

Disaggregate Assessments of Population Exposure to Aircraft Noise

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1 INTRODUCTION

The dual pressures of rapidly growing air passenger and freight traffic and increasing numbers of people living in close proximity to airports and flight-paths is a major social problem in many urban centres around the world. While this impact is manifested through various externalities (e.g., noise, air pollutants, greenhouse gases), it is noise that is the most tangible issue affecting the health and well-being of affected residents. A review of the recent epidemiological literature on this topic, suggests exposure to aircraft noise is linked with a range of psychological, physiological, and cognitive performance effects, including disrupted sleep (Franssen et al., 2004), increased stress and annoyance (Meister and Donatelle, 2000; Bronzaft et al., 1998), hypertension (Rosenlund et al., 2001), reading difficulties for children (Haines et al., 2002), and potentially hearing loss (Chen et al., 2001). It is also clear that the relationship between noise received (dose) and health outcomes (response) is highly complex and depends on many factors (Franssen et al., 2002). Key among these are aircraft movements (numbers, time between movements, respites/breaks, curfews), the intensity of movements, which relate to both aircraft type and the position relative to affected residents, the time of flights, with greater impacts reported for early mornings, evenings and week-ends (Carlsson et al., 2004), whether the aircraft are departing or landing and how this relates to height, the use of thrust, and engine whine, and the different sensitivities and reactions of people to noise (NAL, 1982).

While the health impacts of exposure to aircraft noise continue to be investigated the fact remains that airport operational policies and future plans for capacity expansion must be based on the best possible information on those *at risk* of exposure. Generally, this risk is assessed by computing aircraft noise dosage for a 'typical' day of operations, which is then combined with residential population estimates from a census or other appropriate source. While this gives an overall impression of what might be termed the total 'noise load' such an approach in our opinion suffers from two major short-comings. First, there is significant inter- and intra-day variability in aircraft movements, implying the use of an average does not relate to what is really happening across time. Second, the use of residential-based population estimates do not reflect the fluctuations that occur as people go about their daily lives.

This paper details an approach designed to address both of these problems. The approach takes hourly GIS-based flight movement information and combines this with hourly population estimates that we derive through a computational procedure from a household travel survey. We then apply the approach to study a range of scenarios associated with operations at Sydney's Kingsford-Smith International airport. The results and insights have important ramifications for policy-makers planning flight operations and residential settlement patterns in impacted areas.

2 STUDY METHODS

The quantification of the potential health impacts of aircraft noise requires estimation of 1) noise dosage, 2) the number of people at risk, and 3) the impacts of aircraft noise.

2.1 Estimation of Aircraft Noise Dosage

The general approach for quantifying aircraft noise is to use a metric that describes the total accumulation of sound energy at a given location over some period of time. This metric varies from country-to-country, but typically encapsulates details about the flights (e.g., total

number, maximum noise levels, times at which flights occur) for an annual average day of operations (Franssen et al., 2002). Noise contours are then defined based on joining locations (represented by grid-points) of similar levels and it is these contours that are typically reported on maps and form the bases for policy decisions. In Australia, the metric used is known as the Australian Noise Exposure Forecast (ANEF). The ANEF originated from the U.S. NEF system, with the results being tailored to Australian conditions based on a major noise annoyance survey conducted in the early 1980s by the National Acoustics Laboratory (NAL) involving 3,375 residents living around the airports in Sydney, Melbourne, Adelaide, and Perth (NAL, 1982). The major difference, between the two systems is in the definition and weighting given to sensitive times, which the ANEF defines as 7 pm to 7 a.m. and weights flights at that time by four times, compared to 10pm to 7am and a 10 times weighting for the NEF.

The ANEF is an appealing metric as it incorporates information about flights and community reactions to noise in one measure. It is also the legal noise metric for land use planning controls around airports in Australia. For instance, while no development restrictions are imposed for areas outside the 20 ANEF contour, no new housing is permitted in areas above 25 ANEF and insulation of existing houses is required if the ANEF exceeds 30. However, while the ANEF gives an overall impression of conditions on an average annual day, it does not reflect the fact that operations are in reality quite variable both within and across days, reflecting weather conditions (wind direction in particular), capacity issues, noise-sharing regulations, and air traffic control decisions. It has also faced criticism from the perspective of clearly reporting the impacts of aircraft noise in terms the general public can clearly understand (Australian Parliament, 1995). For instance, the impression given by the ANEF is areas outside the 20 ANEF are not impacted by aircraft noise, yet based on recorded complaints data, this is clearly not true (DOTARS, 2000). A final point that should be realised about the ANEF is that conditions are vastly different from those at the time of the conduct of the NAL survey in the early 1980s. The number of flights/day has increased dramatically - for instance, in Sydney, there were 277 flights/day in 1982, compared to 765 flights/day in 2005. On the flip-side, technological developments have led to quieter aircraft and noise-sharing regimes have been instigated to try to mitigate the overall impact to residents.

In response to these limitations of the ANEF, and largely due the 3rd runway controversy in Sydney in the mid-1990s (Australian Parliament, 1995), a new reporting mechanism was developed by the Department of Transport and Regional Services (DOTARS, 2000). Known as the Transparent Noise Information Package (or TNIP), this freely available software enables a more comprehensible method of reporting enabling users to produce graphical outputs displaying flight paths and tracks, the number and range of events above a certain decibel range for specified time-periods and days, the proportion of days and hours with no movements etc. Underlying TNIP is the U.S. Federal Aviation Administration's Integrated Noise Model (INM), which is widely used for forecasting aircraft noise impacts in the United States (DOTARS, 2000). For the purposes of the current project, we used the TNIP *Partial Contour* module to compute the number of events above 70 db(A)¹, termed 'N70 events', for the scenarios detailed in the results section of this paper. The rationale for this measure is 70 db(A) equates to 60 db(A) inside a house with open windows, which is the sound at which noise will interfere with conversations and watching television and is the design sound standard for normal domestic areas (Australian Standard 2021).

