05 dB difference on the overall levels for most sites, and typically less than 0.5 dB for the more distant locations. Nevertheless, all noise levels presented are given after this correction.

B. Overall results

The filtered measurement results were used to evaluate maximum (L_{max}) as well as Day-Evening-Night noise levels (L_{den}). The latter includes a penalty of 5 dB for evening periods and 10 dB for night-time. The results are summarised graphically in Figures 2 and 3.

Figure 2 shows the average weekly L_{den} with an indication of range. Figure 3 displays both average aircraft L_{Amax} levels over the measurement period, as well as a range corresponding to twice the average weekly measured standard deviation of L_{Amax} levels, which would cover most of the levels typically measured.

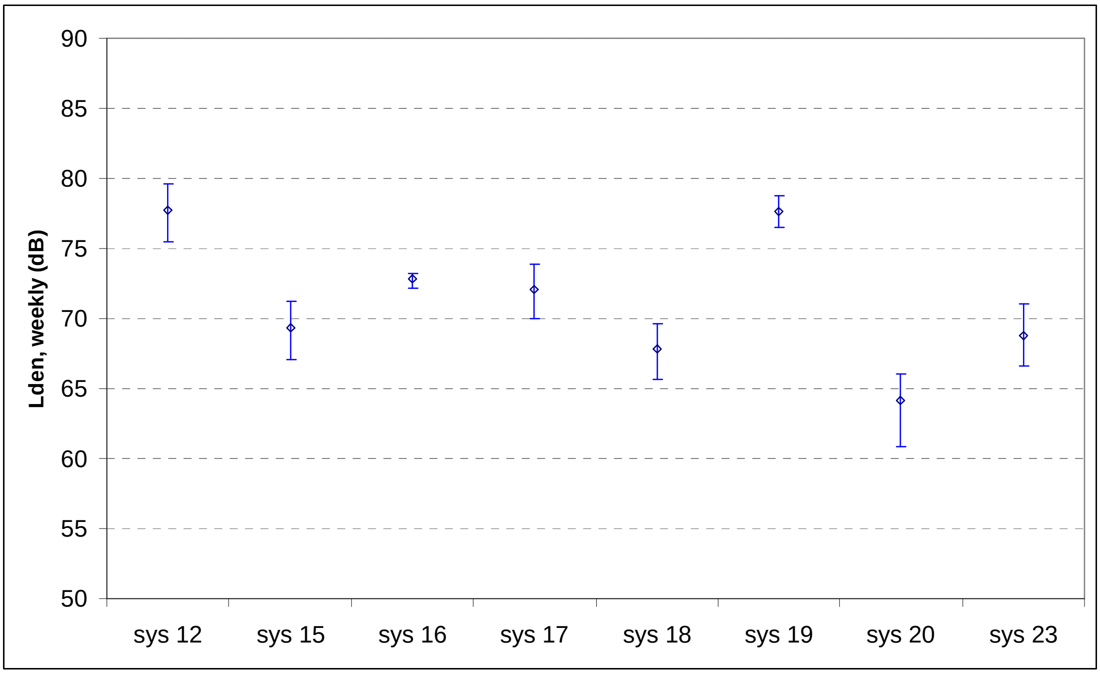

Figure 2: Average and range of measured weekly L_{den} noise levels

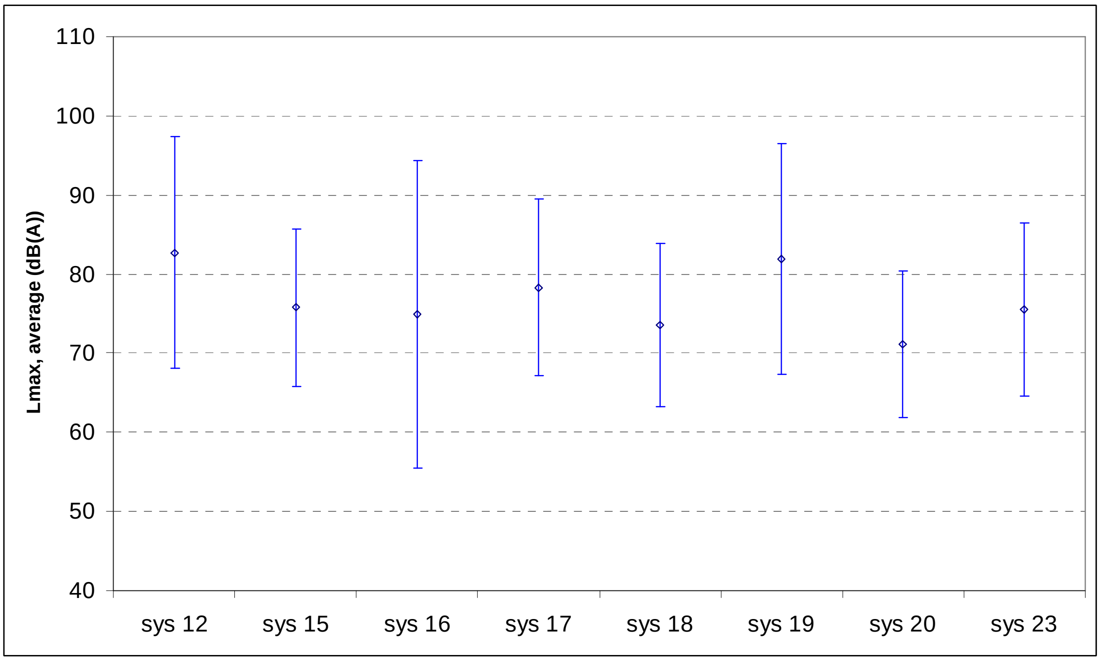

Figure 3: Average measured event L_{Amax} over the whole measurement period. The range shown represents twice the weekly average standard deviation of L_{Amax} levels.

C. Analysis of variability

Variability is an inherent characteristic of environmental sound fields. These variations are attributable to the changes in the type, number and character of sound sources influencing the environment in question, as well changes to the physical environment that alter the way in which sound propagates (most significantly in this situation, wind direction, wind speed, and to a lesser extent atmospheric humidity and temperature). There is a great variety of aircraft types utilising the Dubai airport, all possessing different noise emissions characteristics. Furthermore, traffic density and patterns, meteorological conditions, etc, vary daily and even hourly. Each pilot will take a slightly different trajectory even if following the same designated flight route. All these factors add up to a large potential for variability of the sound levels perceived throughout the affected areas.

The average values presented in the preceding sections provide a useful mechanism for producing a broad rating of a particular location of interest, and coincides with the types of longer term average ratings that can be estimated using noise prediction techniques. However, when utilising noise data to make objective decisions for particular applications (as may be the case when evaluating insulation requirements for noise sensitive buildings) it may be necessary to place greater emphasis on the noise that could occur during much shorter periods, such as intervals defined in minutes or hours.

The measurement data was captured in very short time intervals to enable the variability between short term and long term average noise levels to be investigated. A study of the variability was carried out for two of the measurement locations for a period of one week: see Figures 4 and 5. This shows the variation of the energy-average L_{Aeq} levels over a range of time-scales: five minutes, one hour, one day, and compares it to the weekly average. While daily values can vary by typically 2 dB around the weekly average, the range of variation in hourly values is of the order of 10 to 20 dB typically, which is significant.

