GOVERNMENT OF INDIA
MINISTRY OF CIVIL AVIATION
AIRCRAFT ACCIDENT INVESTIGATION BUREAU

FINAL INVESTIGATION REPORT OF ACCIDENT TO B737-800 AIRCRAFT VT-SYK AT MUMBAI ON 01/07/2019

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FOREWORD

This document has been prepared based upon the evidences collected during the investigation and opinion obtained from the experts. The investigation has been carried out in accordance with Annex 13 to the convention on International Civil Aviation and under Rule 11 of Aircraft (Investigation of Accidents and Incidents), Rules 2017 of India. The investigation is conducted not to apportion blame or to assess individual or collective responsibility. The sole objective is to draw lessons from this accident which may help in preventing such accidents in future.

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SYNOPSIS

On 01.07.2019, B737-800 aircraft was involved in an accident (runway excursion) at Mumbai airport while landing in moderate to heavy rain. The approach to runway 27 of Mumbai airport was stabilized with aircraft flying on autopilot up to a height of 100 feet prior to touchdown. The aircraft while being flown manually had an extended flare and a late touchdown on the runway. As a result, remaining distance available on the runway was inadequate to stop the aircraft. The aircraft crossed the runway threshold and came to rest at a distance of 615 feet beyond the runway.

The Aircraft suffered substantial damage. The passengers were deplaned by using fire ladders. There were no reported injuries.

1. FACTUAL INFORMATION

1.1 History of the Flight

On 01.07.2019, B737-800 aircraft was involved in an accident (runway excursion) at Mumbai airport while landing in moderate to heavy rain. The aircraft was under the command of an ATPL holder (PF) with a CPL holder as First Officer (PM). There were 160 passengers and 7 crew members on board. There was no injury to any of the passengers or crew members. The aircraft suffered substantial damage.

The subject flight was fifth of the day for the aircraft and second for the flight crew. The flight crew had earlier operated Mumbai-Jaipur sector and the incident flight was from Jaipur to Mumbai. There were no technical issues reported by the flight crew either during Mumbai Jaipur sector or on the return leg (Jaipur- Mumbai) till descent into Mumbai.

The pilots had carried out briefing amongst themselves for the approach including the weather and Go Around actions, if required.

The aircraft commenced descent into Mumbai in the late evening hours. As per the reported weather at the time of approach visibility was 2100 metres in rain making it dark. Reported winds were 090/12 Knots. Runway was wet and the trend provided was “temporary reduction in visibility to 1500 metres with thunder/ showers of rain”.

During descend at approximately 7000’ Pressure Altitude, the crew observed an indication for IAS disagree, indicating a discrepancy of airspeed between

the instrument sources for the flight crew. Although this indication was momentary, the 'Non-Normal Checklist' was carried out. The indication discrepancy did not recur for the remainder of the flight.

The aircraft was radar vectored for an ILS approach for Runway 27 at Mumbai. The approach was stabilized by 3800' Pressure Altitude with landing gear down, flaps 30 and auto brake selected at 3. The autopilot was engaged throughout the descent phase and during approach, the second autopilot was also coupled for the ILS approach. At 100', the autopilot and the auto-throttle were disengaged by the PF. The flare manoeuvre consumed approximately 5807' of the runway length prior to the aircraft touchdown with 3881' of runway remaining. After touchdown, the speed brakes deployed automatically and maximum reverse thrust and wheel brakes were applied. The aircraft exited the paved surface at 65 Knots and came to rest at a distance of 615' beyond the end of the runway.

Once the aircraft came to rest, the flight crew advised cabin crew to be at their stations. The pilots were unable to contact ATC through VHF communication. The PF contacted his airline personnel using mobile phone and informed that the aircraft had overrun the runway and requested for step ladders. The ATC activated fire services and the runway was closed for operation. The Cabin crew carried out check on the passengers in the cabin.

The fire services reached the aircraft location and verbal communication was established with the flight crew once the cockpit window was opened.

Two Fire Services personnel boarded the aircraft from the L1 door using a fire ladder. An assessment of the aircraft structure and occupants was made and the fire services personnel informed the cabin crew that deplaning was to be carried out using fire ladders. There were no injuries during evacuation or otherwise.

The Airport Operator and the Airline initiated the 'Disabled Aircraft Removal Plan' with the help of IATA disabled aircraft removal kit available in Mumbai. The aircraft was finally removed from the accident site after 4days and subsequently, runway was declared operational.

Aircraft flight path over the runway
(The parameters include: Ground Speed (Knots), Calibrated Air Speed (Knots) and Rate of Descent (feet per minute)

1.2 Injuries to Persons

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	Nil	Nil	Nil
SERIOUS	Nil	Nil	Nil
NONE	07	160	Nil

1.3 Damage to Aircraft

Aircraft nose gear collapsed and the aircraft was found resting on engines & forward lower section of fuselage. Collapsed NLG penetrated in E & E compartment. Section 41 skin got buckled below floor level with extensive damage to belly area till section 41.

Forward portion of Nose Radome hit the approach lights and got damaged. 10 inches crack was observed which exposed inner area & Weather radar antenna.

