**Comparing Runway Excursion Factors**

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# Abstract

The purpose of this study was to examine causal factors that result in landing runway excursion accidents, which account for a high percentage of aircraft accidents. The project first worked to compare two independent studies for similarities and differences in the causal and contributing factors that result in landing overrun and veer off excursions. While some differences were noted in the coding of data, the top factors appear to be consistent across the two reports: contaminated runways, landing long, and approach condition.

Noticeably from this initial analysis, a surprisingly high number of excursions occurred after stabilized approaches, raising questions as to why these resulted in an accident. The researchers investigated further into these occurrences by reviewing runway condition and pilot factors of excursions that occurred after the completion of a stabilized approach. The researchers found that 49% of excursions after a stabilized approach occurred on a contaminated runway. This was further impacted by variables such as tire failures and landing long and/or fast.

Finally, a review of pilot technique errors was investigated after excursions that resulted after stabilized approaches. Between 1995-2010, 183 runway excursions occurred after a stabilized approach. The majority of these, 130 accidents, were not attributed to pilot technique error; however, in cases where pilot error was detected, the top factors were loss of directional control, improper crosswind correction, poor speed control, and improper flare.

# Introduction

The purpose of this study was to examine the causal and contributing factors between two reports to identify if these factors were consistent across both investigations. The Flight Safety Foundation (FSF) produced the first study and the Boeing Corporation completed the second. The FSF report was an update on incidents/accidents that occurred from 2008-2010 and followed an earlier report that covered incidents/accidents from 1995-2007. This report reviewed worldwide landing runway excursions for all turbine aircraft. The Boeing report was more selective in their analysis. This report reviewed landing excursions from 2003-2010 and only reviewed Boeing aircraft.

The current study started by comparing the top causal and contributing factors of landing excursions from both reports. A second step in this analysis was to take the raw database of runway excursions, provided by FSF, to review excursions that were between 2003-2010 and only Boeing aircraft to best match the data reported in the Boeing report. In order to compare the FSF and Boeing databases, the second step of this analysis was to filter the FSF database of runway excursions by Boeing aircraft and years from 2003-2010. The results indicated that while the ranking order of causal and contributing factors may vary slightly, the top four factors were similar among both databases.

Further investigation was completed in this present study to examine other categories and examine the consistency of factors impacting runway excursions. A review of the type of operators, aircraft type, and type of operation were also completed. Interestingly, a high percentage of runway excursions resulted after a stabilized approach was accomplished. Therefore, the researchers analyzed the leading pilot technique errors that occurred from runway excursions that resulted after a stabilized approach.

# Review of the Literature

Causal factors for aircraft accidents have long been studied and categorized (Flight Safety Foundation, 2009). Research has not only investigated various conditions that lead to accidents, from both human factors and environmental conditions perspectives, but also has investigated where and when specific accidents occur. Various phases of flight and ground movement have all been demonstrated to be researchable categories for better understanding of conditions that lead to accidents because of the unique set of conditions associated with each one. In the runway environment alone, research has distinguished five distinct categories of excursions: landing overruns, landing undershoots, takeoff overruns, landing veer-offs, and takeoff veer-offs (Ayres et al., 2013). Each of these areas is marked by specific aircraft configurations, operational intentions, and control capabilities, which justifies their distinction.

 While these categories differ in specific ways, other factors need to be considered to fully understand the causes of runway excursions. While it might be true that an aircraft that lands short of the runway resulting in an accident might have vastly different causal events than one that overruns on takeoff, there are other aspects that distinguish or perhaps connect these causal factors. The Flight Safety Foundation (2009) conducted a study to better understand how some other methods of categorization might affect the causal factors of various runway excursion events. The foundation’s initial study looked at the type of aircraft (turboprop, turbojet, and business jets) and whether the causal factors for runway excursions were consistent based on aircraft type. In addition, they looked at uses for aircraft, whether they were commercial or privately operated, and a host of weather and pilot factors. The importance of this particular research is that looking at other distinctions for runway excursions, such as the purpose of the operation, may not affect the accident rates themselves, but rather the factors that lead to them.

 Other research has also explored runway excursion causal factors as well. Guan and Yong (2002) explored turbulence and wind shear as possible contributing factors to aircraft accidents on takeoff or landing. In addition to determining that there was a relationship in wind-related events, they proposed several enhanced measurements to better measure changes in wind speed and direction to help alert pilots earlier of the possibility of such wind events.

