Aircraft Accident Modelling for Lydd Airport, Kent

Produced for: Lydd Airport Action Group
The Hook, Madeira Road
Littlestone, Kent, TN28 8QX
blmbarton@aol.com
01797 361 548

Produced by: David Pitfield BSc, PhD, AcSS

Date: 20th December 2010

IN CONFIDENCE

Dr David Pitfield
Lings Farm
47 Main Street
Keyworth
Nottingham
NG12 5AA
D.E.Pitfield@lboro.ac.uk
0115 9374922
07765 783300

1. Introduction

1.1 My name is David Pitfield. I have a BSc degree from the University of Bristol and a PhD from the University of Stirling. I have been a lecturer and researcher at Loughborough University from the 1970's and I am programme director for our undergraduate degree in Air Transport Management. I am also an Academician of the Academy for Social Sciences and visiting research professor at the University of Illinois at Urbana-Champaign.

1.2 I was principal investigator on a research project funded by the Engineering and Physical Sciences Research Council (EPSRC) between 2003-2006 on Improving the Assessment of Risk to Occupants and Communities due to Aircraft Operations on and near Airports. Subsequently I have been involved with the US Airport Co-operative Research Program Project 4-01. This looked at Aircraft Overrun and Undershoot Analysis for Runway Safety Areas and was funded by the US National Academies and Transportation Research Board between 2006-2007 and jointly undertaken with ARA, Maryland, USA. As a result of this work and an earlier project, six publications have appeared in learned journals and edited works along with a number of industry and academic conference presentations.

1.3 I have been asked by the Lydd Airport Action Group to comment on the AEA (1997) methodology (commonly called the Byrne methodology) that is used for the calculation of aircraft crash risk in the UK although superior methods have been developed (Kirkland, 2001; Wong, 2007) and applied (Eddowes et al, 2001; ACRP, 2007; Wong et al, 2009b). I understand the Byrne methodology is a standard method used in nuclear industry safety cases. This research was commissioned by the HSE in 1997. In this I was asked to reflect on previous work by AREVA (2009). Adjustments were made to the application of the Byrne methodology to demonstrate changes in the magnitude of likely aircraft accident risk at London Ashford Airport with its intended development and increase in air transport movements. It was not possible with the resources available to calculate risk using an alternative approach.

1.4 The aim of the Byrne methodology is to predict the number of crashes per year into the target. There are four main stages in the calculation.

(1) Determine which runway directions are relevant.

(2) Evaluate the overall crash rate (per km^2 per year) at the target site. This is evaluated as the sum of the rates for airport-related traffic, and for background traffic. The background crash rates are taken directly from AEA (1997) and represent overflying aircraft in the vicinity of the airport. The airport related crash rate is calculated by taking account of the crash probability per movement for each aircraft category, the number of movements by each category, and the location of the target site in relation to the airport. This is determined for each runway direction considered.

(3) Evaluate the effective target area for the site, taking account of its plan area and height.

(4) Multiply the crash rate per km^2 per year by the effective target area to obtain a crash frequency per year onto the target site

This report concentrates on (1) and (2) as (3) and (4) can be readily derived.

1.5 London Ashford Airport at Lydd has applied for planning permission to extend a runway and build a new terminal building with the aim of increasing the passenger carrying capacity of the airport to 500,000 passengers per annum (ppa) in the first instance. In its Master Plan a throughput of 2 million ppa is envisaged. The present level of movements at Lydd, at something like 20,000 movements, are nearly all light aircraft and helicopters and these movements give rise to a negligible probability of crash risk. The envisaged increases will substantially increase this risk, particularly as there is an unusually high potential for bird strikes given the location of a nearby nature reserve and a need to modify approaches and departure paths due to the location of nuclear and military sites which will result in a higher number of aborted landings for larger aircraft. This will increase the number of 'go rounds' experienced at the airport. Lydd Airport's proposed movements by class of aircraft are broken down according to the Byrne methodology's definition of aircraft categories to comprise 12045 small transport aircraft movements and the 3650 large transport aircraft that are relevant to this analysis. Light aircraft are ignored. 9125 movements of the small transport category are represented by Learjet 35A, Citation 11 and CNA750 Citation X aircraft types which are not attributed to the carrying of passengers. This is shown in Table 1.