There were dents, scratches on both sides of fuselage and damage to retractable landing lights.

Extensive damage was observed on both engines. Aircraft had dragged for approximately 615 feet and then rested on bottom portion of engine cowls. Both inboard & outboard fan cowls were damaged and Intel Cowl lip section

skin was found torn at several places. Inboard reverser cowl was found to be in deployed condition with damage observed at several places.

Stones & mud were observed inside deployed cowl area. Outboard reverser cowl was in retracted position with bottom portion damaged. All fan blades were found damaged beyond AMM limits. Core ingestion (FOD) caused damage to IGVs.

1.4 Other Damage

Few approach lights were damaged due to impact with nose (Radome portion) and landing gear of the aircraft.

1.5 Personnel Information

1.5.1 Pilot Flying

Age	31 years
License	ATPL
Date of Issue	15/09/2016
Valid up to	14/09/2021
Date of Class I Med. Exam.	28/02/19
Class I Medical Valid up to	27/02/20
FRTO Number	15890
Date of issue FRTOL License	10/01/11
FRTO License Valid up to	09/01/21
Total flying experience	5355:23 hours
Total Experience on type	5113:35 hours
Total Experience as PIC on type	1915:28 hours
Last flown on type	01/07/19
Total flying experience during last 01 Year	808:44 hours
Total flying experience during last 6 Months	416:11 hours
Total flying experience during last 30 days	103:09 hours
Total flying experience during last 07 days	19:27 hours
Total flying experience during last 24 Hours	04:26 hours

1.5.2 Pilot Monitoring

Age	30 years
License	CPL
Date of License Issue	18/03/2010
Valid up to	17/03/2020
Date of Class I Med. Exam.	28/09/18
Class I Medical Valid up to	06/10/19
Date of issue FRTOL License	18/03/10
FRTO License Valid up to	17/03/20
Total flying experience	4826:01 hours
Total flying Experience on type	4625:56 hours
Last flown on type	01/07/19
Total flying experience during last 01 Year	878:16 hours
Total flying experience during last 6 Months	447:13 hours
Total flying experience during last 30 days	75:12 hours
Total flying experience during last 07 days	27:42 hours
Total flying experience during last 24 Hours	04:26 hours

1.6 Aircraft Information

Boeing B737-800 is a subsonic, medium-range, civil transport aircraft. The aircraft is installed with two high bypass turbofan engines manufactured by CFM. The aircraft is designed for operation with two pilots and has passenger seating capacity of 168. The aircraft is certified in Normal (Passenger) category, for day and night operation under VFR & IFR.

The maximum all up weight authorised for the aircraft was 70533 Kgs. The subject aircraft bearing MSN 30410 was manufactured in the year 2002. The aircraft was registered with DGCA, India under the ownership of Klaatu aircraft leasing (Ireland). The aircraft was registered under Category 'A' with Certificate of Registration No. 5071. The Certificate of Airworthiness Number 7174 under "Normal category" subdivision Passenger / Mail / Goods was issued by DGCA on 25th April 2019. At the time of accident, the Airworthiness

Review Certificate was current and was valid up to 25th April 2020. The aircraft and its engines were being maintained as per the maintenance program consisting of calendar period/ flying hours based maintenance program approved by DGCA, India

1.7 Meteorological Information

The information as per the MTARs is as below: -

Time UTC HH:MM	Winds knots	Visibility meters	Cloud Base	Temp/ Dew Point	Tempo
17:00	120/05	0800	SCT 008 BKN 015 FEW 030CB OVC 080	26/25	0600 TSRA
17:30	090/12	2100	SCT 008 BKN 018 FEW 030CB OVC 080	26/26	1500 TSRA
18:00	150/05	2100	SCT 010 SCT 018 FEW 030CB OVC 080	25/25	1500 RA
18:30	320/10	1000	SCT008 BKN 015 FEW 030CB OVC 080	25/25	0600 TSRA

1.8 Aids to Navigation

Mumbai airport is equipped with VOR (frequency 116.60 MHz), DME (frequency 1200/1137 MHz), NDB (frequencies 396 kHz), ASDE (frequency 9375 MHz). PAPI & ILS Cat- II lighting is installed on Runway 27. PAPI &ILS Cat-I lighting is installed at 09 & 14 and SALS (Simple Approach Lighting System) is installed at Runway 32.

1.9 Communications

The communication facilities at the aerodrome were serviceable. As per the CVR, the Aircraft was unable to establish contact after the aircraft came to rest beyond the runway using the VHF probably due to damage to the VHF communication system during the accident.