 In addition, Valdes et al. (2010) looked at various accident rates for aircraft landing and taking off in order to develop a probability model to help guide future development of runway safety areas. While there are obvious physical and financial limitations to actually changing runway construction patterns of existing airports, their research does represent an approach to mitigate various runway excursions through the development of a smarter runway design.

The common theme in all of this research, and the following study on runway excursion factors based on certain categorizations, is that safety is a critical concern for aviation operations worldwide. A safer aviation system is in everyone’s best interest, and dedicated research as to how safety can be improved, especially in the context of aircraft arriving and departing, is a positive step towards determining ways in which aviation can improve.

# Comparing Flight Safety and Boeing Reports

The purpose of this section was to examine the causal and contributing factors of runway excursions as measured by two reports. The first report was produced from the Flight Safety Foundation between the years 2008-2010 as an update to a previous report spanning from 1995-2007. The second report was from Boeing between 2003-2010. The reports, gathered from two separate databanks, were studied to analyze the causal factors of these two reports.

Data were outlined from the two reports. The Flight Safety Database was used to examine the reported accident data of runway excursions from 2003-2010, the same dates as the Boeing report to determine if the same frequency of causal factors were

produced. The results are shown in Figure 1.

Figure 1: Boeing Landing Runway Excursions between 2003-2010 from the Flight Safety Foundation Database.

The results of this analysis indicated that contaminated runways are the most frequent cause of runway excursions. Surprisingly, a number of excursions result after stable approaches, and were most often the result of contaminated runways. Unstabilized approaches and long, hard or bounced landings were the other most cited factors.

 An independent coding of runway excursion causal factors was determined by review of the FSF report and the Boeing report as shown in Figure 2. Contaminated runways were consistently a leading cause of excursions, as were excursions that resulted from stable approaches and landing long. The Boeing report more frequently identified tailwind as a contributing factor of landing excursions, along with thrust reverser malfunctions. However, no quantitative value was provided for thrust reverser malfunctions. A possible explanation for the difference in tailwind and thrust reverser malfunction issues may be from how the data was collected or coded by the investigative parties.

Figure 2: Percentage Comparisons of Flight Safety, Boeing, and Independently-coded Purdue Findings of Excursion Factors Using the FSF Database.

# Type of Operator

The Flight Safety Foundation’s (FSF) database compiled runway excursions from 1995 to 2010. The database consisted of 520 incidents/accidents organized from reports compiled from sources such as the National Transportation Safety Board (NTSB) and other various government agencies. The purpose of this section is to determine the primary factors of runway excursions and determine if these factors are similar across the operator of the aircraft.

In the Flight Safety Foundation database, there were eight different categories of operators including Major, Regional, Air Taxi, Non-Schedule, Corporate, Government, Other and Unknown. The primary factors from the overall database had been previously examined and determined to be runway condition, approach quality, touchdown factors, wind factors and reverse thrust factors. The database was then sorted by the eight operating conditions and the conditions within each factor were tallied as shown in Figure 3.

Figure 3: Frequency Count of Landing Excursion Factors by Type of Operator.

It is evident that one of the most prominent factors is runway contamination, regardless of the type of operator. This includes any abnormal phenomenon to occur on the surface of the runway including standing water, slush, ice, obstacles, etc. It is also evident that the government and other categories contain very few data points, making it very challenging to obtain an accurate assessment of those particular variables. The unknown category is also difficult to analyze because it only means that the investigators of the accidents were unable to determine the appropriate category for the aircraft. It is possible all of the observations in the unknown group belong in one of the already existing groups, spread out across the groups, or belong in an entirely new group not accounted for in this data. Aside from the spike of contaminated runways accidents in the Major category, the factors appear to be spread across the remaining categories, approach condition, long landing, hard landing, tailwind, and reverse thrust malfunction fairly evenly, indicating that the factors act similarly across the operators. Figure 4 shows the percentage breakdown of factors and removes government, other, and unknown categories from the sample.

Figure 4: Percentage of Landing Excursion Factors by Type of Operator.

 Figure 4 demonstrates the significance of a contaminated runway in runway excursion factors. Long landings also contributed to a significant portion of the accident database.