Table 1: Lydd Airport: Movements per year by aircraft category- 500,000 ppa

Aircraft Type	**500,000 ppa**	**500,000 ppa**
	Daily Average	**Annual**
B737	4	
A319	4	
BAe146	2	
Total Large Transport	**10**	**3650**
Dash 8	2	
ATR42-500	4	
Saab 340/SF340B	2	
Learjet 35A	4	
Citation11	3	
CNA750 Citation X	18	
Total Small Transport	**33**	**12045**
Total Large & Medium Transport	**53**	**15695**
Cessna 152	25	
Cessna 172	20	
Piper PA 28 Cherokee	15	
Piper PA -34 Seneca	20	
Total Light Aircraft	**80**	**29200**
Total Movements	**123**	**44895**

1.6 AEA (1997) gives the number of crashes per movement measured as crashes per million movements as 1.8 and 0.59 respectively for small and large transport aircraft. A weighted average based on the small and large transport groups above based on a throughput of 500,000 ppa gives a figure of 1.52 (see also AREVA (2009)). The 2 million ppa fleet mix scenario does not provide a detailed analysis of the total fleet mix, only concentrating on the aircraft types supporting passenger travel. If the same number of annual movements (9125) of Learjet 35A, Citation 11 and CNA750 Citation X aircraft types in the 500,000 ppa scenario are included in the 2 million ppa scenario, the weighted average accident rate is 1.33. This average is lower than that calculated for a throughput of 500,000 ppa because of the increased weighting of larger aircraft. These rates allow the calculation of the impact per km^2 which can then be allocated to the airport site or some other appropriate area for analysis. Table 2 gives this aircraft category breakdown.

Table 2: Lydd Airport: Movements per year by aircraft category- 2 million ppa

Aircraft Type	**2 million ppa**	**2 million ppa**
	Daily Average	**annual**
B737	14	
A319	14	
BAe146	10	
Total Large Transport	**38**	**13870**
Dash 8	18	
ATR42-500	8	
Saab 340/SF340B	8	
Learjet 35A	4	
Citation11	3	
CNA750 Citation X	18	
Total Medium Transport	**59**	**21535**
Total Large & Medium Transport	**97**	**35405**

Cessna 152	na	
Cessna 172	na	
Piper PA 28 Cherokee	na	
Piper PA -34 Seneca	na	
Total Light Aircraft	**na**	
Total Movements	**97**	**35405**

2 Byrne methodology

2.1 Byrne's methodology is flawed in its application because the reliability figures (crashes per movement) are based on limited and dated UK data. The crashes per million movements of 1.8 and 0.59 respectively for small and large transport aircraft are based on a sample of 11 and 7 aircraft crashes respectively. In addition, the way in which runway directions are assessed or rejected in applications is questionable and can lead to underestimation. AREVA (2009) only assessed two runway directions at Lydd (landing on runway 03 and taking off from 21) whereas it should have been three (also including landing on 21) and so it understated the overall risk[i].

2.2 Lack of detailed knowledge of an airport can also lead to the incorrect assessment of movements to runway directions as again is the case with AREVA (2009) which assumed movements were allocated to runways according to the prevailing wind. Due to the presence of the Lydd military range to the south of the runway, when landings favour runway 03 and the range is active, it is not possible for most commercial aircraft to land in this direction, which means landings are heavily concentrated on runway 21. More important is the inability of the methodology to account for non standard situations such as the complex set of circumstances at Lydd. Estimates based on Byrne's methodology for two airports with the same fleet mix, number of movements, runway orientation and distance from the hazard, but with widely different exposure to risk factors such as extreme weather conditions or threat from bird strikes, would produce the same answer. This results as other variables that influence risk, such as those noted, are not accounted for.

3 A Better approach to Accident Modelling

3.1 Rather than the use of accident rates, the work at Loughborough (Kirkland et al, 2003, 2004; Wong et al, 2009a, 2009b) has shown that the way forward is to use sophisticated econometric models to analyse the impact on accident frequency of the variables shown in Table 3[ii]. Indeed it may well be that the association between aircraft type and accidents is not causal and that other factors, such as the operational environment or the way the aircraft is flown are the factors that matter. This is supported by the Loughborough research initiative and the subsequent ACRP (2007) work.