1.10 Aerodrome Information

The CSIA (Reference point 19° 05' 30" N 072° 51' 58" E) is a licensed airport both for IFR and VFR traffic with IATA location Identifier code as BOM and ICAO location Indicator code is VABB. The elevation (AMSL) is 12.13 m (40 ft) with reference code as 4F. The airport has two cross runways made of Asphalt. The details of these runways are as given below: -

- Rwy 27 -- 3448m × 60m
- Rwy 09 -- 3188m × 60m
- Rwy 14/32 -- 2871m × 45m

	TORA (M)	TODA (M)	ASDA (M)	LDA (M)	RESA (M)
Rwy 09	3188	3188	3188	3048	240 X 120
Rwy 27	3448	3448	3448	2965	240 X 120

1.10.1 Runway Friction Checks

The friction status of a dry runway surface must be assessed periodically under the terms of ICAO TPN 13. It should also be re-assessed after any maintenance which might have affected the surface smoothness. If during regular inspections or a planned maintenance work, low friction is noticed particularly in TDZ, unless rectification can be immediately achieved, NOTAM action to the effect that “the runway is liable to be slippery when wet” should be taken. Any such low friction condition is conducive to viscous aquaplaning beginning below the ‘aquaplaning speed’ and therefore ‘slippery runway’ landing performance data should be used.

The airport operator has issued an SOP to formalise the friction testing of the runways and to ensure that the standard friction co-efficient is maintained. As per the SOP, the periodicity for the inspection shall not exceed 7 days. As per the information available with the airport operator, the friction test was carried out on 19.9.2017 and the friction level was found to be higher than a minimum of 0.50.

1.10.2 Runway Surface State – Information to the Pilot

The surface state of a wet runway can be assessed by either: -

- the depth of water in the touchdown zone, or
- the measured or observed braking action.

It is unlikely that the actual depth of water on a runway will be passed by the airport operator to an aircraft though ATC. At present, equipment which takes tactical friction measurement on wet runways is rarely authorised for use, so the best information a pilot is likely to get prior to landing is an informal braking action comment made to ATC by a previously landed aircraft. This should be passed by ATC with the time of the report, the aircraft type which made it and any significant change in precipitation since it was received. In the present case, however, no report was made by any aircraft which landed or took off prior to the accident.

ICAO Doc 9981 - Amendments

Annex 14, Volume I contains SARPs related to the assessment and reporting of runway surface condition. The operational practices are intended to provide the information needed by the flight crew. When the runway is wholly or partly contaminated or is wet, the runway condition report should be disseminated as soon as possible. However, runway surface conditions have contributed to many safety occurrences in the past and investigations into these occurrences have revealed shortfalls in the accuracy, real time transmission of assessment of surface condition and reporting methods.

The Air Navigation Commission, ICAO has approved certain amendments to the first edition of the Procedures for Air Navigation Services – Aerodromes (PANS—Aerodromes) i.e. Doc 9981with an applicability date of 5th November 2020.The amendment introduces the division of the PANS-Aerodromes into two parts. Part I contains high-level matters, including aerodrome certification and Part II (Airport Operations Management) contains day-to-day operational matters.

Airport Operations Management part of ICAO Doc 9981 provides operational procedures for the operation and management of airports and related airport

activities. The requirements contained in that part are applicable to the airport operator and/or other relevant entities operating on the airport. The proposed global reporting format for reporting runway surface conditions in a standardized manner will help the flight crew to accurately determine aircraft take-off and landing performance which in turn will result in a global reduction of runway excursion incidents/ accidents. Also, occurrences of disruptions to airport/ air traffic operations and the removal of aircraft disabled at an airport on a runway will be reduced.

The document further requires that the Runway Condition Report (RCR) is used for reporting assessed information. The RCR describes a basic structure applicable for all these climatic variations. The philosophy of the RCR is that the airport operator assesses the runway surface conditions whenever contaminants including water are present on an operational runway. From this assessment, a Runway Condition Code (RWYCC) and a description of the runway surface are reported which can be used by the flight crew for aircraft performance calculations. This format, based on the type, depth and coverage of contaminants, is the best assessment of the runway surface condition by the airport operator.

Changes in conditions are to be reported without delay. The document further informs that there are technologies (emerging) based on the use of a model of the runway surface (describing its geometrical surface) which when paired with sensor information of water depth would allow real time information of the condition of runway.

1.11 Flight Recorders

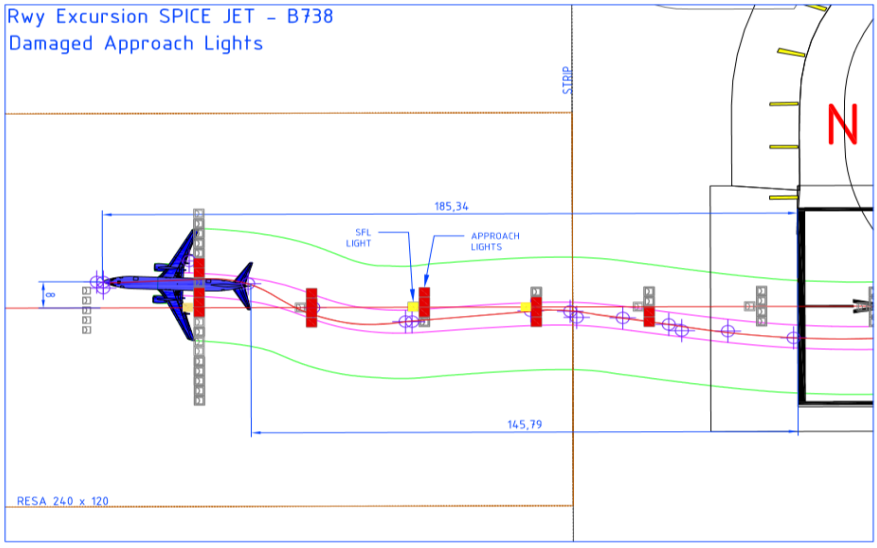
The aircraft was equipped with both SSCVR and SSFDR. The data from both these recorders was downloaded and analysed for the investigation purposes.

