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THE RISK OF OVERRUNS

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Abstract

As safety regulation moves towards requiring a safety audit, airports will require a method of assessing risk with respect to overruns and their consequences, whether after landing or after an aborted takeoff. This paper describes the development of such a method. Normal protection for the aircraft is provided in ICAO's Annex 14 by the 60m strip at the end of a runway, and a recommendation for the installation of a Runway End Safety Area (RESA) of at least 90 metres. In fact, airports vary considerably both in the likelihood of incurring an overrun and in the consequences, while Annex 14 provides only average protection. The risk assessment must be sensitive to the characteristics of the airport (e.g. runway geometry, approach aids), the type of operation (e.g. class of aircraft, class of operator, traffic levels) and the consequences of an overrun (e.g. terrain, man-made hazards). It is recognised that existing overrun databases are of an insufficient accuracy, and therefore a database has to be compiled specifically for this study. The paper reports the construction of a normalised database, with which to calibrate the overrun risk model.

Introduction

The runway overrun is one of today's most common types of aircraft accident / incident. An overrun event is defined as the physical act of an aircraft running off the end of the runway and on to the grass strip, and can occur on take off or landing. A Boeing company study[1] reported that during 30 years of jet transport service 46 accidents and 28 potentially serious incidents have occurred as a result of runway overruns during rejected takeoffs. These accidents have resulted in over 400 fatalities. Many more overruns occur on landing (in the UK approximately four times as many), however, the consequences have not been as serious as there tends to be less energy in the aircraft when it departs the runway. The rate at which these overrun accidents occur has not improved over the last three decades. The resulting coverage by the media has a significant adverse affect on the public's perception of the safety of air travel as a whole.

Air travel is still very much a growth industry, and as air travel becomes more widespread, the overrun accident is likely to become an even more common type of accident. This is for a number of reasons. Firstly, the overrun accident is not receiving the same kind of industry wide attention as certain other types of accident, for example, controlled flight into terrain. Secondly, the number of takeoffs and landings is increasing, which will mean that even if the rate of occurrence remains constant, the absolute number of overruns will increase with obvious adverse effects on the public's perception of the safety of the system. Thirdly, as air travel increases, and more flights are scheduled to regional airports, there are likely to be an increasing amount of operations conducted that are runway length limited, and for which therefore, there is a smaller margin for error. Finally, there is still a trend for heavier aircraft, and while the proposed New Large Aircraft will not necessarily require any greater field length than existing aircraft, the consequences of an overrun are potentially more serious.

Change in safety regulation philosophy

The method of safety regulation, in particular that of the UK, is moving towards requiring a safety audit. This will mean that in practice the aerodrome operator will have to assess the risk and reduce it, if it is deemed to be at an unacceptable level. Therefore a method has to be developed by which the risk of an overrun at a particular airport can be ascertained and ways of reducing the overrun risk, can be determined. This method is illustrated in figure 1.

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Methodology for risk determination

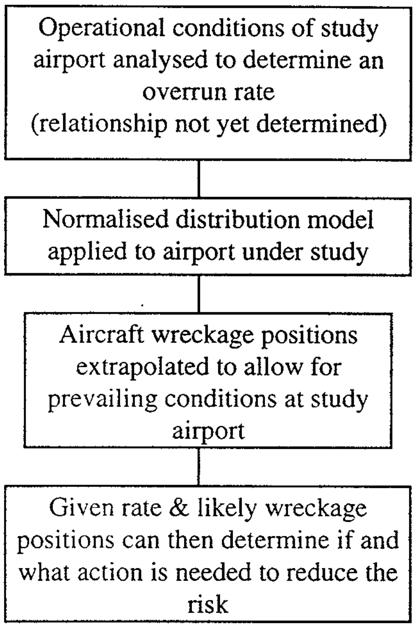

Figure 1.

Factors which increase the risk of an overrun

The factors which can increase the risk of an overrun are numerous, as are the factors which can increase the risk of any type of accident. While it will be impossible to predict when and where an overrun will occur, as the factors that contribute to an event will be in the hundreds and extremely varied, it will be possible to identify the factors which have the largest influence.