Table 3: Model Variables Units & Categories

Variable	Variable Type	Categorical Groupings/Measuring Unit
Equipment Class	Categorical	Heavy aircraft – Maximum Take-Off Weight (MTOW)> 255,000lbs Large jets – MTOW between 41,000lbs and 255,000lbs, e.g. Boeing 737, A320 Large commuter aircraft – MTOW between 41,000lbs and 255,000lbs but smaller than large jets, e.g. regional jets Medium aircraft – MTOW between 12,500lbs and 41,000lbs Small aircraft – MTOW under 12,500lbs
Equipment Type	Categorical	Turboprops Jets
User Class	Categorical	Commercial operation Freight operation General aviation operation
Foreign Origin/Destination	Categorical	Domestic Foreign
Ceiling Height	Continuous	100ft
Visibility	Categorical	<2.00 statute miles (SM) 2.01- 4.00SM 4.01- 6.00SM 6.01- 8.00SM >8.00SM
Fog	Categorical	No Fog Fog
Dawn/Dusk	Categorical	Non dawn/dusk conditions Dawn/dusk
Crosswind	Continuous	Knots
Rain	Categorical	No rain Rain
Electric Storm	Categorical	No electric storm Electric storm
Temperature	Continuous	10°C
Icing Conditions	Categorical	No icing conditions Icing conditions
Frozen Precipitation	Categorical	No frozen precipitation Frozen precipitation
Snow	Categorical	No snow Snow
Airport Hub Size	Categorical	FAA hub (Large/Medium/Small) FAA non-hub

3.2 It is demonstrable that meteorological variables as well as equipment variables have an impact (Wong et al, 2006).

3.3 It can also be shown that a specific airport's exposure to risk can be derived, given observations on the explanatory variables, including meteorology, and a sample of 'normal operations data'. This is a large sample of flights that will include some cases that have the same characteristics as accident cases but where accidents did not occur. This has been demonstrated for two US airports, New York La Guardia (LGA) and Boca Raton, FL (BCT) in Wong et al (2009b).

3.4 LGA is the closest to Lydd in projected air transport movements in the 500,000 ppa scenario and has nearly 6,000 take-offs and landings per annum. The model predicts 1.188E-06 and 1.291E-07 accidents on different runways at LGA where these differences exist because of differences in weather. The target safety level adopted here and in Eddowes et al (2001) is taken as 1.0E-07 or 1 in 10 million per annum. This is common in aviation.

3.5 Other models on the location of accidents and their consequences need further development from those shown in Kirkland et al (2004) and these represent a considerable advance on Byrne. In the meantime there are ways in which the application of the Byrne methodology could be improved, in particular, by revising accident rates and introducing modifications to account for the probability of increased 'go rounds', bird strikes and other risk factors particular to the Lydd site. These calculations cannot quantify the total risk at Lydd but provide an insight into the degree to which Byrne understates risk.

4. Accident Rates

4.1 The work reported in Kirkland et al (2003, 2004) was based on a database compiled from overrun accidents recorded in the US, Canada, UK, and Australia from 1980 to 1998. This database has 180 cases with 26 from the UK and 133 from the US. Kirkland notes that,

"The UK has, over the last few years, experienced a relatively large number of incidents of aircraft overrunning the end of runways" (Kirkland et al, 2004, p.893)