Time (UTC)	Sequence of Events
18:11:09	VOR/ LOC engaged, Altitude: 6996 ft (baro), DME 28.5
18:13:44	Gear Down, Altitude: 5785 ft (baro)
18:14:50	Flap 30 selected, Altitude: 5011 ft (baro)
18:15:50	G/S engaged, Altitude: 4484 ft (baro), DME 14.25
18:16:21	Both Autopilot engaged, Altitude: 4446 ft (baro)
18:19:58	At 1009 ft AGL, DME 3

	• CAS: 156 kts, Vref: 146 kts, • N1 Engine #1: 53.41 #2: 52.7 • ROD: 960 fpm
18:20:26	At 509 ft AGL, DME 1.75 • CAS: 154 kts, Vref: 146 kts, • N1 Engine #1: 58.38 #2: 57.1 • ROD: 795 fpm
18:20:56	Auto throttle disengaged
18:20:57	Both Autopilot disengaged
18:20:58	At 92 ft AGL, DME 0.25 • CAS: 151.8 kts, Vref: 146 kts, • N1 Engine #1: 71.19 #2: 69 • ROD: 795 fpm
18:21:22	Aircraft landed (right wheel first touch) • CAS: 141.5kts, Vref: 146 kts, • N1 Engine #1: 31.22 #2: 30.8 • Landing g: 2.13 g • Roll angle R 3.7 deg

1.12 Wreckage and Impact Information

On 01.07.2019, at 23:51 hrs. (IST) the aircraft overshot RWY 27 after landing and got disabled in the RESA. At 23:58 hrs. (IST) the disabled aircraft removal plan was activated. On 05.07.2019, at 16:47 hrs. (IST) after carrying out inspection of RWY 09-27 post disabled aircraft removal, the runway was handed over for operation to ATC and at 16:54 hrs. (IST) RWY 27-09 was declared serviceable.



The aircraft after touchdown exited the runway as shown above and along its ground track, broke lights (shown in red). The aircraft was substantially damaged, however, the wreckage was self-contained.

1.13 Medical and Pathological Information

The crew had undergone pre-flight medical at Mumbai before departure of Mumbai - Jaipur flight and post flight medical after the occurrence as per requirement of CAR Section 5, Series F, Part III. The pre-flight and post-flight medical tests were satisfactory and the breath analyser tests were negative.

1.14 Fire

There was no fire

1.15 Survival Aspects

The deplaning of passengers in the RESA was carried out with the help of Airport Fire Personnel. The fire step ladder was used for the purpose with Fire Personnel in lead. The above action though carried out with good intent required further analysis from the safety point of view.

In order to fully understand the role played by various individuals and infrastructure used, the scenario was re-enacted. Following issues for the enactment of the “Rescue and Evacuation Drill” having a direct impact to safety were considered: -

a) Communication amongst the cockpit and the cabin crew vis-à-vis desired actions of the cabin crew.
b) Communication between cabin and fire safety staff vis-à-vis speedy evacuation.
c) Escape slides deployment for a speedy evacuation.
d) Decision making on the part of Cabin crew including CRM.
e) Was the fire step ladder appropriate to handle passengers with restricted mobility?

The observations of the above exercise are discussed in “Analysis” part of the report.

1.16 Test and Research

During discussions with the flight crew, both pilots reported their touchdown point on the runway. This was at a point significantly earlier than the actual as established through DFDR parameter readout. The flight crew also reported that the visual reference established was with reference to blurry centre line lights only. There was no visual reference to the runway edge lights. To better understand the crew perspective of the point of touch down and runway length remaining under given weather conditions, an attempt was made to assess flight crew response in a simulator under similar scenarios with a crew set possessing similar experience as the PF of the accident flight. The crew perception based on simulation and follow up discussions with the flight crew is as follows: -

Visual Reference	Visual reference at 200’	Touchdown Point Pilot Perception (A)	Actual Touchdown Point (B)	Variation between A & B
CAVOK	CAVOK	1500’	1500’	0
3000	3000	1500’	1500’	0
550	550	1500	1800’	300’
550	350	1700’	2000’	300’
550	200	2000’	2500’	500’

The assessment was carried out by a team consisting of IIC, pilot investigator and a qualified Designated Examiner (DE) of the operator. While this attempt of assessment was indicative that the crew perception of their actual touchdown point on the runway is definitely effected as the visibility is reduced and is amplified when the visibility is lower than expected (sudden change). The simulator assessment, however, cannot be generalised and requires a similar simulation with a wider sample covering flight crew across the industry.