One obvious risk factor is operating on a wet or contaminated runway (one study quotes the risk as being four times greater than on a dry runway[(2)]), although it would seem reasonable to expect the regulations to allow for this and to create a uniform level of risk throughout the operational environment. To identify the magnitude of the risk posed by operating on a wet or contaminated runway the ratio of the number of accidents that has occurred on a wet or contaminated runway against the number that have occurred on a dry runway has to be compared with the ratio of the number of takeoffs and landings that have occurred on wet runways against those that have occurred on dry runways.

Another factor that has a large influence is the amount of runway that is available over and above the accelerate / stop distance or the landing distance that is actually required. Obviously with a normal fleet mix an overrun is far less likely at an airport with runways in excess of 3000 meters, than at an airport at which the majority of operations are runway length critical. An aircraft may have a problem and take up more runway distance than it was designed to, but the large amount of excess runway will mean that it is less likely to leave the runway end.

A factor which is less obvious is the type of operation, i.e. class of aircraft, class of operator etc. as this determines the certification and operational regulations that govern the flight, and any factoring of takeoff and landing distances that must occur.

Wreckage location

The location of the aircraft after it has overrun is important as it is used in determining a number of different aspects of the aircraft / aerodrome interface, and it also will determine the consequences of the overrun, to a large extent.

Annex 14 of the Chicago Convention of the International Civil Aviation Organisation (ICAO) contains the regulations concerned with aerodrome design[(3)]. A number of the regulated dimensions are directly concerned with minimising overrun consequences. Firstly, a graded runway strip surrounds the runway, which is designed to contain a large majority of all aircraft movements which fail to remain on the runway. The strip must be able to support any aircraft which stray off the runway, and must be free of obstacles. Dimensions of this strip vary with aerodrome code number. Secondly, a runway end safety area (RESA) should be provided for aerodromes of certain code numbers, depending upon the conditions off the end of the runway and the characteristics of the traffic. These should extend for at least 90 metres from the end of the strip, and should be at least twice the width of the associated runway. The safety area should be cleared and graded to a standard so as not to cause damage to any aircraft overrunning or undershooting the runway. The protection given to the aircraft by the provisions of Annex 14 only varies with aerodrome code number, and this code number itself varies with the size of aircraft operating at an airport and with the frequency of operations. However, as was noted above, the actual risk of an overrun varies with a number of other factors.

In addition to the studies to determine required RESA dimensions a number of accident location studies have been carried out either as part of a study into the risk imposed by airport activities on to the population around an airport[4] , or as part of a study into the risk of an aircraft impacting a sensitive site such as a nuclear power station[5] .

In the UK, accident location studies have also been undertaken in order to determine the required dimensions of Public Safety Zones. A Public Safety Zone is an area adjacent to the end of a runway in which development of the land is restricted if that development is likely to increase significantly the number of persons living, working, or congregating there. These zones are established where the number of specified movements at an airport reaches 45000 per year or 1500 in any one calendar month, if it appears likely that the number of these movements will reach 2500 per month. The size and shape of the Public Safety Zones has been decided upon in order to keep the population away from areas in which the risk of being harmed by an aircraft crash is deemed to be above an acceptable level.

The method used in the wreckage location study to determine overrun risk differs from that utilised in these existing studies. All of the existing location studies, whether they are to determine RESA dimensions or the risk to a population around the airport, measure the final aircraft location in relation to the departure end of the paved runway surface. This seems sensible as it is easy to determine where the runway is, and the runway is where all the aircraft start and are aiming to finish their journeys. However, the end of the paved surface is not the point that these accidents should be measured to if we want an accurate picture of where accidents will occur in the future.

In order to predict future events we have to extrapolate from what has already happened, and to do this effectively we have to accurately find out where the aircraft came to rest relative to where it should have come to rest had the system operated as it was designed. In accident location models it is not relevant to measure the accident location to the end of the paved surface. If a rejected takeoff does occur, it is not intended that the aircraft comes to rest exactly at the end of the runway (unless the takeoff is runway length limited and even then it will stop at the end of the accelerate / stop distance). Similarly, when an aircraft lands, it is not intended that it takes up all the available runway before it comes to rest. The departure end of the runway, which is the current standard for accident location reference is at a different point in the flight of the aircraft, depending upon the actual length of the runway, and the type of aircraft using it. It is an arbitrary point which has no relevance to, or bearing on the operation. The example described below illustrates this.

