USE OF LANDING CHARTS [B737]

1. Introduction

The landing stage of a flight is usually the path from 50 ft above the landing threshold and the place where an airplane comes to a complete stop. The 50 ft point is sometimes referred to landing screen height, the same as screen height on the takeoff path.

The landing screen height is fixed to 50 ft for all performance classes of airplanes. Unlike the takeoff screen height which is 35 ft for Class A and 50 ft for Class B airplanes.

The main 3 things which pilots should consider while preparing for landing is weight, speed and landing distance.

1.1. Weight

The maximum weight for landing is the lesser of:

1. Field length limit weight.
2. Landing climb limit weight.
3. Structural limit weight.

Field length limit weight is the weight limited by airplane performance under certain conditions. Usually this weight requires limiting on mountain airfields with short runways.
Landing climb weight is the maximum weight to achieve landing climb requirements (in case of go around).
Structural limit weight is the manufacturer's certified landing weight limit defined in its operational manual.

In some circumstances landing with exceeded structural limit weight is approved by the manufacturer. In that case special maintenance procedures and checks should be applied upon arrival.

1.2. Speed

During the approach down to the landing screen height the airplane must maintain the landing reference speed, known as V_{REF}.

Under regulations covering Class A airplanes, V_{REF} should not be to less than:
1. 1.23 times of the stall reference speed in the landing configuration.
2. the speed of minimum control in the landing configuration.

Boeing Flight Crew Training Manual (FCTM) command speed adjustments should be applied during approach and landing.
1. When using autothrottle, position command speed to V_{REF} + 5.
2. If autothrottle is disconnected or is planned to be disconnected prior to landing, add one half of the steady headwind plus the full gust increment above steady wind. The minimum command speed setting is V_{REF} + 5, maximum is V_{REF} + 20 or landing flap placard speed minus 5 knots, whichever is lower.

V_{REF} is a very important speed since the landing distances in airplane manuals are based on flying at V_{REF}. If the pilot does not follow V_{REF} during the approach, the calculated landing distance will not be achieved.

1.3. Landing distance

The landing distance can be divided into 2 parts: airborne section and ground roll. The airborne section starts from 50 ft of landing screen height and ends on touchdown, when the main wheels touch the landing surface. The airborne section is usually given as 1000 ft. The second section, ground roll, is a distance from touchdown until full stop. However, in normal operations airplanes do not stop on the runway, they rather slow down to a safe speed to vacate the runway and continue taxi to the ramp.

Landing distance required (LDR) is the summary of airborne and ground roll sections. LDR can be calculated using the airplane manual.

Landing distance available (LDA) is the length of a runway from one threshold to the other. Sometimes there are displaced thresholds, which make some parts of the runway unusable for landing.

Pilots need to make sure that the LDR does not exceed the LDA. Always check the LDA on arrival and alternate airfields during flight preparation.

2. Practical example

1.1. Conditions and objectives

Conditions:
Airplane: Boeing 737-800 with winglets and 26K engine rating
Maximum landing weight: 65770 kg
Actual landing weight: 50000 kg
LDA: 2400 m
Runway condition: dry, 1% slope.
Headwind component: 10 kt.
Temperature: +26°, pressure altitude: 4000 ft.

Objectives:
1. Find landing field limit weight.
2. Find landing climb limit weight.
3. Find V_{REF}.
4. Find LDR.

We need to use the Boeing 737 Flight Crew Operational Manual (FCOM) and Quick Reference Handbook (QRH). Make sure you are going to use correct data for certain airplane configuration, engine rating and aviation authority rules.

2.1. Interpolation

Performance data provided in tables view are always shown as round values to simplify the calculations. Pilots have two ways to deal with it: use the next higher number (Boeing officially states this) or simply the closest number to make quick calculations and optionally provide for extra margin. Also sometimes it is reasonable to interpolate between two near numbers.

$$Result = \frac{(X - Xlow) * (Fhigh - Flow)}{(Xhigh - Xlow)} + Flow$$

where
X – input variable ;
Xlow – lowest value of two in table ;
Xhigh – highest value of two in table ;
Flow – lowest corresponding to X value in table ;
Fhigh – highest corresponding to X value in table.

Within this document we sometimes are going to use closest “worse” numbers to avoid long calculations.

2.2. Calculations

2.2.1. Field limit weights

Go to FCOM - Performance Dispatch – Landing – Landing Field Limit Weight – Dry Runway.

1. First we need to correct the field length for the wind. Enter the appropriate table with field length and wind headwind component.

Landing Field Limit Weight - Dry Runway
Flaps 40
Based on anti-skid operative and automatic speedbrakes
Wind Corrected Field Length (M)

FIELD LENGTH AVAILABLE (M)	WIND COMPONENT (KTS)					
	-15	-10	-5	0	10	20
1200			1090	1200	1270	1350
1400	1060	1160	1270	1400	1480	1560
1600	1240	1340	1460	1600	1680	1770
1800	1420	1520	1650	1800	1890	1980
2000	1600	1710	1840	2000	2090	2190
2200	1770	1890	2030	2200	2300	2400
2400	1950	2070	2220	2400	2500	2610
2600	2110	2250	2380	2600	2710	2820
2800	2210	2350	2530	2800	2910	3030
3000	2300	2450	2680	3000	3120	3240
3200	2390	2540	2840	3200	3320	3450
3400	2480	2630	2990	3400	3530	

Result: 2500 m of wind corrected field length. Moving forward.