1.17 Organizational and Management Information

The aircraft was operated by a DGCA approved aircraft operator holding AOP (S-16) in Passenger and Cargo Category which is valid till 16.5.2023. The operator carries out its own maintenance as CAR 145 approved organisation. There is in house training facility for the pilots, cabin crew, airport services and engineering. There were 3 similar incidents of serious nature to aircraft of the operator:

1.17.1 Boeing 737-700 / 2nd July 2019 / Landing into Mumbai

The flight was uneventful till approach. The weather (ATIS) was to expect "ILS approach RWY 27, RWY condition WET, TL FL 55, wind 150 degrees 05 knots, visibility 2100 meters, light thunder storm with rain, cloud scattered 1000ft, broken 1800ft, overcast 8000ft, temperature 25, dew point 25, QNH 1003HPa, QFE 1002HPa". The last weather passed to the aircraft was 13 minutes prior to touchdown and was "visibility 1000 meter, RVR 2000 meters". During the last 4 minutes from touchdown, as per the CVR, the crew had discussed the weather, visibility and tail winds. Throughout the final approach, there were variable tail winds approaching 15 knots. The aircraft was on auto-pilot till 250 ft AGL. Though flare was carried out at 30 ft AGL, the aircraft floated for 16 seconds. Aircraft landed at a distance of 4462 ft from runway threshold. Auto brake was applied for 2 seconds followed by manual braking. Heavy braking was used for deceleration. The aircraft, however, overshot runway and made a 180 degree turn on paved area.

1.17.2 Q-400/ 30th June 2019/ Surat

There was adverse weather all around and at the time of commencing the approach, the visibility was 2000 meters with CB overhead. The visibility was continuously reducing as the aircraft was coming closer to the airport. By the time the aircraft established itself on the ILS, the visibility further reduced with heavy rain. The flight crew experienced “heavy to very heavy rain showers” around the flare height. The PF flared the aircraft high and continued with the landing. The flare was an extended one and the aircraft floated for 15 seconds. “Maximum Reverse” was not selected immediately after touchdown, and by the time “maximum reverse” was selected, it was too late. The aircraft departed the runway at high speed and traversed into soft ground.

1.17.3 Boeing 737, September 2017, landing into Mumbai

During final descent, tower had transmitted the weather information to crew, viz. “continue approach runway 27 wind 310/12 knots, gusting up to 22 knots and heavy rain over the field”. As per the relevant METAR, the “visibility reported was of 700m, RVR for Runway 27 was 800m”. The rate of descent of the aircraft was 600 ft./ min.

In view of the deteriorating and fast changing weather (gusty with heavy precipitation), the flight crew prior to initiation of final approach had discussed various options including slippery / wet runway and go around. As it was not possible to maintain the speeds instructed by ATC and maintain desired separation with the traffic ahead, PF disconnected the autopilot and took over the controls manually at 2000 feet. From the DFDR data, it could be seen that in the last 200 ft of the approach, the aircraft was flying well above the "planned approach descent profile" with the crew maintaining high power settings. High power settings were maintained till close to touchdown. PF had made corrections for deviation in speed, path and rate of descent throughout, due to prevalent gusty conditions. As the aircraft was flying above the glide-slope and with high power settings, the aircraft touched down well past the touchdown zone. With this delayed touchdown, combined with the wet and waterlogged runway and flaps 30, it was not possible to stop the aircraft on the runway. The aircraft left the paved surface of the runway at an approximate speed of 12 kts. and stopped in the slushy area approximately 10 meters beyond the paved surface.

1.18 Additional Information

1.18.1 Boeing 737 Flight Crew Operations Manual (FCOM)

The relevant portion of the FCOM is reproduced below: -

The FCOM describes the behavior of the stabilizer during a dual channel approach, i.e. if the autopilots are subsequently disengaged, forward control column force may be required to hold the desired pitch.

BOEING

Automatic Flight - System Description

737 Flight Crew Operations Manual

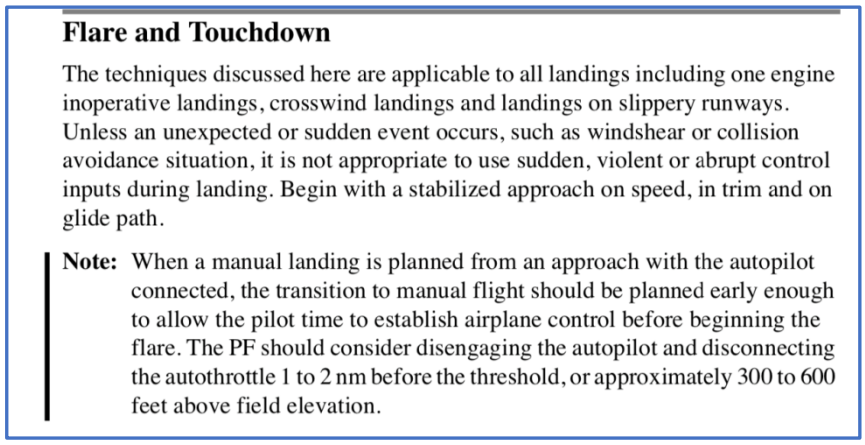
400 Feet Radio Altitude

The stabilizer is automatically trimmed an additional amount nose up. If the A/Ps subsequently disengage, forward control column force may be required to hold the desired pitch attitude.

