BY ODDVARD JOHNSEN

Improving Braking Action Reports

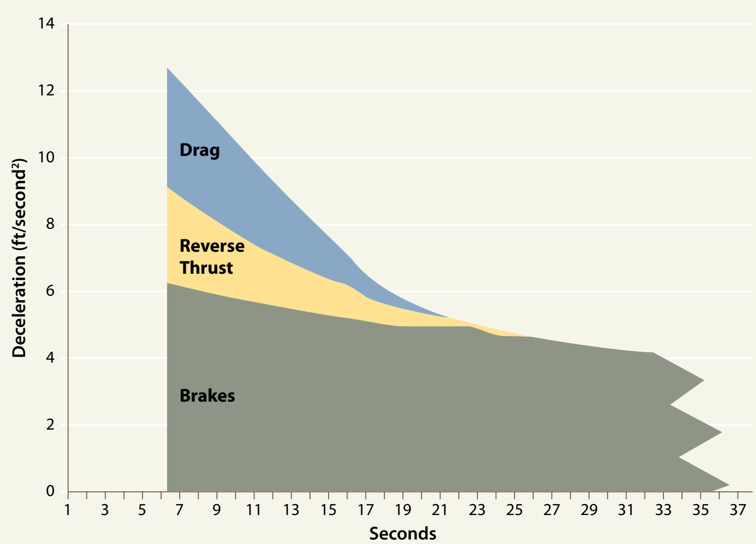
Using performance data from landing aircraft would eliminate current inaccuracies.

The accuracy of braking action reports can be improved substantially by basing them on flight data derived from landing aircraft, research in Norway has shown. This technique could eliminate discrepancies between the braking action measured and reported by airport personnel and the braking action actually experienced by flight crews, as in the following examples:

In December 1999, a Premiair McDonnell Douglas DC-10-10 with 399 people aboard was traveling at about 30 kt when it overran the 2,950-m (9,679-ft) runway at Oslo International Airport in Gardermoen, Norway. The airplane came to a halt about 305 m (1,000 ft) beyond the end of the runway. The DC-10 was moderately damaged, but there were no injuries. To the pilots, the landing had appeared to be normal during the initial phase. It was not until just before they prepared to turn off the runway — at a groundspeed of about 50 kt — that they were caught by surprise by braking action that was described by the captain as "nil." The runway friction measurement that had been provided to the pilots on approach was five hours old and had indicated that braking action was good. Special friction measurements taken about 20, 30 and 40 minutes after the accident also indicated that braking action was good. The investigation determined that these reports were "unrealistic." The temperature was at freezing, and visibility was down to 800 m (1/2 mi) in drizzle and fog.[1]

In December 2005, a Southwest Airlines Boeing 737 with 103 people aboard overran the runway at Chicago Midway Airport and struck two automobiles when it came to a stop on an off-airport road. Preliminary information indicates that the aircraft touched down fast and long, and that the thrust reversers were deployed only seconds before the aircraft left the runway. Although braking action had been reported as good, based on a runway friction measurement taken 30 minutes before the accident, the pilots had used either a medium or maximum autobrake setting. Less than 10 minutes after the accident, another friction measurement was taken, and it too indicated that braking action was good.[2]

Deceleration Factors



Source: Oddvard Johnsen

Figure 1

Relationship Between Braking Coefficients and Reports

Braking action report	Dry	Good	Medium/Fair	Poor/Nil
Airplane braking Mu (approximate)	0.38	0.20	0.10	0.05

Source: Oddvard Johnsen, from Boeing

Table 1

Recent discussions have focused on the use of a reverse thrust credit in calculating landing distance. A question that might remain unanswered until the final report on the Midway overrun is issued is whether the 737's thrust reversers, if used and functioning properly, would have provided enough force to prevent the accident.