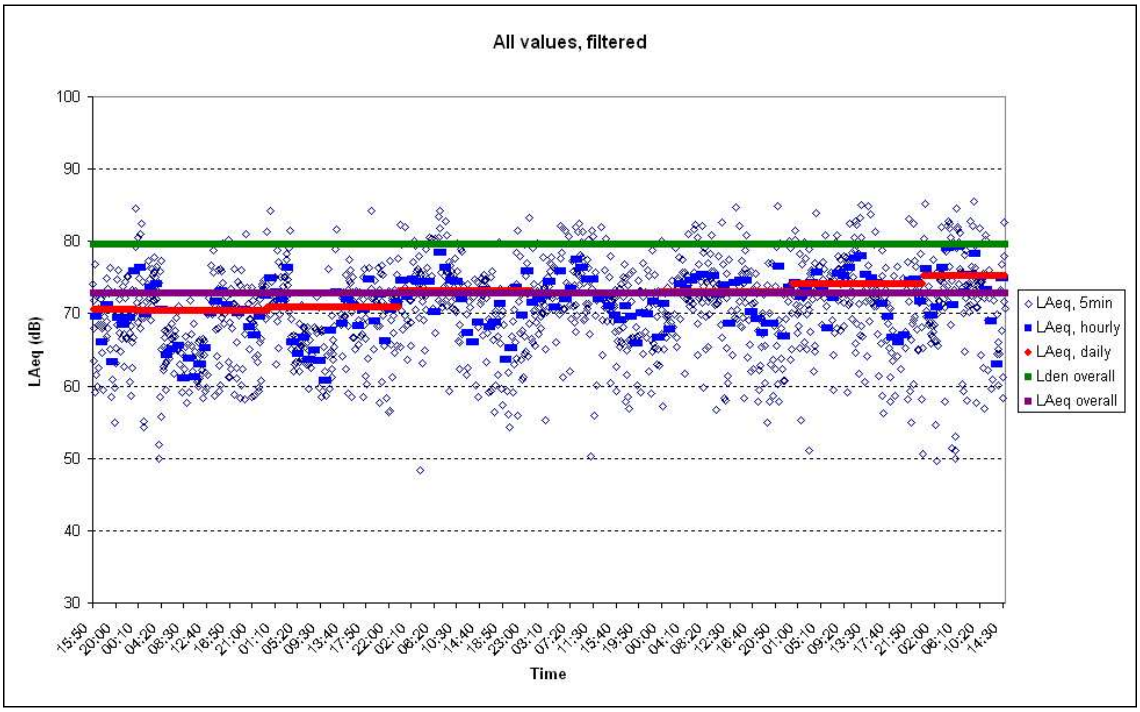

Figure 4: System 12 - week 2 data (filtered)