2.2 Determining the Number of People at Risk of Noise Exposure

Determining the number of people at risk of exposure to aircraft noise requires knowledge of where people are throughout the day and across the week. This is clearly a much greater challenge than knowing where aircraft are and as a result conventional practice is to approximate the location of people based on their residential location from a census or other

¹ Environmental sound is measured in A-weighted decibels, notated as db(A), which are designed to sum sounds across frequencies to correspond to the way people hear.

suitable source (Franssen et al., 2002; Moreno-Jimenez, 2003). The appeal here is the data are readily available and when used in conjunction with aggregate noise metrics such as the ANEF, give an impression of the general impacts. The downside is this does not reflect noise experiences faced by people as they go about their daily lives. For instance, residents in noise-affected areas who work or go to school will likely be most affected in the early mornings and evenings, but not during the day (unless of course they work in a noise-affected area!). Conversely, other segments of the population (e.g., new mothers, pre-school children, elderly) are more likely to be at home for longer periods and during the day, so may likely experience more noise over the day.

To start to address this problem, we adapted a method originally developed and detailed by Roddis and Richardson (1998) for computing daytime populations. The approach uses trip start and end times and locations from a household travel survey as the basis of a query to establish how many people were at a particular location at a particular time. For our application, we used the Sydney Household Travel Survey (SHTS), a one-day continuous travel diary survey of residents in the Sydney Greater Metropolitan Area. Based on advice from the survey sponsors, the Transportation and Population Data Centre (TPDC), we used a five year pooled data set (1998 – 2002). This dataset comprised 42,790 people who made a total of 179,887 trips across all seven days of the week. To obtain population estimates, the sample was weighted up to the 2001 census population based on age, gender, and home location.

There were caveats with using this approach for our particular application. First, given that aircraft noise impacts are relatively localised (as we demonstrate later in this paper), we needed to employ the maximum spatial resolution possible in our population counts taking into account the fact of diminishing sample sizes per unit area selected. Based on some experimentation, we concluded Traffic Zones (TZs), of which there are 1,100, represented a reasonable compromise. We do acknowledge this could potentially result in some discrepancies if a TZ has very low representation from the SHTS sample, but fortunately most of the affected zones in proximity to the airport were also the most heavily sampled. Second, given that noise impacts and population movements exhibit different characteristics not only within days but across days we wanted to employ the maximum temporal dimension possible. Conceivably, while the nature of the survey implies we could generate a population for a specific day, this would clearly result in too small a sample for reliable results at the TZ level. At the other extreme, using the entire sample, while giving us the benefit of the entire 42,790 people, represents a 'typical' day, which is of limited utility for our study. The compromise we selected was to construct separate weekday and weekend populations, which used 5/7^{ths} and 2/7^{ths} of the sample respectively. Note, in this paper, we only report on weekday results as we found the weekend sample was too small to maintain reliability at the TZ scale. A potential option to address these small-area sample size issues is discussed in the concluding section of the paper.

The next part of the problem was how to assign noise dosage from TNIP to the population in the TZs. TNIP provides spatially referenced grid-points (i.e., those used in the original INM study) with the N70 values attached. These grid-points were imported into GIS software and overlain on the TZ layer. From there it was a simple matter of tagging each grid point to the appropriate TZ, using GIS point in polygon functions. Once this was done, the population of each TZ was equally assigned to each grid-point in proportion to the number of grid-points in that TZ. To illustrate how this works, consider the case of TZ164 shown in Figure 1. In this case, six N70 grid points fell in TZ164 (7334, 7335, 7336, 7456, 7457, and 7458) - the other numbers with each point are the computed (in this case daily) N70 values. The population of TZ164 was 4,066 people so approximately 678 (4,066/6) people would be assigned to each grid-point.