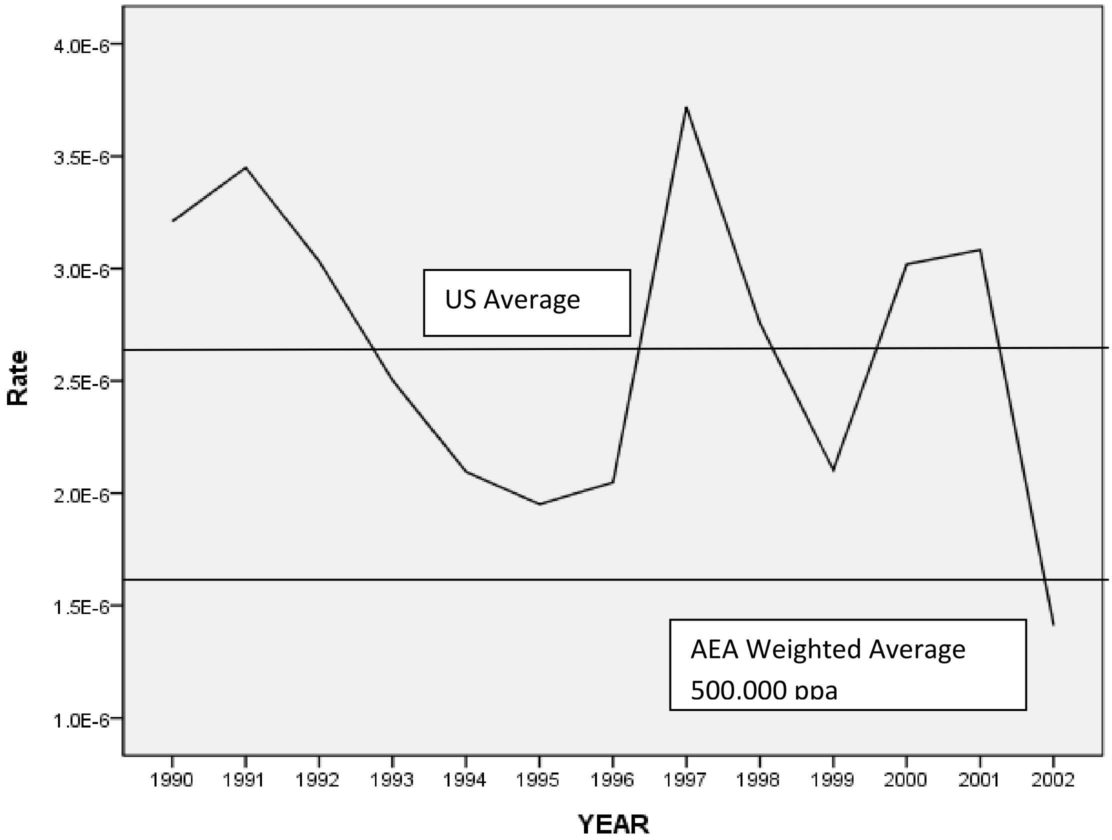
For the UK, he records 1.03 overruns per million landings and 0.22 overruns per million take-offs[iii]. This is based on 26 accidents where 81% are landing overruns. However, overruns only represent one class of accident and subsequent work (Wong, 2007) analyses other accident types where it seems they represent a further 40% of occurrences. On that basis, the UK rate for all aircraft types could be taken as 1.75 per million movements.

4.2 The work summarised in Wong et al (2009a, 2009b) is based on the analysis of 440 accidents. These were recorded in the USA over the period 1982-2002. All the US accidents recorded in Kirkland are included here. The US was chosen as the basis of the work as aviation is a more prevalent activity and so are the numbers of accidents recorded. This is not because the US is more dangerous; it just has more aviation activity and so calculations based on the accidents are statistically significant and more broadly representative of on or near airport accidents. Subsequent work for the ACRP (2007) builds on this analysis.

4.3 The Wong et al (2009a, 2009b) work distinguishes four types of accident that occur at or close to airports[iv]. Overruns are 57% of the total (landing overruns, 45%; take-off overruns 12%), with landing undershoots at 28% and take-off and crash at 15%. Landing accidents dominate the statistics.

4.4 This work does not record details of the air transport movements that are associated with the years in which these accidents occur so a direct estimate of rates is not possible. However, the US Bureau of Transportation Statistics provides data online from 1990 for a wide variety of variables, including flights. For the 13 year period an average of 2.6445 accidents per million movements is derived for on or near airport accidents. The rate for the 1980's would be higher as accidents were higher and air transport movements were lower. The derived rate variations from 1990 are shown in Figure 1 below as is the AEA rate for at throughput of 500,000 ppa.

Figure 1: Accident Rates per air transport movement, Domestic US, 1990-2002.



It is clear that there is no basis for persisting with the use of low accident rates from the dated Byrne (AEA, 1997) work. In particular, as noted earlier, the database used to derive rates for the largest two weight classes is 11 small transport aircraft and 7 large transport aircraft in the 1979-91 period in the UK. Not only is this an insufficient number of observations but it is also not current[v] and includes 5 airfield related accidents at military airfields to increase the sample of large transport accidents.

