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| Institution: | **Loughborough University** |
| Unit of Assessment: | **B14 Civil and Construction Engineering** |
| Title of case study: | **Improved global airfield safety through enhanced aircraft accident modelling** |

**1. Summary of the impact** (indicative maximum 100 words)

A new method for classifying aircraft accidents and modelling the effectiveness of runway end safety areas was developed by Pitfield and colleagues at Loughborough University (1997-present) to improve global airfield safety. It was adopted by the US Airports Cooperative Research Program in 2008, validated at eight airports, and empirically applied at three, including San Francisco and Toronto (2009-2010). It resulted in: the use of enhanced aircraft accident modelling methodologies by aviation practitioners; improvements to global airport risk assessment and safety management regimes; the utilisation of empirical techniques by a commercial consultancy; and evidence being presented to the 2011 UK Public Inquiry into the proposed expansion of London Ashford Airport.

**2. Underpinning research** (indicative maximum 500 words)

Aircraft overruns, undershoots, veer-offs and crashes during take-off and landing account for 90% of commercial aviation accidents worldwide. Runway end safety areas (RESAs) are designed to protect aircraft occupants and residents living near airports by mitigating these events' impact. Inadequate RESA provision may endanger lives and property in the event of an accident while their overcautious application may limit airport capacity and future expansion. However, serious deficiencies in existing RESA assessment techniques were evident as they only considered a restricted number of variables and had limited modelling capability. Few methodologies could accurately quantify the risk of an aircraft accident occurring on or near an airport and those that could focused solely on the interests of specific stakeholders, considered few risk factors, seldom analysed normal airside operations' risk exposure, and were incapable of quantifying the criticality of risk factors or using them to assess the likelihood of accident occurrence. This research addressed these limitations.

Initial EPSRC-funded research **[G1]** was conducted at Loughborough University by Kirkland (Research Assistant, 1 October 1996 – 27 August 2001), Pitfield (Senior Lecturer, 1990-present), and Caves (Research Assistant, 13 October 2003 – 30 September 2006). The research established the need to separate modelling frequency, location, and the consequences of runway overrun accidents. Kirkland's contribution resulted in him obtaining his PhD in 2001. The team produced peer-reviewed publications **[R1]** and won a further research grant (EPSRC, 2003-2006, **G2**). Another researcher, Wong (1 October 2003 – 4 July 2007), then extended the early research and obtained his PhD in 2007. Further peer-reviewed outputs, which distinguished four accident categories – overrun, undershoot, veer-off, and take-off and crash, were published **[R4, R5]**. EPSRC reviewers considered this research internationally leading in 2007 **[R2, R4, R5]**. The Airport Cooperative Research Program (ACRP) – a US organisation sponsored by the Federal Aviation Administration (FAA) to develop practical solutions for airport operators – funded further research **[G3]** and adopted the new methodology **[R3]**. Eight North American airports have validated it and three have applied it directly – San Francisco and Toronto Pearson International Airports and Ugnu-Kuparuk Airport, Alaska (2009-2010).

A new and comprehensive database detailing all commercial aircraft accidents that occurred within a 10 nautical mile radius of airfields between 1982 and 2002 was compiled from 440 National Transportation Safety Board accident reports and a new accident taxonomy was developed. This enabled valid statistical comparisons to be made within individual accident categories for the first time in Kirkland's research on overruns **[R1]**. Loughborough researchers identified statistically significant trends and assessed the prevalence of particular risk factors for specific accident types. These included variables that had not been examined in previous studies such as weather conditions **[R2]**. In the second stage of the bivariate analysis, relative accident involvement ratios

were calculated to quantify the accident propensity of flights under different conditions and levels of risk exposure. In the final stage they calibrated a series of logistic regressions on individual risk factors to obtain odds and risk ratios for accident occurrence. Using multivariate modelling, they examined the performance of different aircraft, local airport and topographic conditions, and the point of first impact and final wreckage location for the four accident types **[R4, R5]**. The resulting predictive power is vastly superior to that of previous methodologies and has global reach and significance (evidenced by **R6** and Section 5). Research to further advance the capabilities of the model are currently being conducted by Pitfield, Budd (Senior Lecturer, 2013-present) and Gleave (Researcher, 1 October 2012 - to date).

**3. References to the research** (indicative maximum of six references)

The six references listed here form part of a larger corpus of academic peer-reviewed research publications and international conference presentations given in the UK, USA, Brazil, Singapore, Japan, Portugal, Italy, Ireland and Indonesia that date back to 2003. References R1, R4, R5 and R6 were published in the top rated international safety research journal, the Journal of Safety Science (5 year impact factor 1.785). R2 was published in the peer-reviewed Journal of Air Transport Management (5 year impact factor 1.394) while R3 was published by the US Transportation Research Board.

