IMPROVING THE ACCURACY OF RUNWAY ALLOCATION IN AIRCRAFT NOISE PREDICTION

David G. Southgate and Jonathan P. Firth

Aviation Operations, Dept of Transport and Regional Services (DOTARS), Canberra, Australia

Abstract

The accuracy of predictions about aircraft noise exposure patterns in the vicinity of airports is highly dependent on the way aircraft movements are allocated to runways during the forecasting process. Conventionally the allocation of movements to runways has been based on the use of 'wind roses' which provide information on wind patterns on an average day. Experience has revealed a number of shortcomings with this approach and DOTARS is now developing a concept for allocating aircraft movements to runways which avoids wind averaging. Work to date indicates that the new approach provides robust runway allocation outcomes and can deliver these very quickly through an essentially automated process. This concept facilitates the carrying out of rapid 'what-if' and sensitivity analyses and enables noise exposure patterns to be reported using descriptors which go beyond the conventional 'annual average day'.

Introduction

In an Environment Impact Assessment (EIA) process the accuracy of aircraft noise exposure forecasts in the vicinity of an airport is likely to be heavily influenced by the robustness of the method used by the noise modeller to allocate aircraft types and movement numbers to the airport's runways.

Conventionally the allocation of aircraft movements to runways is carried out using some form of wind averaging approach. Experience has shown that these approaches do not necessarily generate robust outcomes. For example, in the 1990 Environmental Impact Statement (EIS) for the proposed third runway at Sydney Airport a wind averaging approach gave a prediction that the non-preferred runways would only be used for about 13% of the time if the project were undertaken [1]. In practice, once the third runway opened in late 1994, the non-preferred runways were used for about 30% of the time. The discrepancy between the prediction and outcome led to the credibility of the EIS being very seriously questioned. The Senate Select Committee on Aircraft Noise in Sydney was highly critical of way in which the wind analysis work had been carried out in the project's Environmental Impact Statement (EIS) [2].

In practice it would appear that different levels of sophistication are used when applying wind averaging approaches. Some of the methodologies currently being adopted are clearly inadequate while others appear to be very rigorous and detailed. Nevertheless, as shown later in the paper, applying the 'right' wind analysis methodology does not necessarily deliver the 'right' answer.

Irrespective of the above, even if a technically correct prediction of the noise exposure patterns is given for the 'annual average day', this does not necessarily present a very 'accurate' picture of the noise when viewed from the layperson's perspective. Average day information leaves the decision-maker and the community with no real feel for the extent of the likely variations in aircraft noise exposure patterns – fundamental information when describing aircraft noise which typically varies very markedly from hour to hour, day to day and season to season

The Department has developed a proposed new approach for allocating movements to runways in an effort to overcome these shortcomings. The key driver of this work was the issue raised in the previous paragraph – the imperative to generate a picture of future aircraft noise that goes beyond the annual average day.

Conventional Approach

The conventional method of predicting runway availability from historical wind data is to construct a 'wind-rose' showing the average wind strength and direction at an airport site over an extended period of time (typically a period between 10 and 40 years).

In its simplest form runway availability is calculated by applying selected crosswind and downwind limits to the averaged wind data to arrive at a percentage of time for which particular runways are available. This is then applied to forecast traffic on the 'annual average day' and movements are allocated to runways based on a predetermined hierarchy of noise preferred runways. In an example where runway usage is entirely dependent on wind speed and direction (and is independent of the traffic levels) the usage is directly translated from the availability numbers. For example, if wind allows the noise preferred runways to be available for 80% of the time it is assumed that 80% of the movements at the airport will be on those runways.

This approach is not particularly robust since it does not match the diurnal variations in wind with the diurnal variations in traffic flows – both of these factors can vary widely throughout the day.

A more sophisticated approach was used by the specialist aviation consultants who provided the runway allocations used in the Sydney Airport third runway EIS [3]. This approach addressed the weakness identified in the preceding paragraph by developing an hourly profile for the traffic at the airport on a representative series of typical days and then analysing the probability of the wind speed and direction at the times of the traffic. This approach therefore allocated the traffic to the runways in a way that matched the variations in diurnal and seasonal wind conditions with the variations in diurnal and seasonal traffic conditions. Nevertheless, as indicated earlier, this produced a runway use forecast which proved extremely inaccurate in practice.