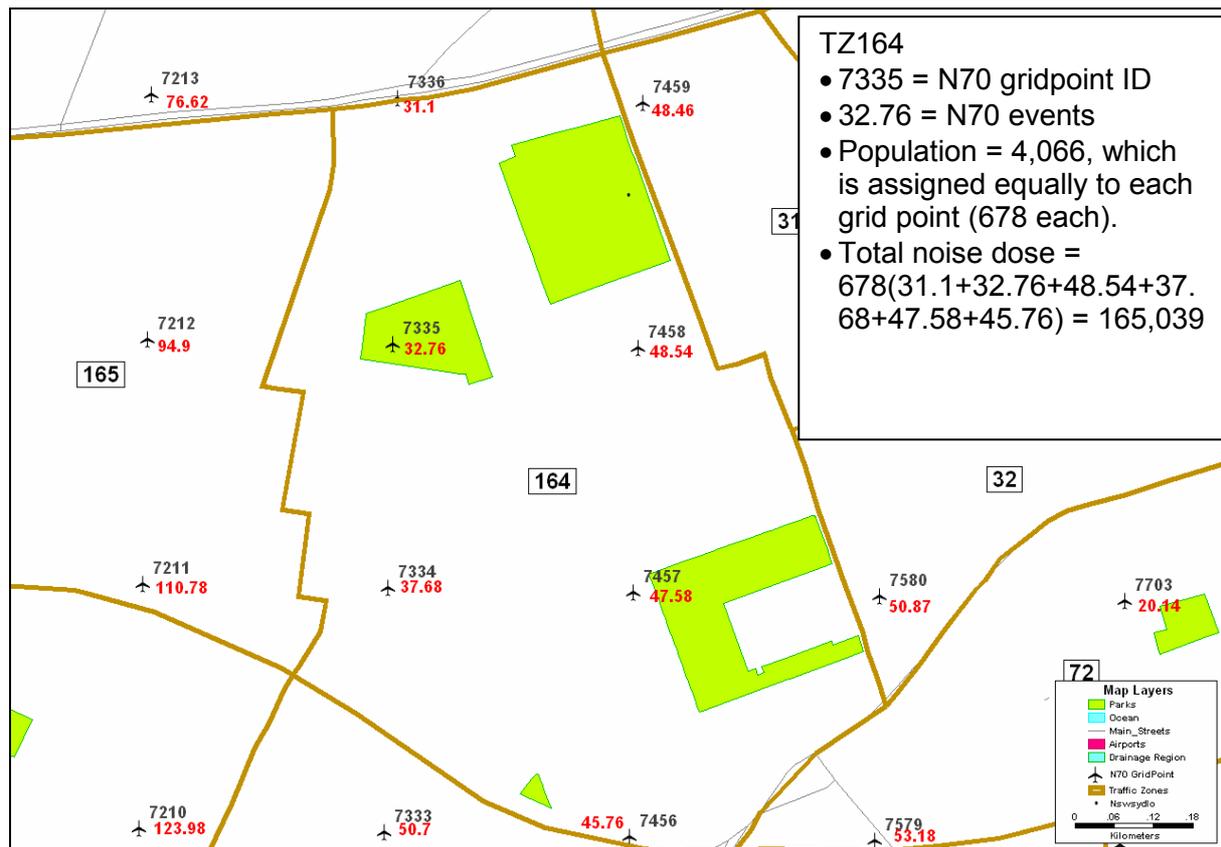


Figure 1: Illustration of Population and Noise Dose Allocation Procedure

We acknowledge this approach leads to an approximation of impacts for two reasons. First, the N70 events vary quite markedly even over a short distance – for instance, in figure 1 the grid-points are only 400 metres apart. One possibility is simply to provide greater resolution on the grid-point output from the INM study. Another is to interpolate N70 values between grid-points within the GIS, something which is non-trivial. Second, the allocation process implicitly assumes the population is spread homogeneously over a TZ. With digital land-use data, it should be possible to improve the reality of this component of the allocation process.

2.3 Estimates of Numbers of People Impacted by Aircraft Noise

With knowledge of the noise dosage and numbers of people at risk, we can estimate the numbers affected against various health-related outcomes using appropriate dose-response relationships from the published literature. This is a complex, on-going area of research with many confounders, with the result that in our opinion, use of such relationships should be seen as indicative rather than absolute. In terms of relationships specifically between N70 events and health outcomes, we were only able to find relationships pertaining to annoyance and these were both highly dated and incorporated much lower numbers of movements than currently (NAL, 1982; Rylander and Bjorkman, 1997). For instance, our analysis of the NAL results suggested an exponential relationship of the form $y = 9.9007e^{0.0225x}$, where y = “percentage seriously affected” and x = N70 events (NAL, 1982, pp. 91). However, the maximum N70 events were 70, compared to more than 250 today.

In light of this, we decided to determine a simple indicator of potential impact, known as a person-event index or PEI (DOTARS, 2000). The PEI sums over the exposed population, the total number of instances where a person is exposed to a noise event above a specified noise level within a given time period. This gives a sense of the total noise load and enables different days and times to be compared with one easily interpretable measure. As an example, taking TZ164 again, as shown the daily PEI for this zone would equal 165,039. For our case, we defined the cut-off for impacts as being above ten N70 events per day and the

cut-off for major impacts as being above 100 N70 events per day (around six per hour over the 17 hours of operation).

3 RESULTS

Using this methodology, we ran several scenarios for Sydney's Kingsford Smith International airport designed to study the impacts of inter and intra-day variability in flights and population movements on noise exposure. The airport is located 12 kilometres to the south of the CBD with two runways facilitating north-south aircraft movements and one runway for east-west movements. Figure 2 shows the location of the airport together with the N70 contours computed for the average annual day in 2005. The close proximity of the airport and flight paths to some of the most densely populated and rapidly growing sections of the city, has been a continuing source of contention (Australian Parliament, 1995; DOTARS, 2000). In response, the airport has had to instigate many mitigation efforts including noise insulation programs, noise sharing policies, and a curfew on flights over populated areas between the hours of 11 pm and 6 am.