4.5 It seems that any new proposed rate should be tempered to take account of the proportion of movements that are for relatively small aircraft classes. The majority of accidents in Wong (2007) are recorded for small and medium aircraft. However, it is the small aircraft that need removing to make the residual result roughly comparable to the classes denoted as large transport and small transport and executive jet in Lydd studies[vi]. A simple average of the accidents excluding small aircraft is 67.75% of the total or 67.82% using a weighted average based on the four accident classes. This results in a reduced accident rate of 1.79 per million movements.

4.6 For Kirkland (2001) there is also a need to reflect the class of aircraft that experienced accidents. For the UK data this information is not directly available but for his total database of 180 accidents, 20 of the landing overruns and 2 of the take-off overruns are for aircraft below 12,500 lbs. There are a further 10 cases where the gross weight is unknown. If half of these are taken to be below the weight limit then the accident rate could be scaled by 85% to reflect the contribution of large and medium aircraft, relevant to this case, resulting in a figure of 1.49 accidents per million. This is very similar to the weighted average of 1.52 used by AREVA (2009) for the analysis of the 500,000 ppa throughput.

4.7 This analysis shows that there is still uncertainty about the reliability figures and further work needs to be undertaken if this approach is persevered with. The evidence based on the larger databases suggests that Byrne (AEA, 1997) reliability figures are too low. Although the larger database based studies means more causes of aircraft accidents are covered, it still does not overcome the problem that one variable (crash rate) is used in Byrne to represent a vast array of complex circumstances some of which are measured in referenced applications using the variables noted in Table 3.

5 New Calculations for Lydd based on Byrne methodology

5.1 The airport lies some 3 miles from the Dungeness nuclear complex, some 2 miles from Lydd military range and under 6 miles from the Hythe military range. In all cases there are vertical exclusion zones for aircraft and no aircraft can fly within 2 nautical miles of the nuclear complex although aircraft from and to Lydd can come within 1.5 nautical miles. These restrictions have an impact on flight paths on departure and approach from certain runways.

5.2 The Royal Society for the Protection of Birds (RSPB) is concerned about the plans to develop the airport at Lydd as it threatens the habitat of some 60 bird species and other rare wildlife to be found on Dungeness nature reserve, the RSPB’s oldest. The presence of birds is also a threat to aircraft but the airport is required by regulation to employ bird scaring techniques to minimise the threat of strikes on jet engines which it could be claimed is incompatible with the aim of nurturing the reserve. A report by a consultant to the Society argues that the airport has not properly addressed these issues[vii].

5.3 Other issues besides the incidence of bird-strikes are whether 'go-rounds' resulting from aborted landings are more likely given the offset Instrument Landing System (ILS) and the necessity for large aircraft to land with a tail wind due to the height restrictions over the Lydd military range, approach paths and the treatment of background crash rates. 'Go-rounds' can be dealt with by assuming a certain percentage of 'go-rounds' result, in effect causing a rise in landing air transport movements on the affected runway whereas the bird strike exposure would raise the probability of accidents. The sensitivity of changes in movements and bird strikes is investigated in the calculations using revised accident rates below. These adjustments do not account for all the particular risk factors at Lydd that are likely to be higher but provide a means by which adjustments could be made to the Byrne methodology results using the new accident rates.

5.4 AREVA (2009) did not calculate crash rate frequency for 2 million ppa but it is given as 2.9009E-06 by Large and Associates (2007). This figure excludes some runway directions. It is understood that British Energy undertook its safety case on the basis of 2 million ppa but the basis for the calculations is unknown. The analysis here is based on three runway directions - landing and taking off from runway 21 and landing on 03, plus the following split shown in Table 4 between runways.

Table4: Lydd Airport Runway Usage*: LAAG versus AREVA

	Landings	Take-off
	% movements	% movements
LAAG		
Runway 21	95	60
Runway 03	05	40
AREVA		
Runway 21	70	70
Runway 03	30	30

*Excludes light aircraft

5.5 The results in Tables 6 and 7 take account of the following location factors based on *x* and *y* distances for both runways as defined in AEA (1997). For runway 03 *x* = 2.641km, *y* = 3.479km and for runway 21, *x* = 4.348km and *y* = 3.479km. These distances reflect the extension of runway 21. This results in location factors for landing on 03 of $F_L(x, y)$ = 0.0001773. Landing on 21 gives $F_L(x, y)$ = 0.00008849 and take-off $F_T(x, y)$ = 0.00082654[viii]. Clearly, the results are sensitive to the definitions of *x* and *y* distances. If *x* and *y* go up, so location factors decrease and accidents per km^2 per annum decrease for a given number of aircraft movements and accident rate per million movements. These figures differ from those provided by AREVA.