Suggested New Approach

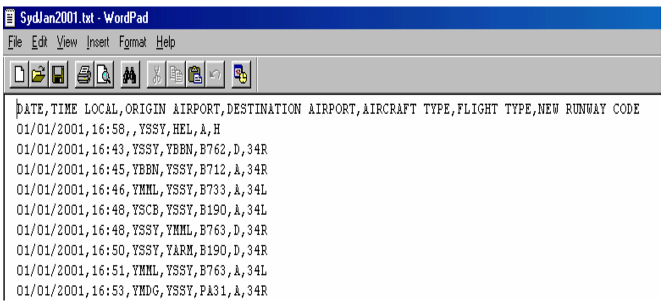
Methodology

In essence, the proposed new approach differs from the conventional approach in that instead of allocating movements to runways **after** having averaged the wind and aircraft movement data it allocates the movements to the runways **before** the averaging.

The proposed new approach takes advantage of the fine resolution wind data sets that are now available. In the past runway allocations have been based on the use of three hourly wind data – wind data sets of 1 minute resolution are now commonly available. Wind data in this form allows movements to be allocated to runways on a movement by movement basis rather than through an averaging process.

The starting point when carrying out a study under the new approach is to construct an aircraft movements data set. This data set differs from the conventional approach in that instead of generating traffic data for an average **day** it is based on generating movements data sets for a future **year** or years. The Department has developed a concept computer program which facilitates the building of these future year data sets [4].

A movements data set contains one line of data for each movement at the study airport. Each line of data contains seven variables – an extract from the 2001 dataset for Sydney Airport is shown in Figure 1.


SydJan2001.txt - WordPad
File Edit View Insert Format Help

```
DATE,TIME LOCAL,ORIGIN AIRPORT,DESTINATION AIRPORT,AIRCRAFT TYPE,FLIGHT TYPE,NEW RUNWAY CODE
01/01/2001,16:58,,YSSY,HEL,A,H
01/01/2001,16:43,YSSY,YBBN,B762,D,34R
01/01/2001,16:45,YBBN,YSSY,B712,A,34R
01/01/2001,16:46,YMML,YSSY,B733,A,34L
01/01/2001,16:48,YSCB,YSSY,B190,A,34L
01/01/2001,16:48,YSSY,YMML,B763,D,34R
01/01/2001,16:50,YSSY,YARM,B190,D,34R
01/01/2001,16:51,YMML,YSSY,B763,A,34L
01/01/2001,16:53,YMDG,YSSY,PA31,A,34R
```

Figure 1. Example of Aircraft Movements Data Set

The key feature of these movements data sets is that the information is 'time stamped' – the data sets contain the date and time of each movement throughout the year.

When constructing the data set for a future year, the first six variables in each line of data can be built up by injecting movements into a data set for a current year. This injection is achieved by forecasting growth/reduction in traffic between the study airport and other airports on a route by route basis. The seventh variable, the allocated runway, has to be determined in one of two ways.

In circumstances where the project being examined does not involve a change of runways or a change in the hierarchy of runway selection rules, the movements data set for the current year already contains embedded wind data and the current runway use patterns can be retained during the injection process. However, in circumstances where the current runway use patterns do not provide a guide to future runway use patterns the movements in the future year need to be allocated to runways through cross matching the aircraft movements data with historic wind data [5].

Wind data sets for an airport are obtained from the Bureau of Meteorology (BOM). The first step in allocating the movements to runways is to convert the wind speed and direction into downwind and crosswind components for each of the runways at the study airport. Rules are then selected for the allocation process. Firstly operational criteria need to be established. For example, the downwind limit would typically be set at 5 knots and the crosswind limit at 20 knots. Secondly a hierarchy of runway operating modes needs to be selected. For example, the noise preferred operating mode may be for all take-offs to be off Runway X. In some wind conditions all runway modes will be available while in some conditions only one mode may be operationally feasible.

In addition to wind constraints, the use of some runway modes may be constrained by the number of aircraft movements they can handle. This factor can be built into the allocation process.

The runway allocation process involves sequentially examining the wind conditions at the date and time of each individual operation in the movements data set and allocating it independently to a runway based on the determined allocation rules. Using a Microsoft Access application developed by the authors this movement by movement allocation process for one year data sets typically takes about 30 minutes for an airport with about 300,000 annual movements.