2. Enter the Field Limit Weight table to find the appropriate limit using corrected field length and pressure altitude.

Field Limit Weight (1000 KG)

WIND CORR'D FIELD LENGTH (M)	AIRPORT PRESSURE ALTITUDE (FT)				
	0	2000	4000	6000	80
1200	46.2	43.6	41.1	38.7	
1400	56.0	53.2	50.2	47.3	44
1600	64.0	61.1	58.3	55.6	52
1800	72.7	69.0	65.5	62.5	59
2000	81.8	77.5	73.5	69.7	66
2200		85.6	81.6	77.3	73
2400			88.1	84.8	80
2600					85
2800					

Decrease field limit weight by 4350 kg when using manual speedbrakes.

Result: 88100 kg of landing field limit weight.

Go to FCOM - Performance Dispatch – Landing – Landing Climb Limit Weight.

3. Next we need to find the climb limit weight. It is a function of temperature and airfield pressure altitude. Enter the appropriate table with these data.

Landing Climb Limit Weight

Valid for approach with flaps 15 and landing with flaps 40

Based on engine bleed for packs on and anti-ice off

AIRPORT OAT		LANDING CLIMB LIMIT WEIGHT (1000 KG) AIRPORT PRESSURE ALTITUDE (FT)									
°C	°F	-2000	-1000	0	1000	2000	3000	4000	5000	6000	7000
54	129	68.6	66.6	64.5							
52	126	69.8	68.3	66.2	63.6						
50	122	71.1	69.6	67.9	65.2	62.6					
48	118	72.4	70.9	69.2	66.9	64.2	61.6				
46	115	73.9	72.3	70.5	68.1	65.8	63.2	60.6			
44	111	75.2	73.6	71.7	69.3	67.0	64.7	62.1	59.6		
42	108	76.5	74.9	73.0	70.5	68.2	65.8	63.6	61.0	58.3	
40	104	77.8	76.2	74.3	71.8	69.4	67.0	64.7	62.5	59.6	56.9
38	100	79.1	77.5	75.6	73.1	70.6	68.2	65.8	63.6	60.9	58.0
36	97	80.4	78.8	76.9	74.5	71.8	69.5	67.1	64.7	62.1	59.2
34	93	81.6	80.1	78.3	75.8	73.2	70.7	68.3	65.8	63.1	60.3
32	90	81.7	81.4	79.7	77.0	74.5	71.8	69.4	66.8	64.1	61.3
30	86	81.8	81.5	81.1	78.2	75.6	72.8	70.2	67.8	65.1	62.3
28	82	81.9	81.6	81.2	79.3	76.6	73.7	71.1	68.4	66.0	63.2
26	79	82.0	81.7	81.2	79.4	77.5	74.5	71.8	69.1	66.5	64.1
24	75	82.1	81.7	81.3	79.5	77.6	75.2	72.4	69.6	67.0	64.5
22	72	82.1	81.8	81.4	79.5	77.6	75.3	72.9	70.2	67.5	65.0
20	68	82.2	81.9	81.4	79.6	77.7	75.3	72.9	70.7	68.0	65.4
18	64	82.3	81.9	81.5	79.6	77.7	75.4	73.0	70.7	68.5	65.9
16	61	82.3	82.0	81.6	79.7	77.8	75.4	73.0	70.8	68.5	66.3
14	57	82.4	82.1	81.6	79.7	77.8	75.4	73.1	70.8	68.6	66.3

Result: 71800 kg of climb limit weight.

Let us compare all the results with respect to field limit weight.

Field limit weight	88100 kg
Climb limit weight	71800 kg
Structural limit weight	*65770 kg*

As we see, landing performance limits are mostly insignificant with long runways. Our most significant performance limit is the climb limit weight of 71800 kg. But the final limit is the structural limit weight because it is the lowest.

2.2.2. V_{REF}

Go to FCOM - Performance Inflight – VREF.

4. The next step is to find V_{REF}. It is a function of flap setting and landing weight. Our landing weight today is 50000 kg.

VREF

WEIGHT (1000 KG)	FLAPS 40	FLAPS 30
85	160	168
80	155	163
75	151	158
70	146	153
65	141	148
60	135	142
55	128	136
50	122	129
45	115	122
40	108	115

Result: V_{REF} is 122 kt.

2.2.3. Landing distance required

Go to QRH – Performance Inflight – Advisory information.

5. The next goal is to find the required landing distance. QRH provides the basic LDR for certain conditions with all needed adjustments. We will try to use Autobrake 2 if within the limits, to safe our brakes. Accurately follow all the adjustments.