On a runway length of 3400 metres, a Boeing 747 is just able to take off at maximum take off weight and is likely to be at the screen height as it crosses the runway end.

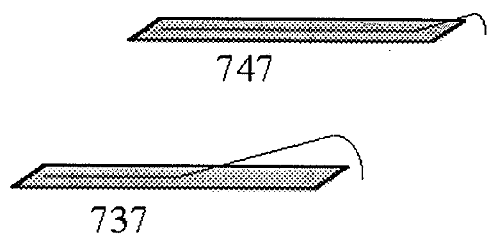

Figure 2.

A 737, also at maximum take off weight and starting roll from the same point, is likely to have reached the same stage of departure roughly 1000-1500 metres earlier. If these aircraft both crash shortly after crossing the far runway end their crash positions will be recorded as being in the same position relative to the runway end. (see figure 2.)

If a location model, with measurements to the runway end, is used on a runway that is 1000 metres shorter, the model will indicate that the aircraft crashed just after the end of the runway. However, if the 737 accident had happened on a shorter runway, it would have crashed 1000 metres beyond the runway end. (see figure 3.)

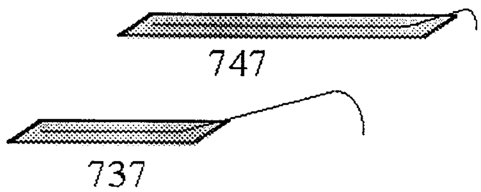

Figure 3.

Measuring the accident location from the end of the runway therefore means that different locations are given depending upon the amount of excess runway available over the required distance. Obviously what is needed is a model which gives an accurate picture regardless of the aircraft / runway combination. In the above example there is a discrepancy of 1000 metres, this would have serious consequences for the calculation of dimensions for Public Safety Zones, (the largest public safety zones in the UK are only 1372 metres in length).

The accident location is also affected by variations in the conditions in which the overrun occurs, and these must be allowed for in the location measurement if we are to obtain useful results.

Results of measurements in relation to required distances

A small sample of overrun accidents has been measured relative to the required distances at this time, but this is enough to show that current location models do not give an accurate picture of what is happening. The required distance has already been calculated in accident reports for some accidents, for others, it is possible to calculate it using flight manual data.

Position relative to landing distance required

Figure 4. shows the final resting place of the aircraft in five overrun accidents that have occurred on landing. None of these aircraft have come to rest more than two hundred metres from the runway, and all the overruns have come to rest within 120 metres of each other. If assumptions about future overruns were just taken from this data it would be natural to assume that all overruns would be contained by a safety area of 200 metres at any airport. A rather different situation is indicated by figure 5. Measuring the accident location in relation to the landing distance required indicates that there is actually a much greater range of overrun distance between accidents. We can also see that two of the aircraft have overrun the landing distance required by nearly 800 metres. This will have greater implications for airports with shorter runways as the typical end of the landing distance required is much nearer the end of the actual runway. This can help to determine the difference in risk between operations on runways of different lengths.

Overrun number 2 occurred to a Gates Learjet 25B, at Northolt airport in the UK, on August 13th 1996. The landing distance required in

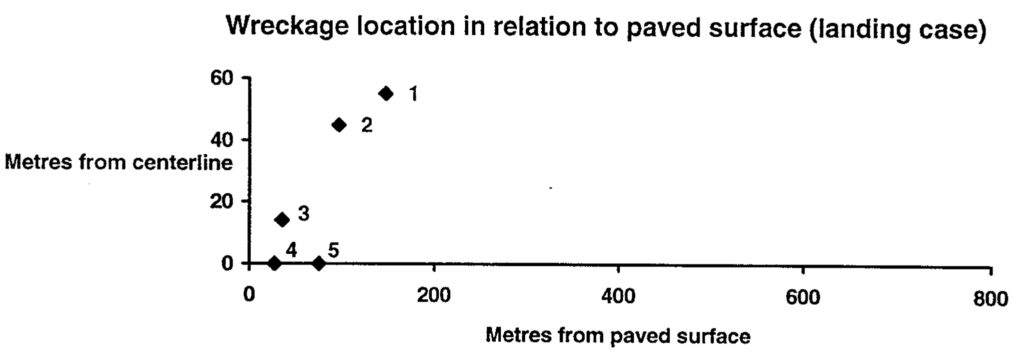

Figure 4.