If the allocation is to be based on say 10 years of past wind data this allocation process is carried out ten times and the final product is ten separate annual movement data sets with the format shown in Figure 1 (also see the Worked Example in the next section). These data sets can, if desired, be reduced down to an annual average day for use in, say, the US Federal Aviation Administration's Integrated Noise Model (INM), or can be used in the Department's noise transparency software TNIP (Transparent Noise Information Package) [6].

The robustness of the allocation process could be improved by refining the rules to take account of certain circumstances. When using fine resolution data sets it will be necessary to ensure that the automatically generated movements files do not contain unrealistic repeated switching between runway modes. The allocation rules may need to be modified to take account of Air Traffic Control (ATC) behaviour – ATC generally tries to avoid changing runway modes during peak periods and in practice may well change runways 'early' in anticipation of a forecast wind change. While wind direction and speed are taken to be the primary weather related determinants of runway use, other weather factors such as wet runways or low cloud may be important influences on runway selection at some airports.

Advantages

The proposed new method has a number of key advantages.

Principally, it allows an automated approach. While some of the approaches currently used are robust they are quite laborious [7]. Automating the process means, in particular, that it is feasible to carry out a range of 'what-ifs' at the analysis stage to test the sensitivity of runway allocations to variations in wind patterns and changes in factors such as the runway use criteria and the selected allocation hierarchy. These sensitivity analyses enable the decision-maker and the community to get a much more 'accurate' picture of likely noise outcomes.

The proposed new method inherently takes into account both the hourly/daily/seasonal pattern of movements at the airport and the hourly/daily/seasonal variations in wind speed and direction.

Very importantly, not averaging the data enables 'time stamped' noise information to be produced. For example, using TNIP allows noise information to be generated for sensitive times in a day or a week, for separate seasons in one year or for a series of years to illustrate annual variability. This provides a much more useful picture of aircraft noise than that generated for the conventional annual average day.

Worked Example – Sydney Airport Third Runway

The situation surrounding the opening of the third runway at Sydney Airport provides an ideal example for testing the validity of the proposed new approach.

The third runway at Sydney Airport opened in November 1994. Operational modes at the airport were changed from those based on a pair of intersecting runways to modes based on maximizing use of the two parallel runways. The noise preferred parallel mode was southerly flow - arrivals from the north with departures to the south over Botany Bay.

As indicated earlier, an analysis of historical wind data in the EIS for the third runway project had predicted that 86.0% of all operations could be handled under the preferred mode with only 12.8% of movements handled in the reverse, northerly flow, mode. However in the first full year of operation northerly flow accounted for 31% of all movements.

As the first step in the validity testing process the proposed new approach was calibrated using actual operational data for Sydney Airport using parallel runways. The Airport only operated in a full parallel runway mode for one calendar year – 1995. Therefore the aircraft movement data set for 1995 was cross-matched with the 1995 wind data to ascertain how closely the actual runway usage matched the runway usage patterns computed using the proposed new approach. The analysis was based on half hourly average wind speed and direction data obtained from the Bureau of Meteorology.

The analysis was repeated using three hourly wind data to see how great a loss of accuracy occurred. Testing of the three hour data was carried out because before 1994 only three hourly data was available and this is what had been used in the EIS analysis. Three hourly data was simulated by extracting three hourly records from the half hourly data set.

The results of this initial analysis are presented in Table 1.

Table 1. Actual and Computed Percentage of Northerly Flow Movements at Sydney Airport (06:00 – 23:00) for 1995

Month	**Actual**	**Half Hour Wind**	**3 Hour Wind**
Jan 95	43.8%	34.1%	34.8%
Feb 95	31.9%	23.7%	23.4%
Mar 95	19.4%	18.2%	18.1%
Apr 95	24.8%	25.4%	19.2%
May 95	24.8%	24.9%	25.8%
Jun 95	26.4%	30.2%	27.9%
Jul 95	27.0%	29.5%	28.4%
Aug 95	33.5%	32.8%	34.9%
Sep 95	28.8%	26.8%	23.1%
Oct 95	31.0%	29.4%	28.7%
Nov 95	43.1%	36.5%	32.6%
Dec 95	38.6%	37.8%	35.8%
Total	**31.0%**	**29.2%**	**27.8%**

It can be seen that both the half hour and three hour wind data sets give results which are in acceptable agreement with the figures for actual usage, with the half hourly wind data giving a marginally better agreement than the three hourly data. While it would be desirable to check this calibration against further operational examples if the data were available, the results shown in Table 1 suggest that the proposed new method is robust.