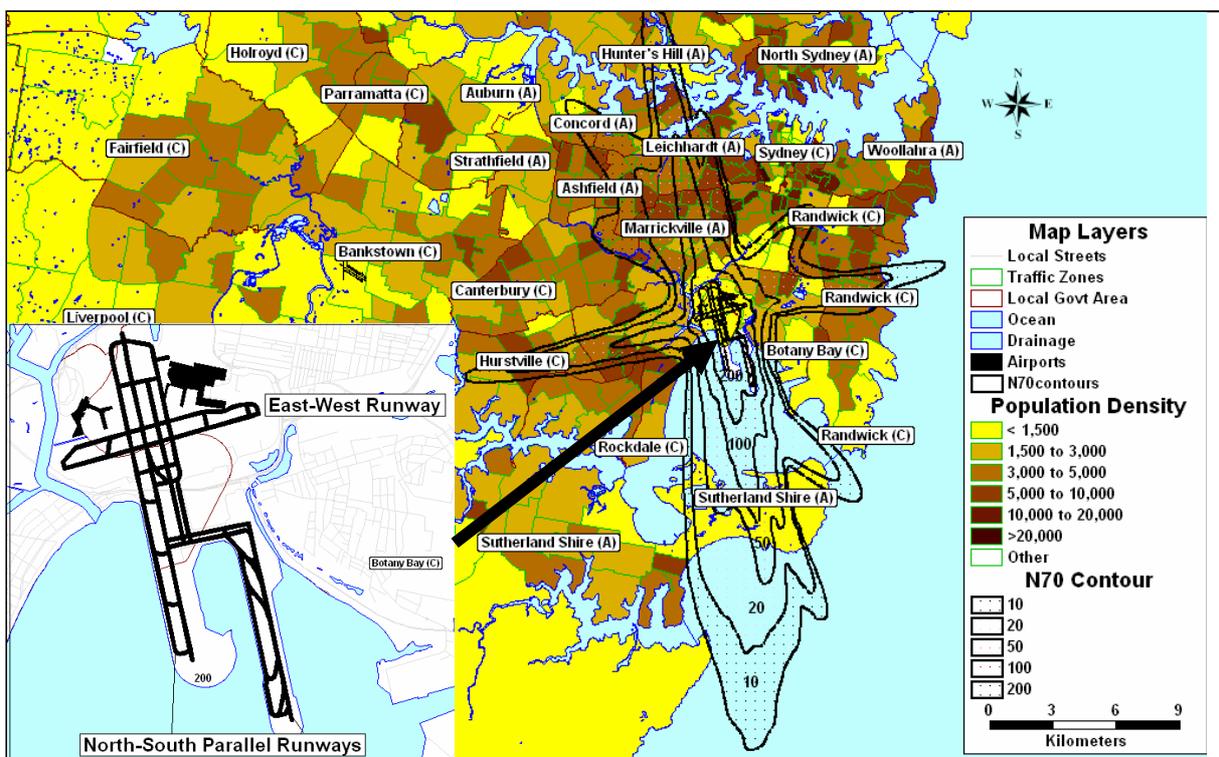


Figure 2: Sydney's Kingsford-Smith International Airport and Surrounding Region

3.1 Variability in Aircraft Movements

In 2005, there were a total of 279,227 flights arriving and departing from Kingsford-Smith, a daily average of 765 flights. The daily range varied from a high of 885 flights on 9th September to a low of 516 flights on Christmas Day. The most heavily trafficked months were September and November, both with an average of 787 flights/day, while the least heavily trafficked month was January with an average of 700 flights/day. Across the week, there was marked variability with Friday the busiest day (832 flights/day) and Saturday the quietest day (650 flights/day). Within days, there was also great variability with arrivals peaking at 32 flights/hour between 7 a.m. and 8 a.m. and departures peaking between 9 a.m. and 10 a.m. at 31 flights/hour. The busiest hours in terms of all movements are 8 a.m. to 9 a.m. and in the evening 6 p.m. to 7 p.m., a pattern that holds true across all seven days of the week.

In addition to differences in the number of flights, the main factor affecting day-to-day variability in potential impacts is the choice of operational mode by air traffic control. The operational mode governs the direction and runway allocation of aircraft arrivals and departures and is a function of wind direction, capacity requirements, and current noise-sharing regulations. In all, there are ten modes, which are described in Table 1 together with the percentage of time each operated for over the whole of 2005 in non-curfew hours – similar computations are provided for 2000 for comparison. The most commonly used are Mode 9 and Mode 10, which are the northerly parallel flow and southerly parallel flow respectively.

Table 1: Percentage of Time in Each Operating Mode (06:00 – 23:00)

Mode	Departures; runways	Arrivals; runways	% of Use (2000)	% of Use (2005)
2	South; 16R	South; 34L	N/A	1.3%
4	South; 16L,16R	South; 34L	3.7%	2.3%
5	South; 16L,16R	East; 25,16R	8.7%	7.1%
7	West; 25, 34L	South; 34L,34R	4.9%	10.0%
8	West, East & North; 25, 34L,34R	South; 34L,34R	5.5%	N/A
9	North & East; 34L, 34R	South; 34L,34R	39.3%	37.1%
10	South; 16L,16R	North; 16L,16R	26.6%	26.3%
12	East; 07	West; 07	0.1%	0.9%
13	West; 25	East; 25	1.3%	2.7%
14A	South; 16L,16R	West; 07,16R	10.1%	12.1%

3.2 Inter-day Variability in Impacts

To assess the day-to-day variability in potential impacts, we computed a range of exposure-based measures for a selection of days from 2005 with different numbers of movements and operational mode characteristics. It should be noted these results were computed using residential population figures (i.e., akin to current practice). Table 2 provides a summary of results. The first point of note is that while the average day gives a reasonable overall impression of the numbers of people at some risk of exposure to aircraft noise and the average individual exposure, it seriously under-estimates the numbers of people at risk of higher levels of exposure. This is indicated here by both the lowest numbers exposed to over 100 (approximately 6/hour) N70 events and the lowest noise concentration. That this is not simply attributable to the number of flights is evidenced by the computations in Table 2 for the quietest week-day of 2005, the 3rd January.

Table 2: Indicators of Exposure to Aircraft Noise for Selected Days in 2005

Date	Total Flights	Dominant Modes of Operation	No. Exposed to >10 N70 Events	No. Exposed to >100 N70 Events	PEI (Number of Person Events)*	% of PEI (> 100 N70 Events)**	Average Individual Exposure***
2005 Average Day	765	N/A	345,824	13,154	12,164,090	18%	35
3rd Jan (quietest weekday)	681	9(48%),10(29%), 14A(16%)	341,214	22,253	12,590,972	23%	37
27th Jan	764	9(41%),14A(38%)	308,500	14,704	10,842,628	22%	35
8th Feb	801	9(94%)	398,158	27,237	14,791,640	25%	37
16th Feb	814	10(77%), 14A(17%)	203,398	40,112	12,740,415	49%	63
14th March (mode 9 day)	819	9(100%)	390,693	27,992	15,272,661	26%	39
15th April (most complaints)	831	10(63%),5(37%)	191,548	35,494	13,156,798	44%	69
9th Feb (mode 10 day)	833	10 (100%)	161,171	57,335	13,948,650	65%	87
18th Feb	848	9(73%),12(21%)	400,535	25,224	16,362,378	22%	41
9th Sept (busiest day)	885	9(92%)	281,260	17,672	12,000,722	25%	43

Indicator of total noise load: Sum (population at each grid point corresponding N70 events).

**Indicator of noise concentration: Proportion of total PEI being imposed on locations with >100 N70 events.

***Indicator of average dosage: PEI/No. Exposed to >10 N70 Events.

A second notable observation is the markedly different impacts of operational mode. Taking the extreme cases of days that operate in the two most common modes, Mode 9 (14th March), and Mode 10 (9th February), the figures suggest that (allowing for a slight difference in total flights) around 2.5 times as many people are exposed to aircraft noise on a Mode 9 day than a Mode 10 day. However, from the perspective of noise concentration, the situation is much worse on a Mode 10 day with approximately double the number of people exposed to more than 100 N70 events. This is dramatically illustrated in Figure 3, which shows visually how the noise is concentrated on TZs to the north and immediate south of the airport. It is also evident that switching modes will generally increase the overall numbers exposed, but reduce the numbers exposed to higher numbers of events as shown by comparing the 15th April with the 9th February and the 18th February with the 14th March.