# Risk Factor Consistency by Aircraft Type

 To understand how risk factors for runway excursions might vary by the type of aircraft, we focused on the two largest manufacturers, Airbus and Boeing, which were the only two manufacturers with enough data from different aircraft types to be reasonably compared. A summary of the different aircraft types within each manufacturer is as follows in Table 1:

|  |  |
| --- | --- |
| **Manufacturer** | **Model** |
| Boeing | 727-100/-200 |
|  | 737 (all variations) |
|  | 747-400 |
|  | 757-200/-300 |
|  | 767 (all variations) |
| Airbus | A300/A310 |
|  | A318/A319/A320/A321 |
|  | A340 |

Table 1: Summary of Different Aircraft Types

The analysis, after controlling for the potential variation of risk factors due to the manufacturer by making comparisons of aircraft within a single company, yielded similar percentages across different categories of risk factors. Figure 5 below shows the risk factors that were used and the corresponding number of instances per aircraft type. For this analysis, a single runway excursion could have multiple causes, and all causes were used as opposed to the primary cause. Frequencies shown indicate the frequency of *risk factors* rather than the frequency of excursions.

 Figure 5: Factors Impacting Airbus Landing Excursions.

 Based on the exploratory look into the variation of causal factors by aircraft type, it did not appear that aircraft type had a meaningful impact on which factors were present.

# Aircraft Class

The Flight Safety Foundation database was further examined based on aircraft class. The class names in this dataset were Turboprops, Business Jets, Commercial Jets, and Other. Of the 520 accident reports: 183 were turboprops, 98 were business jets, 228 were commercial jets, and the 11 remaining were other.

Contaminated runway conditions are, again, a leading factor of landing runway excursions, followed by landing outside of the touchdown zone. Just fewer than 30% of excursions are the result of unstable approaches and just around 10% occur when a tailwind is present. These factors are highlighted in Figure 6.

**Excursion Factors of Aircraft Class by Percentage**



Figure 6: Percentage of Landing Excursion Factors based on Aircraft Class.

# Causal Factors and Runway Conditions After Stabilized Approaches

The purpose of this analysis is to identify the causal factors leading to a runway excursion after a stabilized approach as well as the presence of runway contaminants at the time of the excursion. Out of the 520 runway excursions included in the Flight Safety Foundation database, 183 incidents occurred after a stabilized approach. Boeing, which maintains a similar database, recently published a much higher number in its report titled “Reducing Runway Landing Overruns” (Jenkins & Aaron, Jr., 2012). According to this report, over 68% of all excursions occurred after stabilized approaches, compared to only 35% of all excursions for the Flight Safety Foundation database. It should be noted that a number of the accidents in the Flight Safety Foundation database were unable to be categorized and thus were listed as unknown.

These percentages raise a challenging question, why do so many excursions occur after stabilized approaches? A go-around should be performed for approaches that become unstabilized below 1000 feet under instrument meteorological conditions. The aim of this analysis is to identify the most frequent factors and the runway conditions involved in the 183 excursions identified as being stable.

The analysis includes primary factors as well as secondary and tertiary factors if applicable. First, the different factors are represented in factor categories as identified by the FSF, for example “Wheel Factors” or “Touchdown Factors”. Second, the individual factors have been counted. It is important to mention that for most excursions, more than one factor contributed to the incident. In total, about 713 factors have been identified in 183 excursions.

As shown in Figure 7, wheel factors, which includes factors such as tire failures or main gear collapses, accounted for 113 events. Touchdown factors, such as long or fast landings, amount to a total of 82.

Figure 7: Factor Categories After a Stabilized Approach

Figure 8: Top 10 Factors After Stabilized Approaches

Asymmetric deceleration in the main gear has 34 occurrences, followed by crosswind conditions in 32 cases and loss of directional control in a further 25 cases. Figure 8 highlights the top ten factors leading to excursions after stabilized approaches.

In 49% of all runway overruns after a stabilized approach, the runway was contaminated. This number includes dirt and gravel. Only 32% of all incidents occurred on dry runways. Conditions are unknown in 18% of all cases. About half of all incidents occurred on contaminated runways as shown in Figure 9. This is reflected in the factor analysis, which shows that asymmetric deceleration and other wheel factors are often found in runway excursions. Pilot Technique factors and Flight Crew factors are in the lower half of the factor categories in Figure 7. The results, however, should be used with caution since touchdown factors, such as long and fast landings, arguably could also be included in failures traceable to pilots.