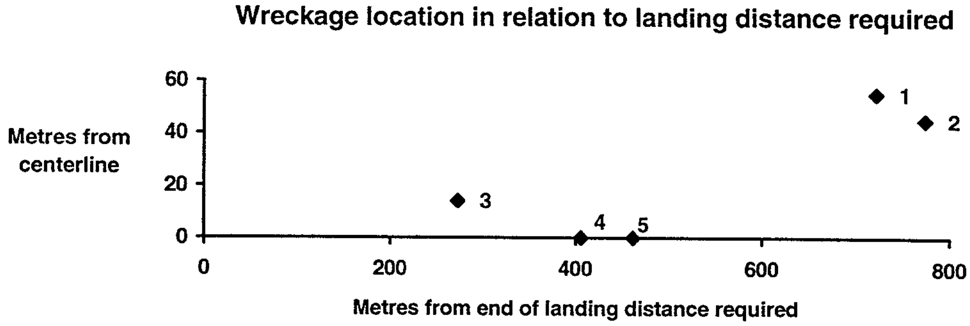

Figure 5.

the prevailing conditions was 1006 metres. However, the actual distance that the aircraft used before it came to rest was 1780 metres, approximately 80 percent more runway than it was designed to have used. The aircraft was eventually brought to a halt by a fence and a van on a road that borders the airport. Had the fence not been there the aircraft would have travelled further still. This was obviously a very significant overrun, and yet we get no indication of this if we relate it's position to the end of the paved surface. We can also see that it overran the landing distance required by more than the aircraft represented by point one, and yet when measuring to the runway it seems as though the overrun was less consequential.

Position relative to accelerate / stop distance required

Figures 6 and 7 compare the distance of the aircraft from the paved surface, with the distance to the end of the accelerate / stop distance required. The results are similar to those in the landing case. When measured from the end of the paved surface, the locations all occur in the first one hundred metres. If these are the only measurements that are available on which to make a decision about RESAs, current dimensions would seem adequate. When taken from the end of the required distance, however, the locations are much more scattered, and the implications for different airports are evident. With a larger data sample the relative risk from operating on different length runways can be calculated.

As an example, point D represents the final resting place of a Boeing 737 which overran runway 31 at New York's LaGuardia airport on the 20th of September 1989. When measuring to the paved surface, the overrun does not seem to be cause for too much concern. It overran approximately 90 metres which is the required length of RESAs, so this type of overrun is already catered for (in fact it wasn't at LaGuardia because the RESA regulations were not retroactive and therefore the airport was not required to provide one). However, if we look at how far the aircraft overran the required accelerate / stop distance we see that the overrun is rather more worrying. It actually overran the required distance by approximately 450 metres which is nearly a quarter of the total runway length, and 40 percent more runway than should have been required. If this flight had been at an airport with a shorter runway the consequences would potentially be much greater. Even with the large amount of excess runway available two people were fatally injured and the aircraft was a total loss.

In addition to highlighting the real severity of the overrun, it is apparent that some of the data points have changed position as they have done relative to the landing distance required, described above. This indicates that some of the more severe overruns are actually currently being recorded as being less consequential, and this suggests that any distribution of points given by a measurement to the end of the paved surface is likely to be closer to a random distribution.