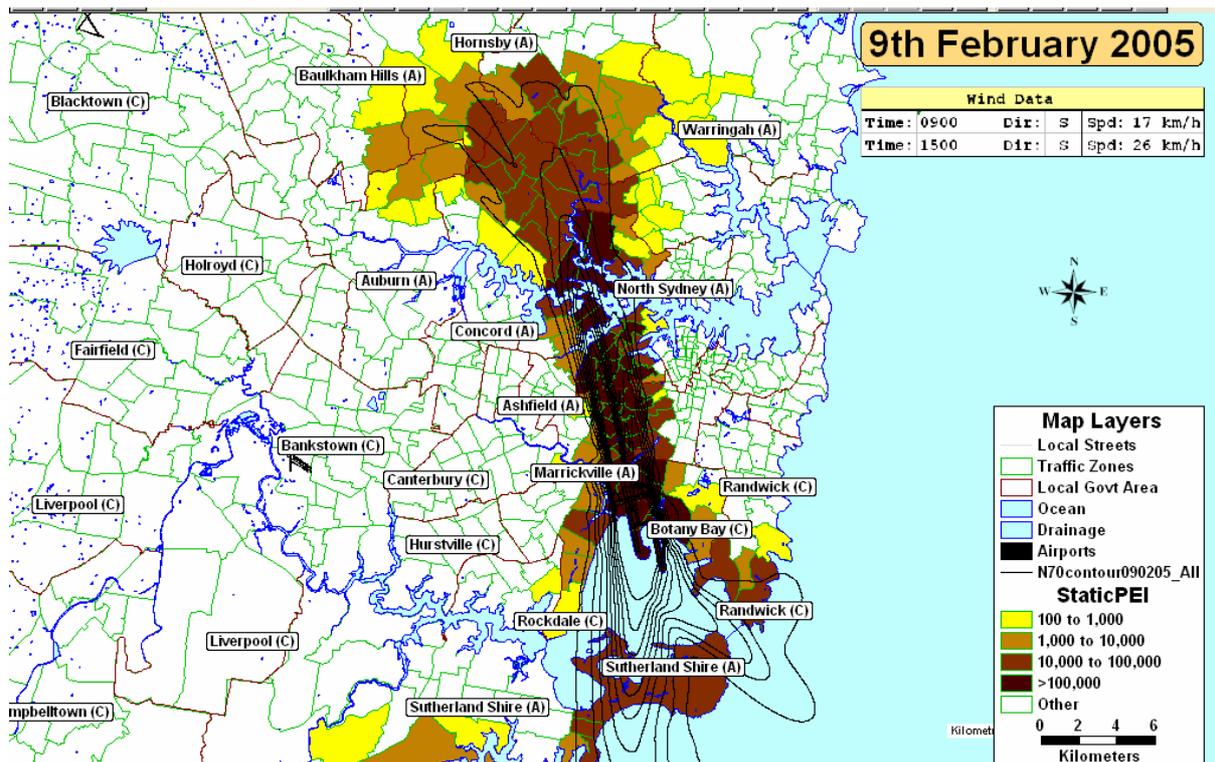


Figure 3: Daily PEI (06:00 – 23:00) for Mode 10 Day, 9th February 2005

3.3 Intra-day Variability in Impacts

Through exploring intra-day variability in impacts, the aim was to answer the following questions. First, what difference did it make using the moving (dynamic) population versus the residential (static) population in terms of the conclusions reached on overall daily impacts? Second, how does total exposure actually vary across the day based on both variations in aircraft movements and people’s locations?

To answer these questions, we selected some of the days shown in Table 2 and computed hourly N70 movements using TNIP. We then determined the numbers exposed to various levels of N70 events and the PEI for the static and dynamic populations. A major caveat here was processing time, with each hour taking approximately 15 minutes to run in TNIP so that for a 17 hour day, this takes around four hours of TNIP runs alone.

The most significant finding was that the numbers exposed and PEIs were always higher using the dynamic population. As one example, Figure 4 indicates the static and dynamic-based PEIs together with the number of movements during each hour for the 9th February, a Mode 10 day. Overall, the dynamic PEI was seven percent higher than the static PEI. Focusing on the variation over the day, the greatest hour of exposure is between 8:00 – 9:00, when movements are at their highest with the main surprise being why there is a fall between 6:00 and 7:00 p.m., when movements peak again. One potential explanation is simply that a significant proportion of these events were not N70 events.