Figure 9: Runway Conditions After Stabilized Approach Excursions

# Pilot Error Techniques after Stabilized Approaches

Under further investigation of landings, it was determined that a relationship existed between unstabilized approaches and contaminated runways as well as unstabilized approaches and failure to go-around. However, there was little investigation into accidents occurring after stabilized approaches and the associated pilot factors determined to be a factor in the accident.

While many could argue that an accident following an unstabilized approach should never have occurred in the first place because a go-around should have been initiated, accidents that occurred after a stabilized approach may not have had issues until shortly before or after touchdown. Unlike unstabilized approaches, stabilized approaches are conducted within the parameters set by the industry for safe flight. Therefore, research should be conducted to determine causal factors, in particular pilot factors, of accidents that occurred after a stabilized approach. This may reveal underlying factors that could be predictors for an incident or accident or shed light on areas of operations that may require more training or specialized attention.

Figure 10: Pilot Error Factors of Excursions After Stabilized Approaches

The database was used to investigate stabilized approaches and isolate the pilot factors associated with the accident. However, 50 accidents were unable to be identified as stable or unstable. In total, 183 approaches out of 520 were classified as stable between 1995 and 2010. All factors contributing to the accident were accounted for including those found to be in conjunction with other factors and are shown in Figure 10.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** | **Pilot factor 1** | **Pilot factor 2** | **Pilot factor 3** | **Total** |
| **Altitude control** | 2 | 1 | 0 | 3 |
| **Crosswind compensation** | 15 | 4 | 0 | 19 |
| **Directional control** | 17 | 8 | 0 | 25 |
| **Improper flare** | 5 | 1 | 1 | 7 |
| **Improper line-up** | 4 | 0 | 1 | 5 |
| **Sink rate control** | 1 | 1 | 0 | 2 |
| **Speed control** | 4 | 4 | 1 | 9 |
| **Unknown** | 5 | 0 | 0 | 5 |
| **None** | 130 | N/A | N/A | 130 |

Table 2: Pilot Error Factors on Excursions After Stabilized Approaches

The results in Table 2 illustrate the breakdown of pilot causal factors for these accidents. The majority of the accidents, 130, had no attributable pilot factors. After no discernable pilot factor, loss of directional control occurred most frequently with 25 occurrences, followed by crosswind compensation and speed control with 19 and 9 respectively. Factors such as altitude control, improper flare, improper line-up, and sink rate control were all found to be factors.

# Conclusions

 This report analyzed factors that resulted in landing runway excursions.  Two reports were compared, one from the Flight Safety Foundation and one from Boeing Aircraft.  A comparison of the two reports and independent data analysis yielded no major differences in the primary factors that impact a landing runway excursion.

Further analysis was completed to review different distinctions within the data set that may have influenced the factors of runway excursions.  Specifically, this study looked at the type of operator, aircraft type, and aircraft class.  Results indicated that contaminated runways were consistently the most cited factor of landing runway excursions.  In addition, landing long and landing with excess speed were two other issues frequently cited.

The type of approach completed was an area that this study investigated in more depth.  Having a stabilized approach was not necessarily a guarantee that a landing excursion would not occur.  Even after a stabilized approach, issues such runway contamination, crosswinds, and maintaining directional control were most frequently noted as factors that influenced the excursion.  When pilot factors did contribute to excursions after stabilized approaches, failure to maintain directional control, crosswinds, and improper speed control were the most common.

# References

Ayres, M., Shirazi, H., Carvalho, R., Hall, J., Speir, R., Arambula, E., & Pitfield, D. (2013). Modelling the location and consequences of aircraft accidents. *Safety Science*, *51*(1), 178-186.

Flight Safety Foundation. (2009). *Reducing the risk of runway excursions: Report of the runway safety initiative*. Flight Safety Foundation Runway Safety Initiative.

Guan, W. L., & Yong, K. (2002). Review of aviation accidents caused by wind shear and identification methods. *Journal Chinese Society Of Mechanical Engineers*, *23*(2), 99-110.

Jenkins, M., & Aaron, Jr., R. F. (2012). Reducing runway landing overruns. *Aero Quarterly. 3,* 14-19.

Valdes, R. M. A., Comendador, F. C., Gordun, L. M., & Nieto, F. J. S. (2010). The development of probabilistic models to estimate accident risk (due to runway overrun and landing undershoot) applicable to the design and construction of runway safety areas. *Safety Science,* *49*, 633-650.