If FLARE is not armed by approximately 350 feet RA, both A/Ps automatically disengage.

1.18.2 Flight Crew Training Manual (FCTM)

The relevant portion of the FCTM is reproduced below: -



Flare and Touchdown

The techniques discussed here are applicable to all landings including one engine inoperative landings, crosswind landings and landings on slippery runways. Unless an unexpected or sudden event occurs, such as windshear or collision avoidance situation, it is not appropriate to use sudden, violent or abrupt control inputs during landing. Begin with a stabilized approach on speed, in trim and on glide path.

Note: When a manual landing is planned from an approach with the autopilot connected, the transition to manual flight should be planned early enough to allow the pilot time to establish airplane control before beginning the flare. The PF should consider disengaging the autopilot and disconnecting the autothrottle 1 to 2 nm before the threshold, or approximately 300 to 600 feet above field elevation.

The FCTM extract above advises the pilot to disconnect the autopilot early enough to establish airplane control before the flare. The recommended altitude is 300 – 600 feet above field elevation.

1.18.3 Auto Flight System

The B737-800 has a feature in the auto-flight system wherein if both Autopilots are engaged while carrying out an ILS approach, the aircraft will trim the stabilizer for a nose up compensation in preparation for the final flare and touchdown (Auto land) maneuver. This trim bias is carried out automatically with the trim wheel movement taking place in the cockpit at about 400'. In the event that the Autopilot is disengaged after this automatic trim input, the aircraft would have a nose pitch up trim which needs to be compensated by the pilot to maintain desired flight path.

1.18.4 Monsoon Operations – Requirements

To enhance the operational safety during adverse weather particularly in the monsoon season which is prevalent in India procedures are laid down in Annexure to the CAR Section 8 Series C Part I. As per these procedures, the operator is accountable and has to ensure that pilots are qualified and efficiently trained before undertaking flights into adverse weather. The crew who is rostered to fly during monsoon should have undergone annual adverse weather ground training even if the crew have flown during adverse weather

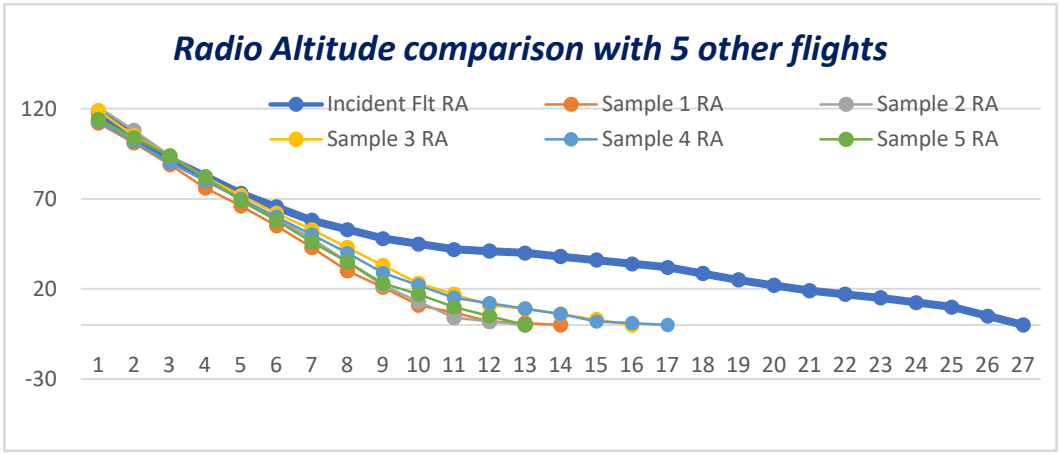
previously. Ground training may be combined with the annual recurrent training programme of pilots, and should invariably cover Aircraft Performance during Take-off and Landing with specific emphasis on wet and contaminated runway conditions, calculation of take-off and landing field lengths and impact of individual failure events, Use of weather radar, Techniques of weather avoidance, Indian monsoon climatology and ALAR and Adverse Weather Tool Kit. PF should have acted as PM on commercial transport aircraft during a minimum of one monsoon season prior to obtaining PIC rating for the first time. PF should have at least 100 hours experience on type to operate the flight as PIC during adverse weather conditions unless the PF has a minimum of three monsoon seasons as PM on type prior to obtaining PIC rating for the first time. In cases where a PIC is short of the 100 hours requirement or his endorsement has been obtained prior to or during adverse weather, the pilot may continue to fly as PIC during adverse weather conditions till PF achieves 100 hours provided the PM has a minimum of 1000 hours on type and a minimum of two monsoon seasons on type.