Having calibrated the new method it was then applied to the ten years of wind data (1978 to 1987) that were used in the EIS analysis. The actual aircraft movements from 1995 were assigned to a notional parallel runway regime using the wind data for each of the ten years to produce ten separate 'what-if' scenarios based on 1995 traffic. An average figure for the whole ten year period was then derived from the individual year data. The results of this analysis are presented in Table 2.

This analysis generated a proportion of northerly flow movements for the years 1978 to 1987 which was significantly lower than the computed and actual outcomes for 1995 shown in Table 1. Very importantly the computed average proportion of northerly movements (12.8%) was directly in line with the prediction contained within the EIS.

This outcome, involving two quite different approaches giving the same result, built confidence in the computational validity of both approaches. However, while this agreement was reassuring it left open the question of why the actual operations in 1995 were so different to the predictions made in the EIS using the 1978 to 1987 wind data.

An explanation is provided in a 1997 paper from the Bureau of Meteorology Research Centre (BMRC) which suggests that the problem may result from the quality of the wind data [8]. From 1939 until August 1994 wind readings for Sydney Airport were taken from a Dines pressure-tube anemometer located near the intersection of the two runways. From 16 August 1994 readings were taken from a new Synchrotac anemometer located near the threshold of Runway 34L. The BMRC report contains an analysis of average wind speeds from 1940 to 1995 and concludes that at the time of the changeover readings from the old anemometer required an adjustment of +2.7 m/s (5.2 knots) to match those recorded by the new instrument.

To ascertain the significance of this under reporting of wind speed a sample year – 1984 – was selected. The wind speed records for this year were increased by 5.2 knots for all wind speeds greater than 0.5 knots and the 1995 movements were re-allocated to runways, in the same manner as used in the computation of Table 2, using the adjusted wind data. It should be noted that the adjustment factor for 1984 may have been different to that for 1994 but this level of detail is not provided in the BMRC report. For this analysis it was assumed that the 1994 adjustment factor could be applied to the 1984 data. The results of this re-allocation are presented in Table 3.

Table 2. Computed Percentage of Northerly Flow Movements at Sydney Airport (06:00 – 23:00) for 1978-1987 'What-if' Scenarios using 1995 Traffic Data

	Year of Wind Data										
Month	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**Ten Year Average**
Jan	12.3%	23.7%	13.8%	15.4%	12.8%	15.7%	17.4%	15.2%	22.7%	13.7%	16.3%
Feb	16.1%	18.6%	13.3%	5.7%	19.5%	11.7%	12.3%	22.3%	15.0%	23.7%	15.8%
Mar	11.6%	9.0%	6.0%	7.6%	7.3%	19.2%	10.9%	9.6%	16.5%	5.2%	10.3%
Apr	2.9%	10.8%	11.6%	1.2%	6.8%	12.1%	8.6%	1.0%	10.6%	6.7%	7.2%
May	6.1%	0.9%	6.7%	4.2%	12.2%	11.8%	2.3%	2.5%	1.2%	4.7%	5.3%
Jun	6.8%	1.5%	15.6%	19.1%	0.6%	11.3%	5.1%	1.9%	2.5%	4.2%	6.9%
Jul	10.1%	11.2%	9.2%	12.2%	1.7%	11.3%	15.1%	4.8%	12.9%	3.4%	9.2%
Aug	7.2%	8.2%	17.1%	15.4%	9.0%	12.8%	24.1%	14.9%	16.9%	6.9%	13.2%
Sep	15.3%	26.0%	21.6%	12.1%	13.0%	29.9%	11.4%	5.4%	6.8%	12.2%	15.4%
Oct	17.5%	17.4%	24.7%	12.8%	11.4%	15.8%	15.5%	19.2%	15.1%	18.9%	16.8%
Nov	15.3%	16.7%	23.9%	10.4%	17.6%	20.5%	12.3%	15.4%	10.9%	37.1%	18.0%
Dec	18.5%	24.2%	22.2%	19.6%	13.0%	11.2%	9.9%	21.4%	24.8%	23.1%	18.8%
Total	**11.7%**	**13.9%**	**15.6%**	**11.4%**	**10.3%**	**15.3%**	**12.1%**	**11.1%**	**13.0%**	**13.3%**	**12.8%**

Table 3. Computed Percentage of Northerly Flow Movements at Sydney Airport (06:00 – 23:00) Using Adjusted 1984 Wind Data and 1995 Traffic.