ADVISORY INFORMATION

Normal Configuration Landing Distances

Flaps 40

	LANDING DISTANCE AND ADJUSTMENT (M)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°C		APP SPD ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	65000 KG LANDING WEIGHT	PER 5000 KG ABOVE/ BELOW 65000 KG	PER 1000 FT STD/ HIGH*	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 5 KTS ABOVE VREF40	ONE REV	NO REV
Dry Runway												
MAX MANUAL	915	55/-50	20/25	-35	115	10	-10	20	-20	35	15	35
MAX AUTO	1135	55/-60	25/35	-40	140	0	0	25	-25	55	0	0
AUTOBRAKE 3	1590	85/-100	40/55	-70	235	0	0	45	-45	90	0	0
AUTOBRAKE 2	2030	125/-140	60/80	-95	330	20	-35	60	-60	95	35	35
AUTOBRAKE 1	2260	150/-165	75/95	-115	390	55	-65	65	-65	85	155	220

Let us go through this table step by step.
1. **Basic distance.** For **65000 kg of reference** weight the basic distance is 2030 m.
2. **Weight adjustment.** Our actual landing weight is 50000 kg, this is 15000 less than the reference weight. As stated in the table, we should deduct 140 m from every 5000 kg of difference. So, 2030 – (140 * 3) = 1610 m.
3. **Altitude adjustment.** We need to use the notes below the table:

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed, two engine detent reverse thrust, and auto speedbrakes.
For max manual braking and manual speed brakes, increase reference landing distance by 55 m.
For autobrake and manual speed brakes, increase reference landing distance by 45 m.
Distances and adjustments for GOOD, MEDIUM, and POOR are increased by 15%.
Includes distance from 50 ft above threshold (305 m of air distance).
Altitude adjustment for STD altitudes valid up to 8000 ft pressure altitude.
Altitude adjustment for HIGH altitudes valid for altitudes above 8000 ft up to 14000 ft.
***For landing distance at or below 8000 ft pressure altitude, apply the STD adjustment. For altitudes higher than 8000 ft, first apply the STD adjustment to derive a new reference landing distance for 8000 ft then apply the HIGH adjustment to this new reference distance.**

STD adjustment is 60 ft and pressure altitude is 4000 ft. So 1610 + (60 * 4) = 1850 m.
4. **Wind adjustment.** Our headwind component today is 10 kt, So, 1850 – 95 = 1755 m.
5. **Runway slope adjustment.** 1755 – 35 = 1720 m.
6. **Temperature adjustment.** Here we are going to deal with the standard atmosphere (ISA) and its deviation.
As per ISA, the temperature rate is 2°C for each 1000 ft. Therefore:

ISA Temperature = 15 – 2 * altitude (in 1000 ft).

Our pressure altitude is 4000 ft, so ISA temperature = 15 – 2 * 4 = +7 °C.
Actual temperature is +26 °C, therefore ISA deviation is 19 °C. We need to add 60 m twice:
1720 + 60 * 2 = 1840 m.
7. **Approach speed adjustment.**
We are going to use standard V_{REF} + 5 adjustment. So, 1840 + 95 = 1935 m.
8. **Reverse thrust adjustment.** No need, both reversers are in use.

Result: LDR is 1935 m.

2.3. Example results

The airplane is going to land with the following parameters:

Landing weight: 55000 kg
Performance limit landing weight: 71800 kg [Climb limit weight]
V_{REF} = 122 kt.
Command speed: 127 kt [Autothrottle is use].
LDR: 1935 m.
LDA: 2400 m.
Autobrake: 2.

2.4. Other circumstances

It goes without saying that the airplane manufacturer provides performance data for different situations. You can use manuals, such as FCOM and QRH to get all necessary and relevant information.
For example, any runway condition is taken into account there.

Dry Runway

MAX MANUAL	960	55/-55	20
AUTOBRAKE MAX	1215	60/-65	30
AUTOBRAKE 3	1725	95/-110	45
AUTOBRAKE 2	2190	140/-150	65
AUTOBRAKE 1	2415	165/-180	80/

Good Reported Braking Action

MAX MANUAL	1530	85/-90	40
AUTOBRAKE MAX	1625	90/-100	45
AUTOBRAKE 3	1985	110/-125	50
AUTOBRAKE 2	2520	160/-175	75/
AUTOBRAKE 1	2775	190/-205	90/

Medium Reported Braking Action

MAX MANUAL	2085	130/-140	65
AUTOBRAKE MAX	2130	140/-145	65
AUTOBRAKE 3	2215	140/-145	65
AUTOBRAKE 2	2580	160/-180	80/
AUTOBRAKE 1	2795	190/-205	90/

Poor Reported Braking Action

MAX MANUAL	2720	190/-195	90/
AUTOBRAKE MAX	2725	190/-195	90/
AUTOBRAKE 3	2745	195/-195	90/
AUTOBRAKE 2	2905	200/-205	100
AUTOBRAKE 1	3025	215/-220	100

Any other special or abnormal landing distance calculations could be found in a special chapter “Non-Normal Configuration Landing Distance” in QNH.

Always check that you use correct performance data for a particular flight. Do not mix it up because it could lead to unexpected airplane behaviour or insufficient performance.