In addition to the specific requirements, general conditions are also laid down. The relevant ones are as follows: -

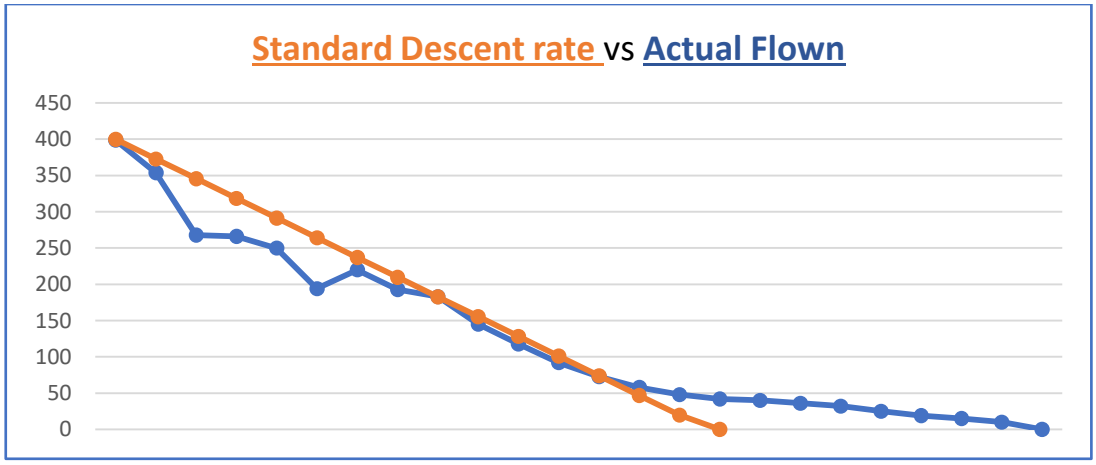
- Approach briefing prior to Top of Descent shall include wet/ contaminated Actual Landing Distance calculation.
- Scheduled Operators shall prepare a quick analysis table for use during normal operations for wet/contaminated ALD and 1.15*ALD in view of the high cockpit workload environment. For aircraft where the ALD is factored by at least 15% to derive an Operational Landing Distance, this figure may be used.
- ILS approaches are to be preferred to non-precision approaches. In case of non-precision approaches, emphasis must be given on CDFA (Continuous Descent Final Approach).
- Greater emphasis be given on stabilized approaches. “Go around” is encouraged in case the pilot is not comfortable.
- Full flap landing, adequate usage of reverse thrust and consideration of extra en-route/ terminal fuel computation shall be adhered to. (Type specific manufacturer’s guidance accepted)

1.18.5 Rate of Descent

A comparison of rate of descent as in the subject flight was made with 5 other flights of the same aircraft (from DFDR data) having similar landing weight. The graph below shows the comparison of these flights from Radio Altitude of 120 feet to touchdown.



The standard descent rate v/s actual flown by the aircraft is as follows:



1.19 Useful or Effective Investigation Techniques

Nil

2.0 ANALYSIS

2.1 General

- Both operating flight crew were appropriately licensed and qualified to operate the flight. Their preflight Medical was valid. They had undergone all refresher training and nothing was wanting as per the requirements.
- The aircraft had valid Certificate of Airworthiness/ Airworthiness Review Certificate at the time of incident. The aircraft held valid Certificate of Release to Service. The mandatory Modifications and SBs were complied with.
- The training and experience requirements of the flight crew were as per those laid down in the CAR. They fulfilled the mandatory requirements laid down for Monsoon operations by DGCA.
- Cabin crew were qualified on Safety and Emergency Procedures as laid down by DGCA.

2.2 Weather

The meteorological reports for the period commencing 1700z to 1830z consistently show thundershowers and rain over the aerodrome. The crew had obtained the ATIS “R” at 1723z which was identical to the METAR at 1730z. In addition to the METAR, the ATIS included the “runway condition as wet, and the CB to the north with top of 8 Km”.

At the time of landing 1827z, the actual weather would be similar to the METAR reported at 1830z which has a considerably lower visibility at 1000m (RVR 1800m) and temporary reduction to 600m in Thundershowers and rain. The pilots would have, therefore, experienced a much lower visibility than that which was expected at the time of landing.

Reduced visibility during the flare (as reported by the pilots) may have impaired the depth perception of the pilots. This probably led to the pilots waiting for the radio altimeter auto callouts and then initiated the flare input on the control column at approximately 30 feet RA.

During discussions with the flight crew, it was observed that in the pilots' assessment, the touchdown point was beyond the touchdown zone but was much earlier to the actual touchdown point as per the DFDR readout. However, the flight crew did not consider to "Go Around".