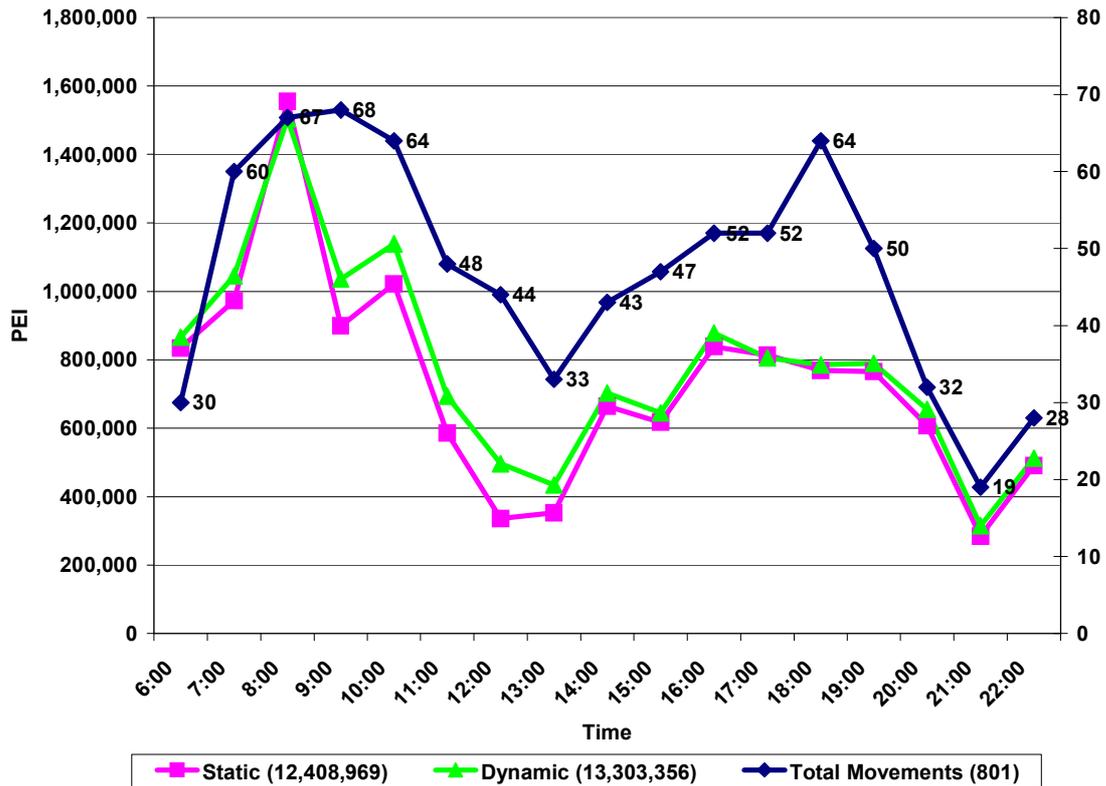


Figure 4: PEI Comparisons Using Static and Dynamic Population Methods (February 9th 2005)

Another example is shown in Figure 5, for the 8th February, which was predominantly a Mode 9 day. In this case the dynamic PEI was 20 percent higher than the static PEI. The pattern of exposure over the day is however, quite different to the previous example with the PEI generally tracking movements apart from the 10 p.m. – 11 p.m. time-slot. The reason for this spike is this marks a peak take-off time for international departures, which under Mode 9, pass over some of the most heavily populated areas of the city to the north.

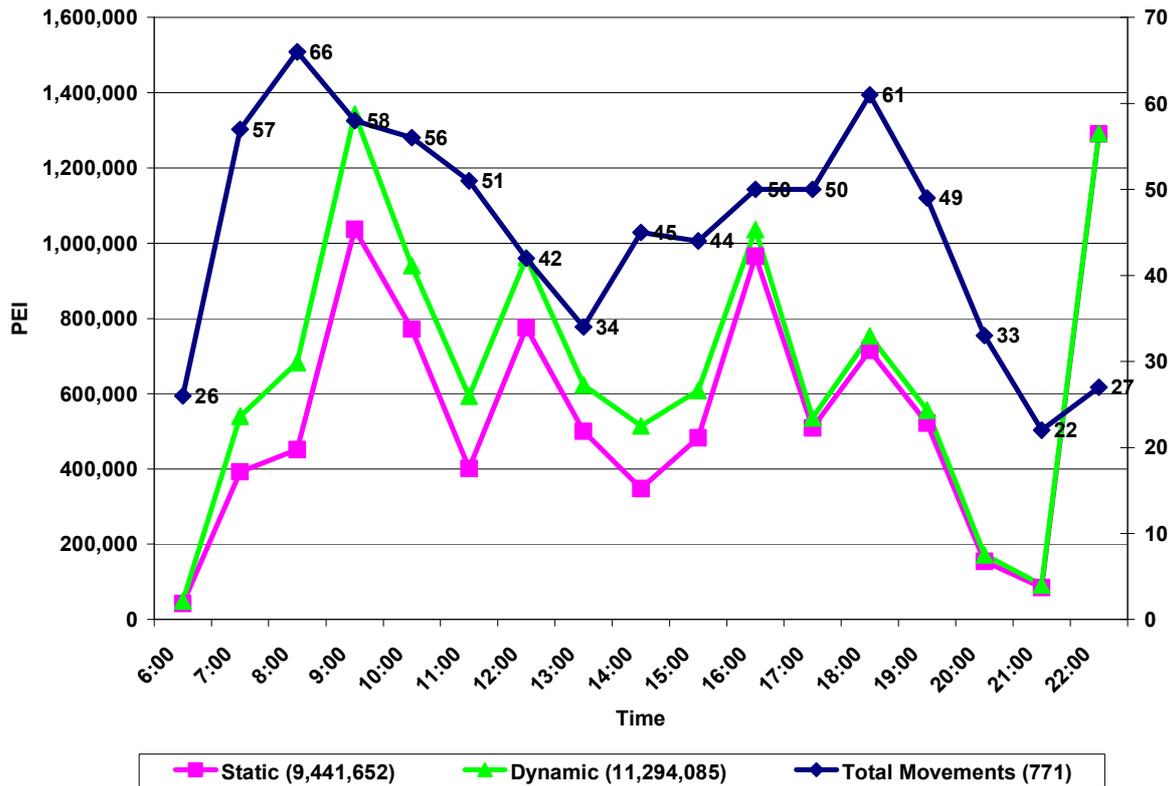


Figure 5: PEI Comparisons Using Static and Dynamic Population Methods (February 8th 2005)

While it is possible to explain most of the nuances in these variations across the day, perhaps the most puzzling phenomenon is that the exposure-based measures for the static population both track and are consistently lower than using the dynamic population. Intuition suggests the reason they track each other is because we are in actuality summarizing for a broad spatial area such that departures and arrivals tend to cancel each other out. As to why the dynamic figures provide consistently higher PEIs, the issue is quite simply that overall the areas most affected by aircraft noise in Sydney experience a larger net increase in population compared to the residential population than those areas less affected. To investigate this further, we prepared several maps showing the absolute difference between the dynamic and static-based PEI for various days and time-periods. One example is shown in Figure 6 for the mode 9 day of 8th February between 9:00 – 10:00 a.m. with the N70 contours for that hour overlain to give an idea of the direction of the aircraft. What is happening here is the TZs to the immediate north-east of the airport are contributing disproportionately highly to the PEI due to both the influx of people and the fact this is under the main flight path to the north-east.