Deceleration Factors

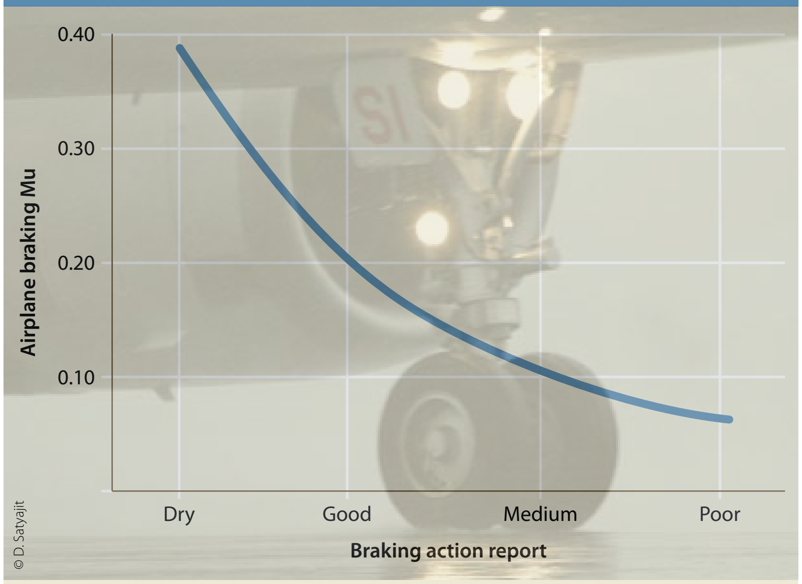
Before discussing the various methods of assessing runway friction and braking action, it is important to understand the fundamentals for the landing distances published by aircraft manufacturers in advisory material such as the airplane flight manual (AFM) and the quick reference handbook (QRH). AFM data are the foundation for on-board performance computations (*ASW*, 2/07, p. 22).

Landing distance theoretically is a function of the maximum available negative acceleration (deceleration) at any given time until the aircraft stops. Deceleration comprises three major factors that vary over time: aerodynamic drag, reverse thrust and braking.

Figure 1 shows the approximate distribution and relationship among these factors throughout a landing run. These relationships are not constant. Deceleration from aerodynamic drag and reverse thrust diminishes quickly. Although these factors influence performance throughout the landing run, for practical purposes, aerodynamic drag and reverse thrust may be disregarded at speeds below 60 to 50 kt; at these lower speeds, wheel braking is the factor that really counts.

Aircraft manufacturers use the term *airplane braking Mu*, which must not be confused with the same term used by the International Civil Aviation Organization (ICAO) for friction measurement. Airplane braking Mu is in many ways an expression of an average sustainable level of deceleration, when aerodynamic drag and reverse thrust are factored out. Table 1 and Figure 2 (p. 38) show the relationships developed by Boeing between braking action reports and airplane braking Mu. The curve in Figure 2 illustrates the dynamic nature of this. The non-linearity of the relationships is important, because it differentiates airplane braking Mu

Relationship Between Braking Coefficients and Reports



Source: Oddvard Johnsen, from Boeing

Figure 2

Reference Landing Distance, Boeing 737-700*

Landing distance per QRH	1,690 m
Air distance	305 m
Safety margin 15%	253 m
Net landing distance	1,132 m
Average deceleration for landing run	1.89 m/s^2
Average g force for landing run	0.19 g
Airplane, medium braking action	0.10 g
Deceleration attributed to aerodynamic drag, reverse thrust, etc.	0.09 g

QRH = quick reference handbook

*Medium/Fair braking action

Source: Oddvard Johnsen

Table 2

from the commonly used ICAO terminology for mechanical braking-action testing devices.

Reference landing distances found in the QRH incorporate non-runway items such as aerodynamic drag and reverse thrust. The QRH does not indicate how much each factor contributes to deceleration and, thus, landing distance; however, there are ways to estimate their contributions. Table 2, for example, shows reference data for medium/fair braking action for the 737-700.