R1 Kirkland, I.D.L., Caves, R.E., Humphreys, I.M. and Pitfield, D.E. (2004) An improved methodology for assessing risk in aircraft operations at airports, applied to runway overruns, *Safety Science*, 42(10), 891-905. DOI: 10.1016/j.ssci.2004.04.002

**R2 Wong, D.K.Y., Pitfield, D.E., Caves, R.E. and Appleyard, A.J. (2006) Quantifying and characterising aviation accident risk factors, *Journal of Air Transport Management*, 12, 352-357. (Assessed by EPSRC as internationally leading in 2007). DOI: 10.1016/j.jairtraman.2006.09.002**

R3 Pitfield, D. E. (with J Hall, M Ayres Jr., D Wong, A Appleyard, M Eddowes, H Shirazi, R Caves, R Speir, T Puzin) (2008) *Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas*, Airport Co-operative Research Program, Project 4-01, US National Academies and Transportation Research Board, 2006-2007, Applied Research Associates, Elkridge, MD. Available online: http://www.nap.edu/openbook.php?record_id=14137

**R4 Wong, D.K.Y., Pitfield, D.E., Caves, R.E. and Appleyard, A.J. (2009) The Development of a more Risk Sensitive and Flexible Airport Safety Area Strategy. Part I. The development of an improved accident frequency model, *Safety Science*, 47, 903-912. DOI: 10.1016/j.ssci.2008.09.010**

**R5 Wong, D.K.Y., Pitfield, D.E., Caves, R.E. and Appleyard, A.J. (2009) The Development of a more Risk Sensitive and Flexible Airport Safety Area Strategy. Part II. Accident location analysis and airport risk assessment case studies, *Safety Science*, 47, 913-924. DOI: 10.1016/j.ssci.2008.09.011**

R6 Ayres, M., Shirazi, H., Carvalho, R., Hall, J., Speir, R., Arambula, E., David, R., Gadzinski, J., Caves, R., Wong, D., and Pitfield, D. E. (2013) Modelling the location and consequences of aircraft accidents, *Safety Science* 51, 178–186. DOI: 10.1016/j.ssci.2012.05.012

**Grants awarded:**

G1 Caves, *Runway overrun risk assessment and consequence analysis*, EPSRC (GR/M20983/01), Aug 1998 – Jul 2001, £102,367

G2 Pitfield, *Improving the assessment of risk to occupants and communities due to aircraft operations on and near airports*, EPSRC (GR/S20000/01), Sep 2003 – Sep 2006, £302,386.

G3 Pitfield, *Aircraft Overrun and Undershoot Analysis for Runway Safety Areas*, Airport Co-operative Research Program, US National Academies and Transportation Research Board (Project 4-01), Sep 2006 – Oct 2007, $250,000 (with ARA, Maryland, USA).

**4. Details of the impact** (indicative maximum 750 words)

Incorporation of the research findings in US Transportation Research Board guidelines **[C1, C2]** has changed practices of RESA design and evaluation **[C3, C4, C5]** and led to improvements in RESA design at three airports **[C4, C5]**. This has directly improved the safety of the 74+ million annual passengers, 830,000 aircraft movements, and tens of thousands of airport workers and local residents at these sites **[C6]** by informing and improving airport safety modelling and management systems **[C4, C5]**. The research underpinned Pitfield's contribution as Evidence in Chief at the 2011 UK planning inquiry concerning the proposed expansion of London Ashford Airport, near Dungeness nuclear power stations. Pitfield's evidence enhanced public and practitioner understandings of the risks of aircraft accidents on and near airports and contributed to the Office for Nuclear Regulation's (ONR) decision in 2012 to review how the risk aircraft pose to nuclear safety is evaluated. In October 2013, Pitfield, Budd and Gleave were contracted to undertake external research with the UK Health and Safety Executive in Support of the ONR Chief Inspector's Evaluation of Accidental Aircraft Crash risk and develop a new off-airport crash model **[C7]**.

Public and practitioner dissemination of the research at the ATRS Annual Conference in Brazil in 2005 attracted attention from the Brazilian Civil Aviation Authority (BCAA). Following the move of a BCAA employee to US-based consultancy Applied Research Associates (ARA), Pitfield and colleagues at Loughborough University developed and won a joint bid with ARA for funding from the US Airport Cooperative Research Program to implement their research **[C3]**.

The resulting international academic/industry collaboration directly led to the publication of ACRP Report 3 *Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas* in 2008. This report details a nine-step procedure for evaluating a RESA to determine the probability that an incident will occur during aircraft operations at or near an airport with severe consequences **[C1]**. This procedure, underpinned by the Loughborough team's research, is now widely known as 'ACRP 3'. In ACRP Report 50, published in 2011, ARA extended ACRP 3, adding, among other things, a freely-available risk-analysis software tool for calculating the risk associated with RESA designs **[C2]**.