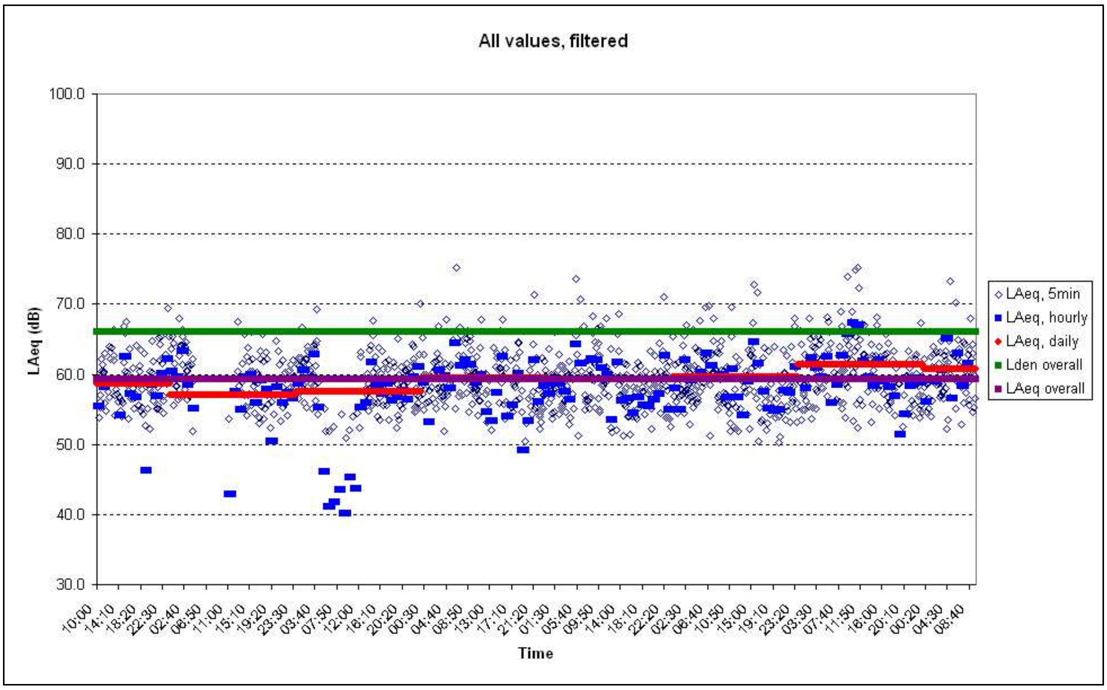

Figure 5: System 20 - week 2 data (filtered)

4. NOISE PREDICTIONS

In the case of aircraft noise modelling, predictions provide a method of producing long term average noise levels associated with average input conditions. Accordingly, an environmental aircraft noise model does not provide an exact simulation of day to day reality, but a representative estimate of the potential long term noise impact. The following type of information is required:

- Runway positions
- Aircraft types and numbers
- Aircraft flight paths, including ground tracks, vertical profiles, and takeoff/landing directions.
- Receiver location heights and distributions
- “Modal split”: distribution of directions in which aircraft take off and land

Following the publication of European Directive 2002/49/EC, noise mapping is now required across Europe as a way to manage Environmental Noise. To this effect, calculation methods were recommended in the European Directive 2003-613-EC. For aircraft noise, the ECAC Doc 29[1] method is recommended, as supplemented by a segmentation procedure described in the AR-INTERIM-CM report[2]. Consideration was given to a range of prediction methods but it was concluded that ECAC Doc 29 would be most appropriate for the study.

The methodology is implemented in the IMMI noise modelling software[3], produced by Woelfel, which is widely used for noise mapping projects and has been extensively validated.

It was recognised that the procedure for the model states that the predictions relate to average atmospheric conditions characterised by 25 degrees Celsius and 70% relative humidity. In the UAE, atmospheric conditions throughout the year clearly differ from this stated average. A theoretical study indicated that noise levels are expected to be lower by a factor of less than 1 dB in the higher temperatures encountered during the survey, because of reduced atmospheric absorption, leading to prediction which marginally overestimate the level of noise.

5. COMPARISON OF ANALYSIS AND MEASUREMENTS

A. Model set-up

The goal of constructing a reference model was not to directly predict the values which were measured in reality, but to investigate how these measurements relate to model outputs. To provide a comparison with the measurement results obtained from the noise survey, the predictions for the Dubai International Airport have been produced accounting for conditions that occurred over a 2 month period during July and August 2006 overlapping with the survey period. Where assumptions had to be made, the implications of variability were tested.

Each departure and arrival was classified according to the period in which it occurred (day, evening or night) and the aircraft types were identified according to the ICAO code. The aircraft types were then grouped into representative categories, or emission classes, according to the recommendations of the adopted noise modelling procedure. An analysis of measured frequency spectra for a sample of aircraft pass-by event confirmed that the source spectra used in the model were representative.

Horizontal flight tracks were taken from the standard Instrument Departure and Arrival charts for Dubai International. As detailed radar data for the flights was not available, the width of the flight corridors was estimated to be several hundred meters, increasing with distance from the runway as the flights disperse. Iterative trial calculations indicated that the effect of the exact corridor width was not significant to the calculations at the measurement locations.

The available information did not define the vertical takeoff profiles for aircraft departing from Dubai airport. In the absence of such detailed information, reference has been made to the standard takeoff profiles available for each of the reference classes of aircraft in the noise model. These standard aircraft profiles account for the typically preferred and unrestrained takeoff profile that is commonly observed for major aircraft type, and are generally regarded as representative data where detailed specific records are not available. The standard profiles were cross referenced against specific restrictions in place for Dubai International and for the purpose of noise modelling were found to be compatible.