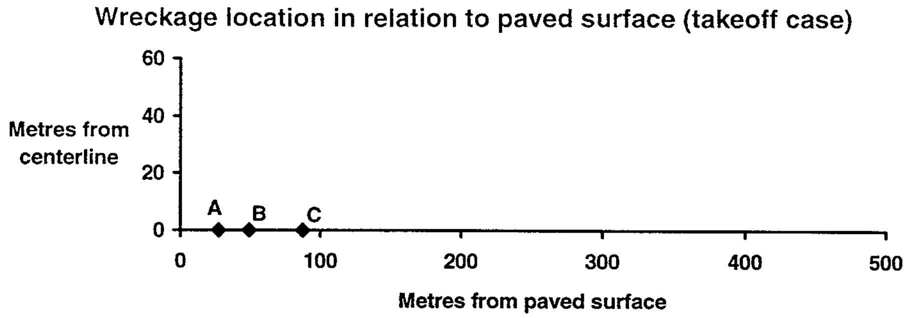

Figure 6.

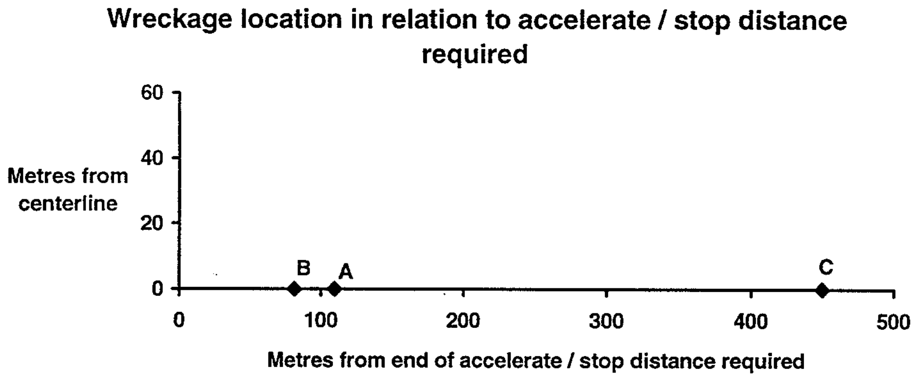

Figure 7.

The compilation of the overrun database is in a very preliminary stage but it has been shown that it is possible to relate the final resting positions of the aircraft to the end of the required distances.

Normalisation to reference conditions

When looking at the overrun risk at a particular airport it is necessary to evaluate where overruns that have occurred at other airports would have come to rest. The overruns that have occurred, therefore need to be normalised to reference conditions.

Often, in a runway overrun it is the characteristics of the ground over which the aircraft has overrun that determine the final resting position. The slope and type of terrain are two characteristics that can have large effects. An aircraft will travel further downhill than it would on level terrain. Likewise, an aircraft will travel further over hard terrain than it would over soft ground.

Another variable that can have an effect is the steering action that a pilot takes to avoid obstacles in the overrun area, or to slow the aircraft more rapidly.

In some cases the aircraft has hit an object or encountered terrain that has stopped it instantly, and in these cases the final position has depended greatly on local conditions. A good example of this would be the overrun that occurred to an MD-82 at New York's LaGuardia airport on the 2nd March 1994. This aircraft overran the runway and was prevented from going into the river by a sea wall. It is estimated that it would have carried on for another 50 metres had it occurred at an airport with a normal overrun area.[(6)]

In addition to normalisation for terrain factors, there has to occur a normalisation for the factors that determine the length of the required distance. These factors include aircraft weight, altitude of the airfield at which the overrun has occurred, airfield temperature, and variations in runway slope and friction. These will affect the length of the overrun in the same way as they affect the landing and accelerate / stop distance. These normalisation calculations will be performed utilising aircraft performance data obtained from the flight department at the UK Civil Aviation Authority. This procedure is shown in Figure 8.

There is also the possibility that the overrun would have been a different type of accident had it occurred at a different airport, and this must be taken into account when applying the location distribution to an airport under study. An example of this would be the takeoff overrun that occurred to a HS 748 at Stansted airport on March 31st 1998. The aircraft took off, and climbed to approximately 150 ft when the pilot realised that one of his engines was on fire. Due to the large amount of excess runway available the pilot was able to put the aircraft back down, however, it overran the runway.