After factoring out the air distance included in QRH landing distance values and a 15 percent safety margin, the net landing distance is 1,132 m (3,714 ft). By using the landing reference speed, VREF, and a full-stop configuration, we can derive an estimated average deceleration for the landing run of about 0.19 g. By comparing this to corresponding airplane braking Mu for medium/fair, which is 0.10, we see that approximately 0.09 g is attributed to factors that are not dependent on the runway. The challenge is to extract the airplane braking Mu portion from a landing run.

Current Methods

Current methodologies for assessing braking action can be broken down to the following major groups: visual/qualitative, subjective and mechanical.

Table 3 is from Safety Alert for Operators (SAFO) 06012, *Landing Performance Assessments at Time of Arrival (Turbojets)*, issued by the U.S. Federal Aviation Administration (FAA) on Aug. 31, 2006. It illustrates how qualitative braking action reports are related to runway contaminants. Today, we know that simple descriptions of contaminants do not easily convert into braking action. There are a multitude of factors influencing braking action, such as the status of the runway micro texture and the weather history, to mention a few examples.

The subjective method is simply pilot reports. The pilot's

Relationship Between Braking Action Reports and Runway Contaminants

Braking Action	Dry (not reported)	Good	Fair/Medium	Poor	Nil
Contaminant	None	Wet Dry snow (< 20 mm)	Packed or compacted snow	Wet snow Slush Standing water Ice	Wet ice

Source: U.S. Federal Aviation Administration

Table 3

assessment of braking action is a personal judgment that is influenced by a number of factors; given the same conditions and aircraft, two pilots likely will judge the conditions differently. Various factors affect the pilot's perception. Braking action on a long runway, for example, might be perceived as better than braking action on a shorter, marginal runway where the end seems to approach substantially faster. A pilot with experience in harsh winter conditions will most likely judge braking action to be better than a pilot with little experience in such conditions.

Particularly in Northern Europe and North America, airports use various types of mechanical devices to measure runway friction. Although the devices produced by different manufacturers vary somewhat in design, they all follow the basic principle of braking a wheel against the pavement at a constant ratio and at a constant speed. The friction scale begins at 0 and goes to 1. ICAO has assigned measured coefficients to braking action estimates (Table 4). Although there is no correlation to airplane braking action — and aircraft manufacturers state that the coefficients should not be confused with airplane braking Mu — these numbers are still applied as a foundation for in-flight performance analysis.

In particular, the visual/qualitative and mechanical methods are applied in a uniform manner, regardless of aircraft type. However, we know that the same ambient conditions can have substantially different effects on a light turboprop airplane compared with a heavier and faster jet.

We also know that snow contaminants can produce considerably different degrees of "slipperiness" in one geographic region, compared with another. One factor is the salt content of the environment; qualitatively, the same contaminant produces a different slipperiness in a coastal environment than in an inland environment.

Relationship Between Runway Friction Measurements and Braking Action Reports

Measured Coefficient	Estimated Braking Action	Code
0.40 and above	Good	5
0.39 to 0.36	Medium to good	4
0.35 to 0.30	Medium	3
0.29 to 0.26	Medium to poor	2
0.25 and below	Poor	1

Source: Oddvard Johnsen, from International Civil Aviation Organization

Table 4

Little Progress

Because of the complex interactions among ambient factors, as well as their interactions with various elements of aircraft dynamics, a definitive determination of braking action is impossible. The current methods of assessing braking action are indirect. With the exception of subjective pilot reports, none of the methods actually uses the aircraft as a reference.

A Braathens 737-700, like the one shown here, was used in braking performance information tests in Tromsoe, Norway.

Furthermore, there has been little or no progress in the development of effective measures to improve the quality of information associated with operating on contaminated runways. Although effort and resources have been devoted to national and international programs to improve the understanding of braking action, practical results have been few.