5.6 The following table shows the runway movements for the 500,000 ppa and 2 million ppa scenarios provided by the Lydd Airport Action Group for the three runway directions considered.

Table 5: Runway Movements used in the calculation of Accident Frequencies

Runway	500,000 ppa	2 million ppa
Cat 3 Landing runway 21	5721	10229
Cat 4 Landing runway 21	1734	6588
Cat 3 Landing runway 03	301	538
Cat 4 Landing runway 03	91	347
Cat 3 Take Off runway 21	3614	6461
Cat 4 Take Off runway 21	1095	4161
Total	12556	28324

5.7 Table 6 shows frequencies with bird strikes allowed to influence the accident rates utilised, as well as allowing for an increase in apparent movements on runway 21 to account for the increased likelihood of 'go-rounds' given the noted difficulties with approaches. It can be seen that without these enhancements, the accidents per km^2 per year is at 1.55326E-05 using the accident rate based on Kirkland (2003, 2004) whereas with the US derived average rate per movement this figure increases to 1.86600E-05. An intermediate set of results with extra movements at 1% and rates enhanced by 1% to account for bird strikes gives 1.57103E-05 and 1.88735E-05 respectively. Neither case represents an acceptable level of safety given the standards of 1 in 10 million occurrences. Table 7 shows similar results for the 500,000 throughput with the lowest results also being beneath the aspired safety level.

Table 6: Accident Frequencies allowing for 'go-rounds' and bird strikes, 2 million ppa

Landing Movements on Runway 21	0	+1.0%	+5%	+10%
Rate 1.49	1.55326E-05	1.55548E-05	1.56435E-05	1.57543E-05
+1% for bird strikes	1.56879E-05	1.57103E-05	1.57999E-05	1.59119E-05
+5%	1.63092E-05	1.63325E-05	1.64256E-05	1.65420E-05
+10%	1.70858E-05	1.71102E-05	1.72078E-05	1.73298E-05

Landing Movements on Runway 21	0	+1.0%	+5%	+10%
Rate 1.79	1.86600E-05	1.86866E-05	1.87931E-05	1.89263E-05
+1% for bird strikes	1.88466E-05	1.88735E-05	1.89811E-05	1.91156E-05
+5%	1.95930E-05	1.96209E-05	1.97328E-05	1.98726E-05
+10%	2.05259E-05	2.05552E-05	2.06725E-05	2.08190E-05

Table 7: Accident Frequencies allowing for 'go-rounds' and bird strikes, 500,000 ppa

Landing Movements on Runway 21	0	+1.0%	+5%	+10%
Rate 1.49	6.88584E-06	6.89567E-06	6.93499E-06	6.98414E-06
+1% for bird strikes	6.95470E-06	6.96463E-06	7.00434E-06	7.05398E-06
+5%	7.23014E-06	7.24046E-06	7.28174E-06	7.33334E-06
+10%	7.57443E-06	7.58524E-06	7.62849E-06	7.68255E-06

Landing Movements on Runway 21	0	+1.0%	+5%	+10%
Rate 1.79	8.27225E-06	8.28406E-06	8.33130E-06	8.39034E-06
+1% for bird strikes	8.35498E-06	8.36690E-06	8.41461E-06	8.47424E-06
+5%	8.68587E-06	8.69827E-06	8.74786E-06	8.80986E-06
+10%	9.09948E-06	9.11247E-06	9.16443E-06	9.22937E-06

6 Conclusions

6.1 The Byrne model is an inadequate measure of airport related crash frequencies since there is uncertainty over aircraft crash rates and the model is limited in its capacity to assess overall risk, particularly in complex circumstances such as those that apply at Lydd.

6.2 A more accurate way in which to estimate crash frequencies is to have data on the mix of flights at the airport and various other variables, the prevailing weather over the seasons of a year and a sample of normal operations data that allows frequency to be expressed as risk.