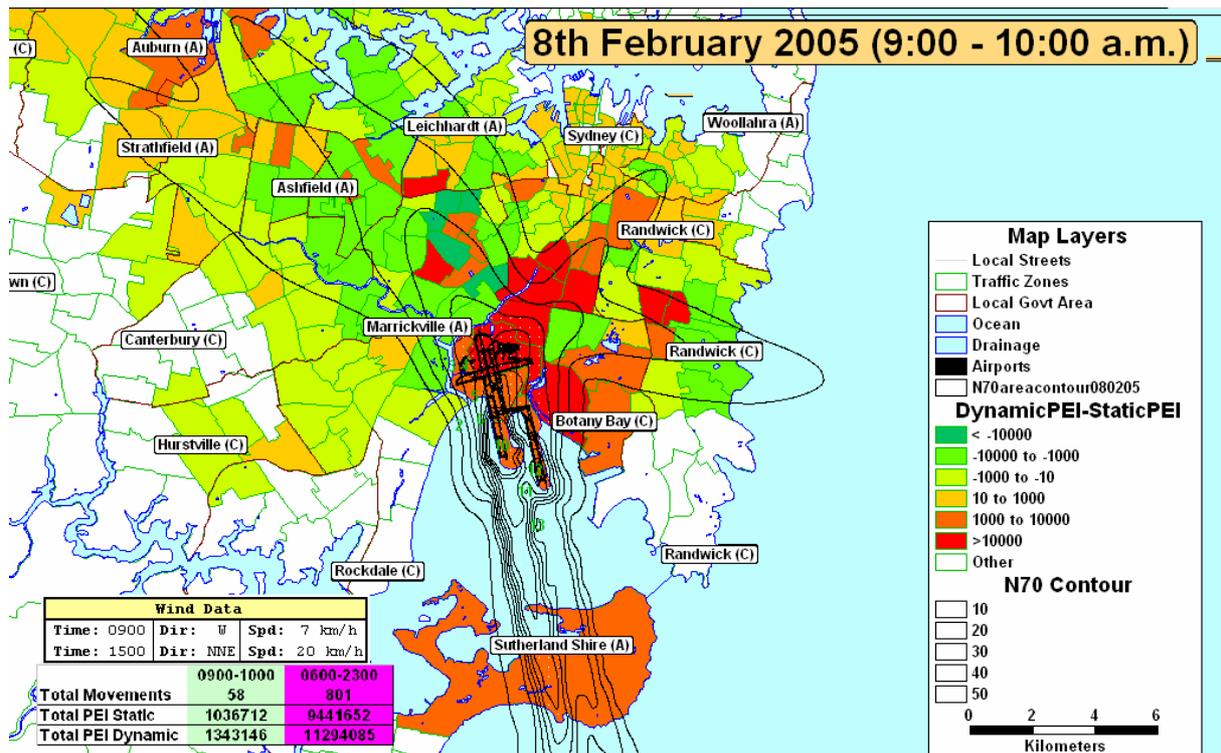


Figure 6: Comparison of Dynamic and Static PEIs (8th February 2005, 9:00 – 10:00 a.m)

3.4 Inter-Hour Variability in Impacts

Having established intra-day variability, the next issue is how exposure varies based on the choice of operational mode for particular hours of the day. To investigate this issue here, we selected the ANEF defined morning sensitive hour of 6 a.m. – 7 a.m. in which impacts are weighted at four times compared to non-sensitive hours (NAL, 1982). This hour also coincides with the arrival of many larger aircraft associated with long-distance passage from overseas to Australia. For the sake of the comparison, we selected days with the same number of movements, in this case 27, which was the average for this time-period across the year and computed the PEI based on the moving population. During this hour, within the restrictions of weather conditions, the main objective is to maximise arrivals over the water from the south, which corresponds to Mode 7 and Mode 9. Note this still involves passing over the populated area of Kurnell, which is on the peninsular of land to the south of the airport. A summary of results are provided in Table 3.

Table 3: Impacts of Operational Mode on Exposure between 6 a.m. – 7 a.m.

Date	No. of N70 Events/Hour*	>15	10-15	6-10	3-6	TOTAL
22nd March (Mode 5, 8% of time)	Persons Exposed	2,608	26,857	14,461	10,524	54,450
	Dynamic PEI	46,343	303,352	130,180	45,399	525,274
	% of PEI	9%	58%	25%	9%	100%
15th Feb (Mode 7, 40% of time)	Persons Exposed	244	4,649	10,593	35,218	50,703
	Dynamic PEI	3,854	55,978	79,863	145,214	284,909
	% of PEI	1%	20%	28%	51%	100%
21st Feb (Mode 9, 19% of time)	Persons Exposed	864	1,878	8,804	17,613	29,159
	Dynamic PEI	15,751	28,590	53,688	75,222	173,251
	% of PEI	9%	17%	31%	43%	100%
10th Feb (Mode 10, 24% of time)	Persons Exposed	2,515	23,490	32,070	51,701	109,777
	Dynamic PEI	42,879	272,692	229,842	209,148	754,561
	% of PEI	6%	36%	30%	28%	100%
2nd March (Sodprop, 5% of time)	Persons Exposed	779	2,398	1,668	1,695	6,539
	Dynamic PEI	13,918	32,219	6,800	6,745	59,681
	% of PEI	23%	54%	11%	11%	100%

*All days shown have the same number of flights (27) for this hour.

The results show in terms of overall impacts, Mode 10 is the worse. It results in almost double the number of people receiving at least three N70 events in comparison to the next worst mode (Mode 5), and the greatest PEI overall. The ‘optimal’ mode in terms of reducing overall PEI is evidently the use of the ‘Sodprops’ mode which sees both arrivals from and departures to the south. However, the use of this mode is dictated by capacity and weather restrictions. Of particular interest here is while the most frequently used mode, Mode 7, results in the lowest numbers exposed to the largest numbers of N70 events, when viewed overall, the PEI is higher than Mode 9. The reason is to do with departures as shown in Figure 7. Under Mode 7, departures are to the west, which has one runway available, while for Mode 9, departures are to the north and east via parallel runways.