Month	% Northerly Flow
Jan	29.5%
Feb	24.7%
Mar	19.4%
Apr	23.7%
May	28.5%
Jun	28.9%
Jul	37.3%
Aug	50.3%
Sep	22.6%
Oct	28.8%
Nov	22.1%
Dec	21.8%
Total	**28.2%**

It can be seen by cross comparing the 1984 entries in Tables 2 & 3 that adjusting the wind speeds resulted in a significantly different figure for the proportion of northerly flow movements (it increased from 12.1% to 28.2%). The percentage obtained using the adjusted wind data was similar to the actual and computed results for 1995 shown in Table 1.

This analysis would appear to indicate that the discrepancy between the EIS prediction and outcome for the third runway at Sydney Airport arose because of shortcomings in the wind data sets rather than failings in the assessment methodology used. The evidence suggests that there was no significant change in the wind regime between the 1980s and the 1990s and that a 10 year wind data set can provide a sound basis for runway allocation predictions.

Many of the concerns of the wind analysis in the third runway EIS focused on gusts and the influence these would have on predictions of runway availability due to crosswinds [9]**.** The analysis in this paper suggests that the critical wind factor for runway allocation for Sydney Airport is the downwind and that robust results can be obtained without the need to make specific allowance for gusts.

Conclusions

The work to date indicates that the proposed new method provides robust runway allocation predictions. Further testing of the method, using a range of airports with different wind and traffic regimes, is required to confirm the preliminary findings.

While the indications are that predictions arrived at using this method are not likely to be significantly different from those achieved using a rigorous application of wind averaging techniques, the proposed new methodology is much simpler and quicker than conventional wind analysis approaches. It therefore provides opportunities for the carrying out of multiple sensitivity analyses through the examination of a range of what-if scenarios.

The nature of the proposed new system is such that it can be essentially automated using a simple software interface.

The worked example for Sydney Airport indicates that predictions of the levels of runway use for that airport are going to be highly sensitive to variations in the wind regime for wind speeds under 10 knots. This reinforces the need for EISs to contain sensitivity analyses for runway allocations. It also reinforces the need to ensure the robustness of the wind data sets that are being used for the runway allocation predictions in EIS processes.

The proposed new approach is particularly attractive in that while it still enables the generation of conventional noise contours it also facilitates the production of noise information which goes beyond the annual average day. The 'time stamped' data sets underpinning the system enable both long and short term variations in noise exposure patterns to be revealed and also allow the generation of noise information for sensitive times.

References

[1] Kinhill Engineers, *Proposed Third Runway Sydney (Kingsford Smith) Airport: Draft Environmental Impact Statement,* Section 10.4, 1990.

[2] *Falling on Deaf Ears,* Report of the Senate Select Committee on Aircraft Noise in Sydney, paragraphs 7.34-7.50, 1995.

[3] Kinhill Engineers, *Proposed Third Runway Sydney (Kingsford Smith) Airport: Supplement to the Draft Environmental Impact Statement,* Vol 1, Section 10.4, 1991.

[4] Department of Transport and Regional Services, *Transparent Noise Information Package Future Year Builder* http://www.dotars.gov.au/avnapt/sepb/and/tnip.htm#FYB

[5] Op cit 4, TNIP Future Year Builder User Manual.

[6] Department of Transport and Regional Services, *Transparent Noise Information Package* http://www.dotars.gov.au/avnapt/sepb/and/tnip.htm

[7] Op cit 3.

[8] Potts R, Monypenny P, Middleton J, “An analysis of winds at Sydney Kingsford Smith Airport and their impact on runway availability”, BMRC Research Report No 62, Bureau of Meteorology Research Centre, 1997.

[9] Op cit 3, paragraphs 10.4.1-10.4.3.