6.3 In the absence of this, the approach used here is to build on Byrne with more up to date and more firmly based accident rates derived from broader UK and US databases to demonstrate trends in risk. The results still understate the risk at Lydd. In particular, a case can be made for increasing these rates to allow for bird strikes and enhancing landings on runway 21 to account for 'go-rounds'. Relatively conservative rates for UK accidents and minimal correction for these two factors, give an estimate of 1.57103E-05 for a 2 million throughput; an unacceptable rate. The estimates in Tables 6 and 7 may be used to reflect the trend of additional risk.

References

AEA (1997) The Calculation of Aircraft Crash Risk in the UK, J.P.Byrne, AEA Technology, Warrington, Cheshire for HSE (150/1997).

AEA (1992) Aircraft Reliabilities and Airfield Dependencies, Byrne, J P & Jackson, P, AEA RS 5407

ACRP (2007) Aircraft Overrun and Undershoot Analysis for Runway Safety Areas. Final Report. Prepared for Airport Cooperative Research Program (ACRP), Jim Hall, Manuel Ayres Jr., Derek Wong, David Pitfield, Andrew Appleyard, Mark Eddowes, Hamid Shirazi, Robert Caves, Richard Speir, Tara Puzin, Applied Research Associates, Elkridge, MD, November 2007-10-09.

AREVA (2009) London Ashford Airport (Lydd) Development: Aircraft crash risks to Dungeness nuclear power stations (R09-014 A).

Eddowes, M., Hancox, J. And A. MacInnes (2001), Final Report on the risk analysis in support of aerodrome design rules. Report for the Norwegian Civil Aviation Authority, AEA Technology, Warrington, Cheshire.

Kirkland, I. (2001), The Risk Assessment of Aircraft Runway Overrun Accidents and Incidents, unpublished PhD thesis, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK.

Kirkland, I., Pitfield, D.E., Caves R.E. and I.Humphreys (2004), An Improved Methodology for Assessing Risk in Aircraft Operations at Airports, applied to runway overruns, **Journal of Safety Science**, 42, 891-905.

Kirkland, I., Pitfield, D.E., Caves R.E. and M.Hirst (2003), The Normalisation of Aircraft Overrun Accident Data, **Journal of Air Transport Management**, 333-341.

Large and Associates (2007), Nuclear Safety of the Nuclear Power Plants at Dungeness as determined by the Proposed Development of London Ashford Airport, R3136-A1.

Wong, D.K.Y, Pitfield, D.E., Caves, R.E. and A.J.Appleyard (2006), Quantifying and characterising aviation accident risk factors, **Journal of Air Transport Management**, 12, 352-357

Wong, D.K.Y. (2007), The Modelling of Accident Frequency using Risk Exposure Data for the Assessment of Airport Safety Areas, unpublished PhD thesis, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK.

Wong, D.K.Y, Pitfield, D.E., Caves, R.E. and A.J.Appleyard (2009a), The Development of a more Risk Sensitive and Flexible Airport Safety Area Strategy. Part 1. The development of an improved accident frequency model. **Journal of Safety Science**, 47, 903-12.

Wong, D.K.Y, Pitfield, D.E., Caves, R.E. and A.J.Appleyard (2009b), The Development of a more Risk Sensitive and Flexible Airport Safety Area Strategy. Part II. Accident location analysis and airport risk assessment case studies. **Journal of Safety Science**, 47, 913-24.

[i] The runway direction pointing south west in the direction of the town of Lydd is called Runway 21 and the runway direction pointing north east in the direction of Dymchurch/Hythe is called runway 03. Lydd Airport has one instrument landing system (ILS) on runway 21. There is no ILS on runway 03.

[ii] The data is analysed using Poisson Regression.

[iii] These accidents include veer-offs.

[iv] This distance was defined as 10km.

[v] The rate calculations conflate military accidents with civilian for sparser classes.

[vi] The lack of an exact correspondence between weight classes prevents a precise match. This discrepancy is most noticeable when defining small transport and executive jet as this boundary is lower than that for medium and large commuter aircraft in the US data. The large jets definitions are similar.

[vii] http://www.wildlifeextra.com/go/news/lydd-airport876.html#cr

[viii] The distances are from the centre of R063, that is, the centre of the restriction zone.