B. Comparisons between predictions and measurements

Noise levels were computed for the locations of the measurement systems, using their GPS-measured positions and estimated heights. Figures 5 and 6 below provide a comparison of the predicted noise levels for the EU rating metric, the day-evening-night level (L_{den}), and maximum event levels (L_{Amax}), respectively.

To further demonstrate the relationship between measured and predicted levels, a more detailed comparison is presented for a single example measurement location, System 19, in Figure 7. This chart presents a comparison of the predicted L_{den} parameter with the measured values derived on a daily and weekly basis for a period of one week.

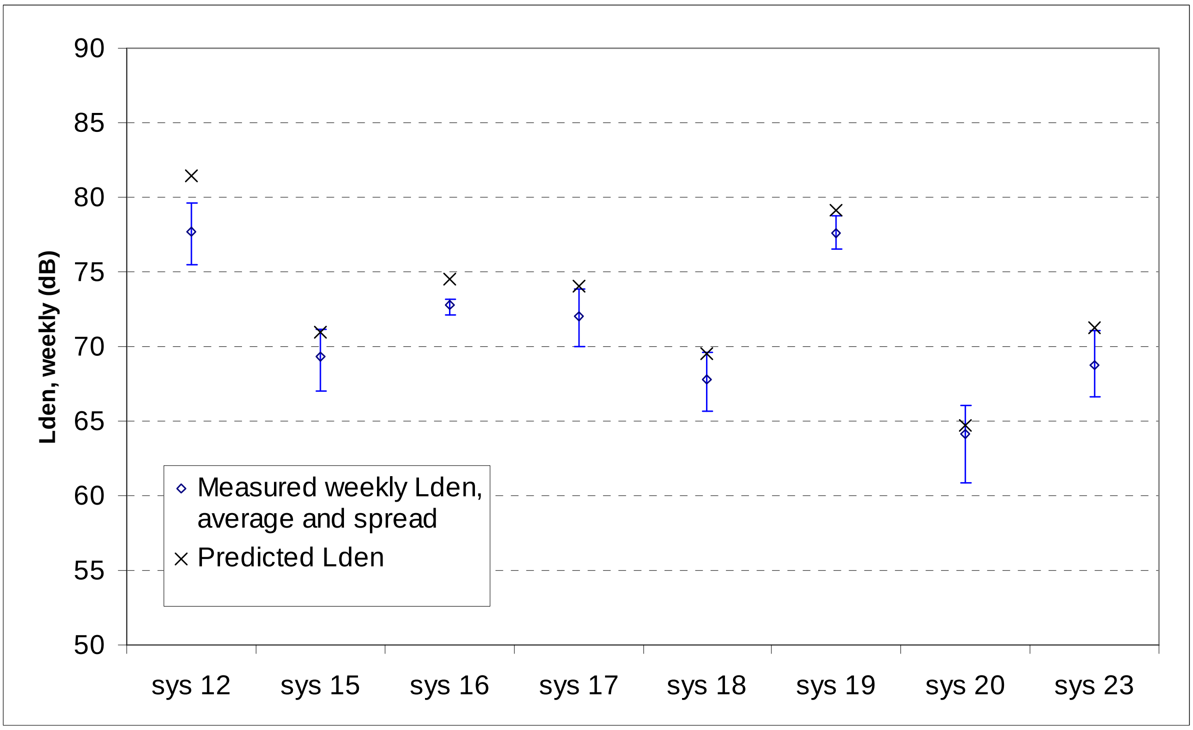

Figure 5: L_{den} levels - measurement and prediction comparison

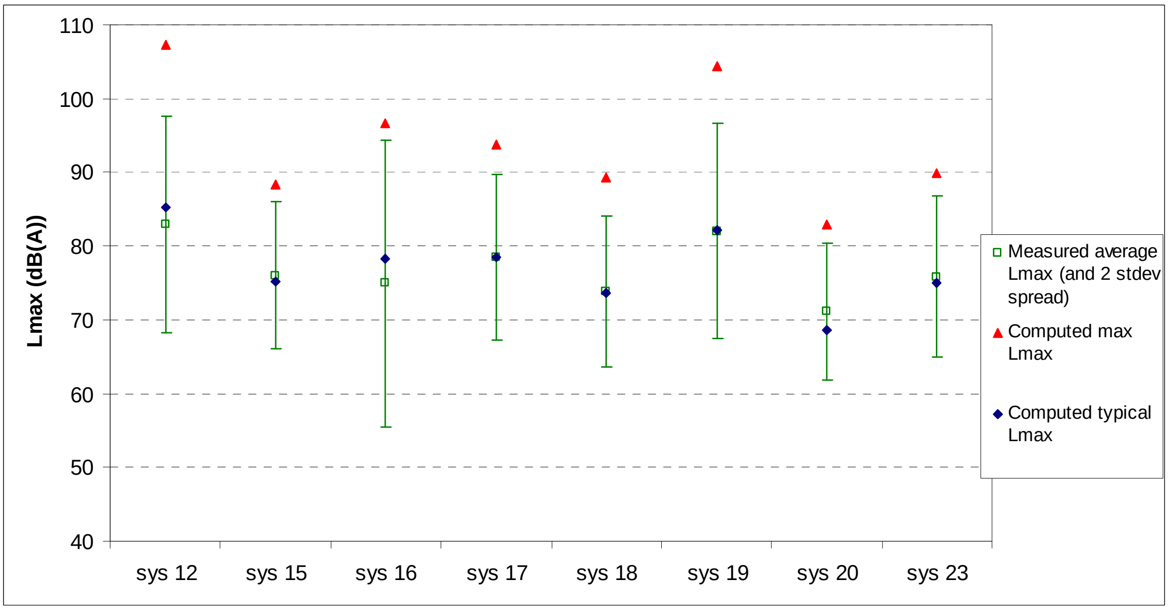

Figure 6: L_{Amax} levels - measurement and prediction comparison

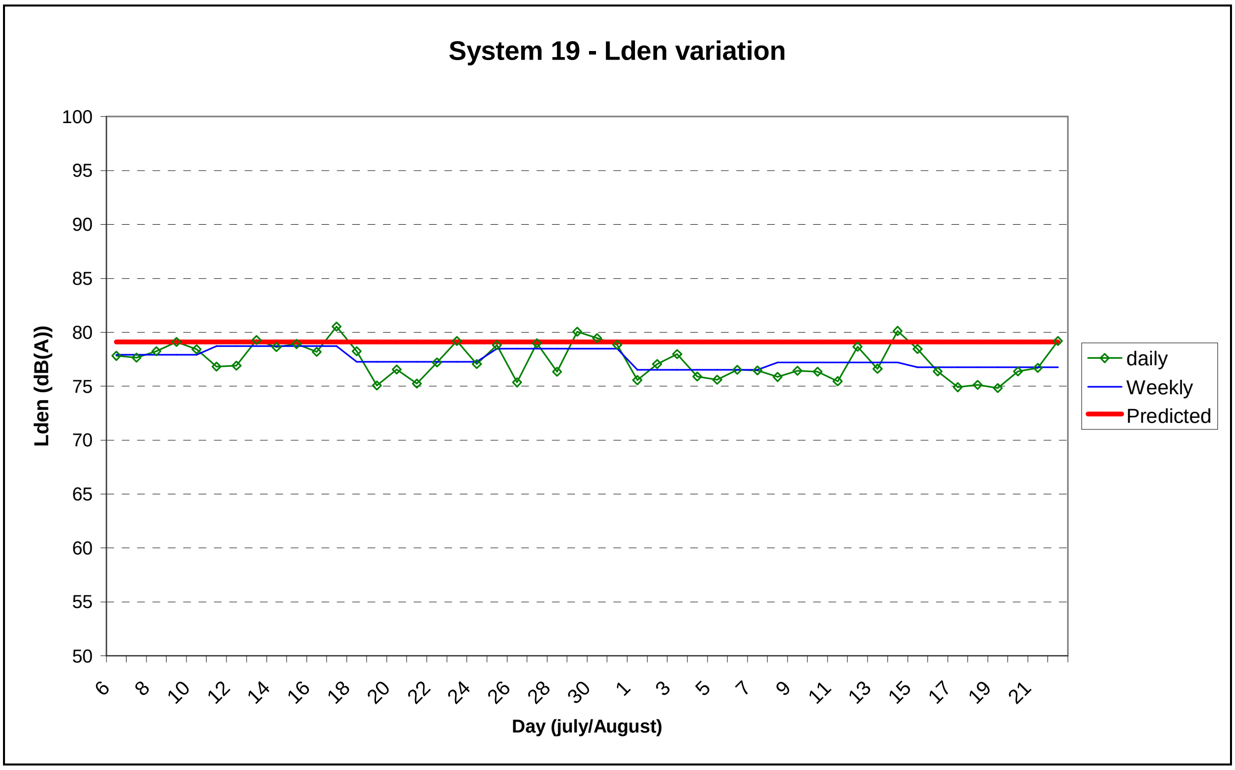

Figure 7: System 19, L_{den} levels, predicted and measured (daily and weekly)

The results of the comparison shown in Figures 5 and 7 indicate the predicted L_{den} noise levels are generally marginally above the average measured noise levels, and generally correlate very well with the upper range of levels. In particular, in Figure 7, the daily L_{den} determined from the measured dataset at this location was found generally to be within a 5 dB range between 75 and 80 dB. The predicted L_{den} falls at the upper end of this range of weekly L_{den} values, and above the large majority of daily values.