To comply with new national regulations, US airports must enhance their RESAs to meet FAA design standards by the end of 2015. In pursuit of this, San Francisco International Airport (SFO) proposed a set of RESA development alternatives and commissioned ARA to evaluate them using ACRP 3 (2009-2010). SFO needed to quantify the extent to which each non-standard alternative would reduce the risk of severe accident consequences and compare this with the risk reduction that would be realised were SFO able to implement standard RESA designs. The first phase of SFO's RESA-development program began in 2012 with completion anticipated in 2014 **[C4]**. The fatal Asiana Airlines Boeing 777 undershoot at SFO on 6$^{th}$ July 2013 illustrated the vital importance of this work.

In Canada, new regulations regarding RESAs are currently being drafted by Transport Canada following recommendations from the Canadian Transportation Safety Board. Like SFO in the US, the Greater Toronto Airports Authority (GTAA) used ACRP 3 and ACRP 50 as the principal sources for its assessment of risks associated with the RESA designs proposed for Toronto Pearson International Airport. The process culminated in an option for each runway end and the recommendation that an engineered materials arrestor system be installed. The GTAA board of directors adopted the recommendations and implementation will be completed in 2015 **[C5]**.

In 2011, the UK Secretary of State for Communities and Local Government called in a planning application for expansion of London Ashford (Lydd) Airport. Pitfield participated in the subsequent public inquiry **[C8]** as an expert witness for Lydd Airport Action Group (LAAG). In his proof of evidence, he explained how the methodology could be applied to Lydd. He estimated the risk posed by the proposed airport expansion of an aircraft crashing into one of the nuclear power stations at Dungeness and contrasted the sophisticated Loughborough model with the Byrne model, a UK industry standard for risk assessments. Permission for the airport's expansion has recently been granted. Following criticism from Pitfield and others of the Byrne model, the Office for Nuclear Regulation convened an independent technical advisory panel (TAP) in 2012 to provide advice on aircraft crash hazards in relation to nuclear safety. Pitfield was asked to participate in the

TAP from November 2012 **[C9]**. Public awareness of the importance of aircraft-accident modelling has been enhanced by: Pitfield's participation in the public inquiry and the publication of articles referring to his evidence in the *Kentish Express* local newspaper and in the print and online editions of *The Guardian* national newspaper **[C10]** and Gleave's interviews on Sky News, BBC News, Al Jazeera and Channel News Asia (2012 and 2013) on the subject of aircraft safety incidents.

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

The following sources of corroboration can be made available at request:


**C1** *ACRP Report 3 – Aircraft Overrun and Undershoot Analysis for Runway Safety Areas*, (2008) Airport Co-operative Research Program, Washington DC: Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_003.pdf

**C2** *ACRP Report 50 – Improved Models for Risk Assessment of Runway Safety Areas*, (2011) Airport Co-operative Research Program, Washington DC: Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_050.pdf

**C3** Letter from Principal Engineer, Applied Research Associates and Project Manager of ACRP 4-01. A copy of this letter, complete with signature, is available.

**C4** Letter 'Subject: ACRP 3 Application at San Francisco International Airport' from the Airport Planning Manager, San Francisco International Airport, Bureau of Planning and Environmental Affairs. A copy of this letter, complete with signature, is available.

**C5** Letter 'Re Airport Cooperative Research Program Use at Toronto Pearson International Airport' from the General Manager, Operational Communications, Greater Toronto Airports Authority. A copy of this letter, complete with signature, is available.

**C6** 2011 passenger and air traffic movement statistics derived from www.flysfo.com and www.torontopearson.com/en/airport_statistics_and_reports/. Documents downloaded from these sites available as pdfs

**C7** Email (dated 2nd Oct 2013) from HM Inspector, Defence Engineering Assessment, Bootle confirming the contract award. A copy of this email is available.

**C8** Lydd Airport Development Inquiry, Inquiry Programme

**C9** Email from the Office for Nuclear Regulation (ONR) Parliamentary Business Team to the Department for Transport, sent 9 May 2012 'Re: London Ashford Airport, Lydd, Kent' including announcement by HM Principal Inspector (Nuclear Safety) of ONR's intention to convene a technical advisory panel (TAP) to provide objective, scientific and technical based advice on aircraft crash hazards in relation to nuclear safety assurance and improvement and letter from the Office for Nuclear Regulation (ONR) dated 21st July 2012 inviting Dr David Pitfield to join the Technical Advisory Panel (TAP). A copy of this letter, complete with signature, is available.

**C10** Press articles: 'Risk of nuclear crash "higher than we think"', The Guardian, p. 11. (22 February 2011), 'Airport opponents in nuclear danger claim', Kentish Express (19 May 2011).