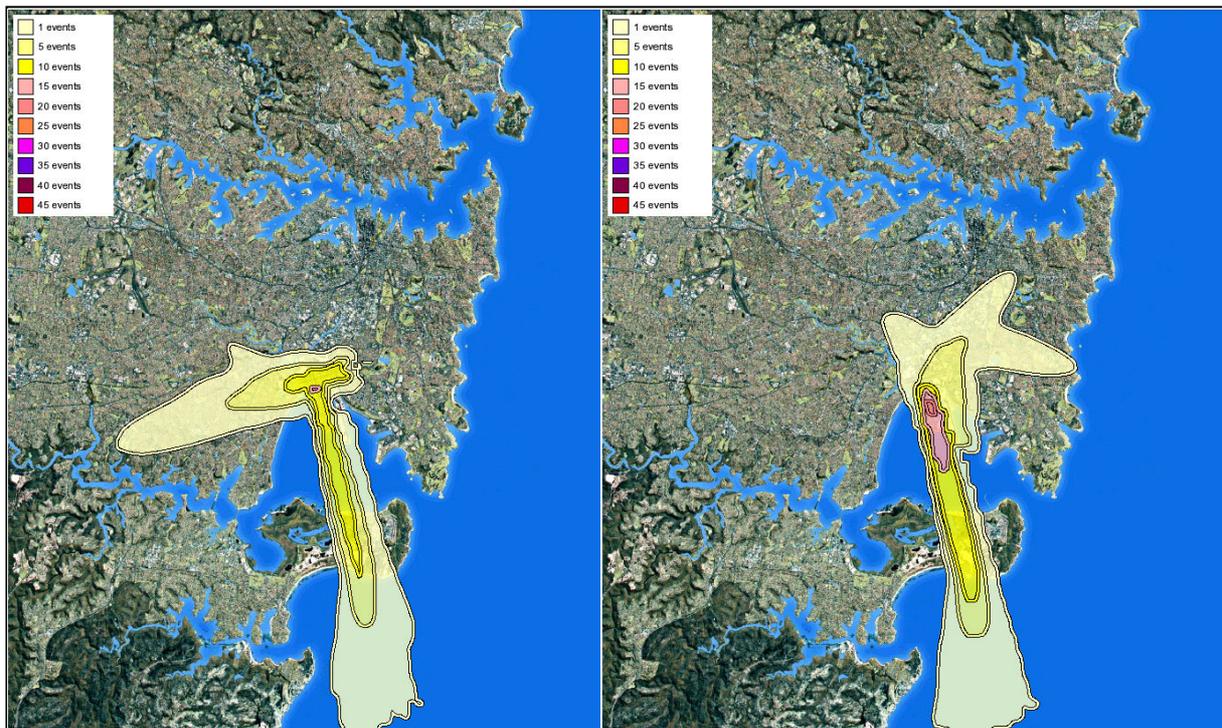


Figure 7: N70 Contours at 6 a.m. – 7 a.m. for Mode 7 (left) versus Mode 9 (right)

4 DISCUSSION & CONCLUSION

Through the examples presented here, we have demonstrated the potential of this approach to provide greater insight into how population exposure to aircraft noise varies both temporally and spatially. Perhaps the first and most pertinent point to make is that exposure is highly variable both within and across days suggesting the use of an annual average or other summary measure is only partially reflecting people's noise experiences. A second point to emerge is the use of a residential-based population estimate appears to result in under-estimates of numbers potentially affected and spatial misrepresentation of impacts as suggested by the difference between dynamic and static-based PEIs in figure 6. Clearly, this could be case-specific to the airport considered here, but never-the-less the issue is that intuitively we must try to incorporate some realism into where people actually are in relation to noise. As we have alluded to here, this has to be done within the limitations of available data, which quickly becomes insufficient the more disaggregate one gets. This could conceivably be enhanced in the future by the use of emerging synthetic-based approaches for generating much larger samples at smaller scales of spatial resolution (Greaves, 2006).

Following on from these points, we need to distinguish here between indications of population-based exposure and personal noise dosage. Population-based measures, such as those presented here, provide a count of people who happen to be at a given location at a given time. Personal dosage refers to what an individual experiences over the day, which is clearly more relevant for assessing noise experiences and potential reactions. For instance, it appears logical that a person living under a flight-path who goes to work from 9am – 5pm (assuming it is in a non-affected location), will not be particularly concerned about flights during the day. However, they may be more affected by noise when at home, particularly as the morning (7-9 am) and early evening (5-8 pm) periods coincide with the peak periods for aircraft movements. A response may be quite different for someone who is home-bound under a flight-path, who may find the accumulation of noise over the day to be the big issue. Gathering such information, typically requires questioning people about their perceptions and reactions to noise and relating this in some way to the dosage received through direct measurement, which is a highly expensive process (Franssen et al., 2002). There may be ways to bridge the gap between population-based exposure and personal dosage through enhancements to the approach we have described here. One way is to tag our sample members and compute the number of noise events they are exposed to as the day proceeds. This could also give insights into the duration of exposure (continuous hours), which appears to be critical in explaining response to noise (NAL, 1982).

A final and perhaps most important point relates to how this information can be used as part of the decision-making process. We argue a more detailed understanding of the potential exposure impacts is essential for day-to-day operational decisions, instigation of noise-sharing policies, and major initiatives such as constructing new runways. The case study here showed, for instance, the markedly different effects of particular modes on the total numbers exposed versus the concentration. The information is also of great importance for the planning of future settlement patterns – for instance, the areas affected by Sydney airport have been targeted for major population densification over the next twenty years. The ramifications of these issues are not going to go away, particularly as the growth in air traffic continues to grow into the foreseeable future.

5 REFERENCES

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