At an airport with a longer runway, it is likely that the aircraft would not have overrun. It is not as straight forward, however, if we apply this overrun to an airport with a shorter runway, as three different scenarios could have occurred. One, the pilot could have decided that he needed to get the aircraft down as soon as possible and put it down in the same place relative to the accelerate / stop distance available. Two, he could have tried to make it back to the airport and crashed in the process, in this case the aircraft could have ended up anywhere in the vicinity of the airport. Three, he could have tried to make it back to the airport and been successful, in which case there would have been no crash. It would be impossible to say which of these scenarios would have happened, and therefore this example serves to illustrate the caution that must be applied when extrapolating crashes to other airports.

Scope of the overrun database

The database that is being compiled will include overruns that have occurred to aircraft in the UK, the USA, and Australasia since 1980. The compilation of this database will enable a greater understanding of the factors which determine the final resting place of an aircraft that has overrun the runway, and what factors have an effect on the risk of an overrun occurring.

Normalisation Procedure

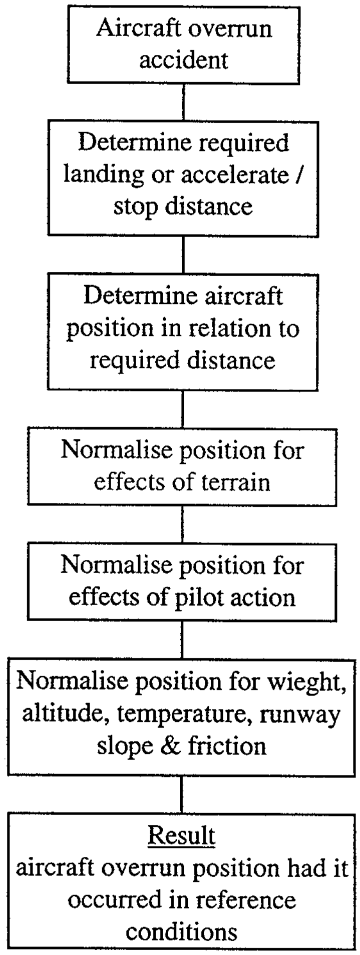

Figure 8.

Conclusion

The safety audit soon to be required by safety regulation authorities, necessitates the development of a method by which the overrun risk at a particular airport can be calculated. Current aircraft overrun location models are not suitable, and therefore a new database has had to be compiled. This new database takes into account the performance of the aircraft, and relates the wreckage location to the required distances. This therefore avoids the inaccuracies that are inevitable when measuring to the end of the paved surface.

The overruns will also be normalised to reference conditions, which is vital to ensure an accurate model but which has not been attempted in any earlier studies.

(1) "Takeoff safety training aid" Boeing Airliner, Jul-Sep 1992.
(2) "Safety aspects of aircraft performance on wet and contaminated runways", Gerard van Es, Alfred Roelen, Eric Kruijsen, Marijn Giesberts, NLR, March 1998.
(3) Annex 14 to the Convention on International Civil Aviation, Volume 1. Aerodrome Design and Operations. July 1995 ICAO.
(4) "Manchester Airport PLC, Proposed second runway, rebuttal of evidence, Third party Risk" DNV Technica, August 1994, MA 1046
"Airplane crash risk to ground population" Solomon, K.A., et al. UCLA-ENG-7424, March 1974
"Third party risk around Vantaa airport of Helsinki", Aho E. et al, IVO International Ltd. for Finnish Civil Aviation Authority, 1995.
(5) "A method for the site specific assessment of aircraft crash hazards", Roberts, T.M., United Kingdom Atomic Energy Authority - Safety and Reliability Directorate, SRD R338, 1987.
"Criteria for the rapid assessment of the aircraft crash rate onto major hazard installations according to their location", Phillips, D.W., United Kingdom Atomic Energy Authority - Safety and Reliability Directorate, SRD R435, 1987.
"A study into the distribution of near airfield accidents (for fixed wing aircraft of mass greater than 2.3 Te)", Jowett & Cowell, Atomic Energy Authority - Safety and Performance Division, AEA RS 5168, 1981.
(6) Aircraft Accident Report, NTSB/AAR-95/01