The work that has been done has failed for several reasons, primarily because it has been stuck to "old tracks" without renewed thinking. The approach has been too academic, with little understanding of actual airline operations.

Tromsoe Experience

In 1999, I was assigned by the Norwegian Aircraft Accident Investigation Board (AAIB) to serve on the team formed during the investigation of the Premiair DC-10 accident to examine the ability of modern aircraft to provide essential braking action information. The test program involved the collection of flight data from 2000 through 2005. The tests were conducted with a Braathens 737-700, and the bulk of the information was collected at the Tromsoe airport in northern Norway, where winter conditions are common.

Among the results of the tests and subsequent analyses was a method to derive airplane braking Mu from flight data after a landing run. This method uses the aircraft as a reference and essentially factors out the aerodynamic drag and reverse thrust elements of the landing run. Data recorded in the velocity interval between 60 and 30 kt are used to compute peak levels of deceleration. The computations result in braking action measurements that are very much in line with QRH and AFM data.

Although this method represents a way of calculating braking action that is still an estimate, it is more directly derived than the methods used today. Furthermore, it uses the dynamic scale of airplane braking Mu, which is the foundation for aircraft performance advisory information found in the QRH/AFM.

Using aircraft data to calculate braking action is a more objective and consistent method. Today, data can be transmitted more easily from aircraft after landing — for example, via a data link or wireless ground link. The frequency at which braking action information is collected — a function of the number of aircraft landing — also is much greater than the intermittent methods currently used.

Grouping Data

The tests at Tromsoe pertained only to the 737-700, and the results were developed with reference to Boeing advisory material, including the definitions of airplane braking Mu and braking action. Similar reference material has not been analyzed for other types of aircraft.

The founding principle for current braking action reports is that they should apply to all aircraft types. Flight data calculations, however, must conform to the basic data in the AFM/QRH. We know that the same ambient conditions can provide different braking action for two different aircraft. However, it would be impractical and cumbersome to develop a reference system for each and every aircraft model. "One size fits all" is not the way to go either. But creating groups of similar aircraft would make this aircraft-data method more workable.

The question that will always remain is: What about the first flight in the morning? The answer might be a ground vehicle that can be fitted with a data recorder and dynamic calculation systems harmonized to a set of predetermined aircraft groups.

Commercial aviation safety no longer depends on pilots' local knowledge, experience and intuition; we are now in a digital world with "boxes" to be filled. The result is that inaccuracies are amplified when runway conditions are critical. There is no quick fix, but by using the appropriate tools and making use of today's ability to acquire, compute and transfer data worldwide in an instant, it is possible to counter the trend of increased runway excursions.●

A retired airline captain, Oddvard Johnsen has served for the past 35 years as an advisor to the Norwegian AAIB on runway conditions and installations. He is a former vice chairman of the International Federation of Air Line Pilots' Associations (IFALPA) Airworthiness Study Group and participated in the Halla Banor (Slippery Runways) Program, conducted by IFALPA and the Aeronautical Research Institute of Sweden in the 1970s. Johnsen also participated in the Joint Winter Runway Friction Measurement Program, conducted by the FAA and Transport Canada in the 1990s.

Notes

1. Norwegian Aircraft Accident Investigation Board report no. 5/2001, *Report of Aircraft Accident at Oslo International Airport, Gardermoen Runway 19L, December 6, 1999.* Pertinent portions of the report were translated into English by Oddvard Johnsen for *ASW*.
2. U.S. National Transportation Safety Board preliminary report no. DCA06MA009; Aviation Safety Network <http://aviation-safety.net/database/record.php?id=20051208-0>.

InSight is a forum for expressing personal opinions about issues of importance to aviation safety and for stimulating constructive discussion, pro and con, about the expressed opinions. Send your comments to J.A. Donoghue, director of publications, Flight Safety Foundation, 601 Madison St., Suite 300, Alexandria VA 22314-1756 USA or donoghue@flightsafety.org.