Figure 6 indicates the computed maximum noise levels associated with individual pass by events. The chart indicates two types of calculated maximum levels; a “max L_{max}” which represents the worst noise level generated by the entirety of the air traffic from Dubai airport (irrespective of how infrequent the noisiest aircraft event is) and a second representing a computation made with the one aircraft grouping that was most prominent in the aircraft data. The former and latter are presented for correlation with the maximum and average of the measurement range indicated. It is noted that the indicated measurement range represents the typical spread of values (statistically, two standard deviations or approximately 95% of the measured values). In considering the comparison of these noise levels, it is worth noting that such levels are widely variable as they relate to a very brief instant in time. Notwithstanding this characteristic variation of maximum noise levels, the predicted and measured levels again indicate a close degree of correlation.

Given the conservative design of the noise model demonstrated from its application to other large scale airports (for a large airport near Brussels, in Belgium[4]), these findings are in line with expectations.

6. CONCLUSION

Based on the above findings, the chosen methodology and approach is considered to have been a robust means of estimating upper average noise levels for the prevailing aircraft operations and environmental conditions at the Dubai International Airport, providing a positive indication of the model's suitability for assessing longer term aircraft noise trends in the Middle East. The relationships deduced from this comparison of predicted and measured noise levels provided a useful reference in the study of another airport development in the area.

The study highlighted that day to day or hourly variations from long term predicted value are commonly significant. This highlights the importance of using predicted data in its proper context, recognizing the strengths it can offer in terms of depicting longer term relative trends, but conversely the limitations or caution that must be applied when attempting to use such data for applications relating to shorter term assessment periods.

The results also highlighted that comparisons of predicted data with short term measurement studies may offer little meaningful results, since these comparisons are highly prone to the variations evident on the day or time of the measurement.

These observations were in line with guidance[5] on the measurement of environmental noise produced in the UK by a consortium which included Hoare Lea Acoustics.

ACKNOWLEDGEMENTS

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