2.3 DFDR Analysis

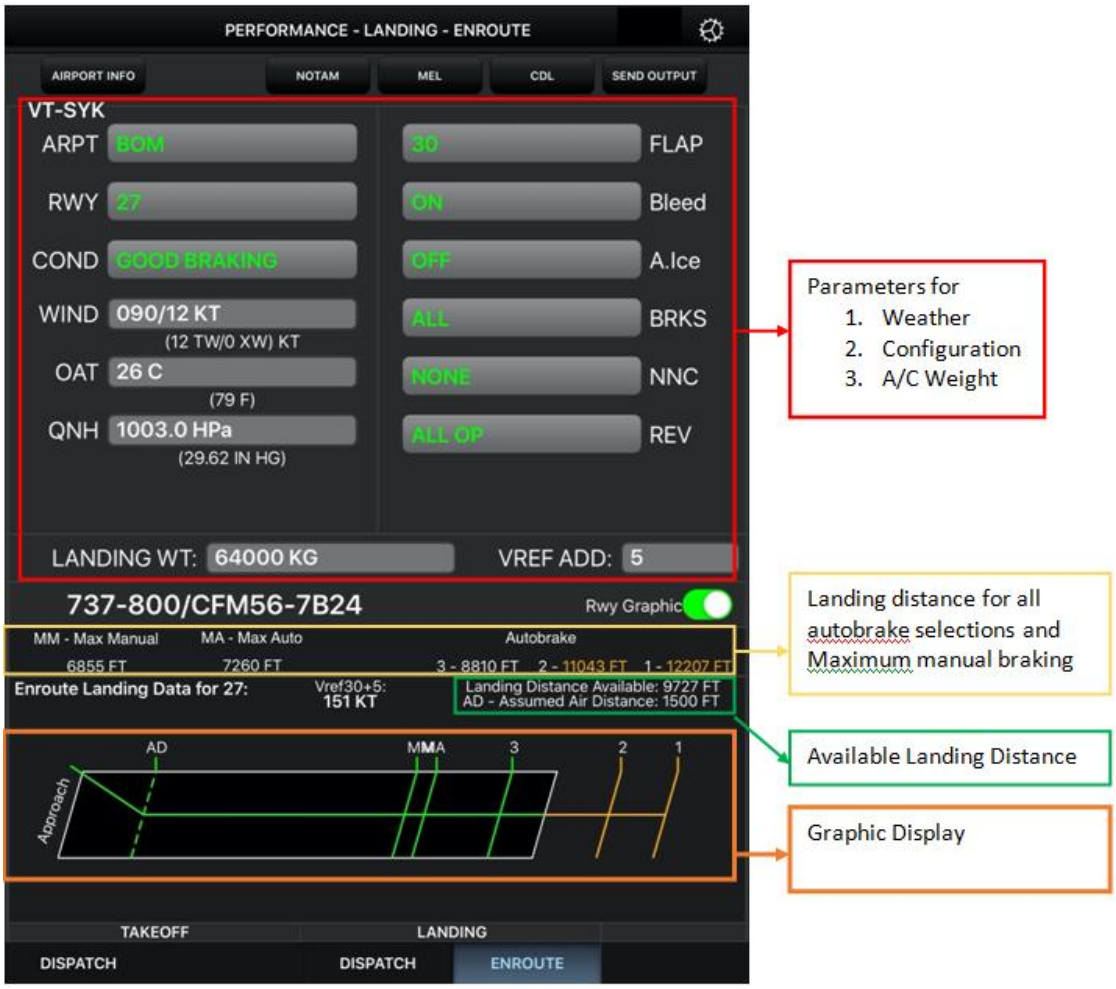
As per the available DFDR parameters, the following was established.

Approach Phase	DFDR Parameters	Remarks
>3800'	Second Autopilot engaged	Dual Channel Approach selected
350' RA	Pitch trim moves from 5.68 to 6.3 units with elevator down application of 2.7 units	This is an autopilot feature on the B737 to have a trim up bias for Autoland.
118' RA	Auto-throttle & Autopilot are disconnected	Transition to manual flight
118'–42' RA	There is an increase from 154 KCAS to 173 KCAS in 13 seconds with the Thrust initially at 70% N1 reducing to 60% N1	Excess thrust for phase of flight
50' RA - Touchdown	The Thrust is further reduced from 60% N1 toward Idle thrust at 34' RA.	With an approximate Ground Speed of 169 Knots from 50' RA to Touch Down the aircraft has travelled approximately 6635'. This took approximately 23 seconds in the flare
Touchdown	1.7 G (vertical) at touchdown Speed Brakes (spoilers) deployed immediately upon touchdown	The aircraft has a firm touchdown on the runway and the auto speed brake function is activated
8 seconds after touchdown	Thrust reversers are fully deployed and produce 84% N1 for maximum Reverse thrust	The aircraft is now committed to landing. A Balked landing is no longer an option.
4 seconds after touchdown	Maximum Manual Brake application. Autobrake does not engage during the landing roll	The pilots realize the remaining runway length remaining is far lesser than anticipated.
48 kts	The Nose Gear indicates in the Air	The aircraft has rolled off the paved surface
Aircraft Stop	• Ground Speed remains at =1.5 Kts • Vertical G remains at = 1.01g • Nose & Right Main gear = Air	The aircraft has come to rest with the nose gear and right main landing gear sensors failed
31 seconds after stop	The speed brake panels are retracted	This is commensurate to the evacuation checklist being carried out (CVR)
44 Seconds after stop	The APU is selected on	This is commensurate with the crew decision of not evacuating (CVR)

2.4 Operational Aspects

2.4.1 Flight Operations

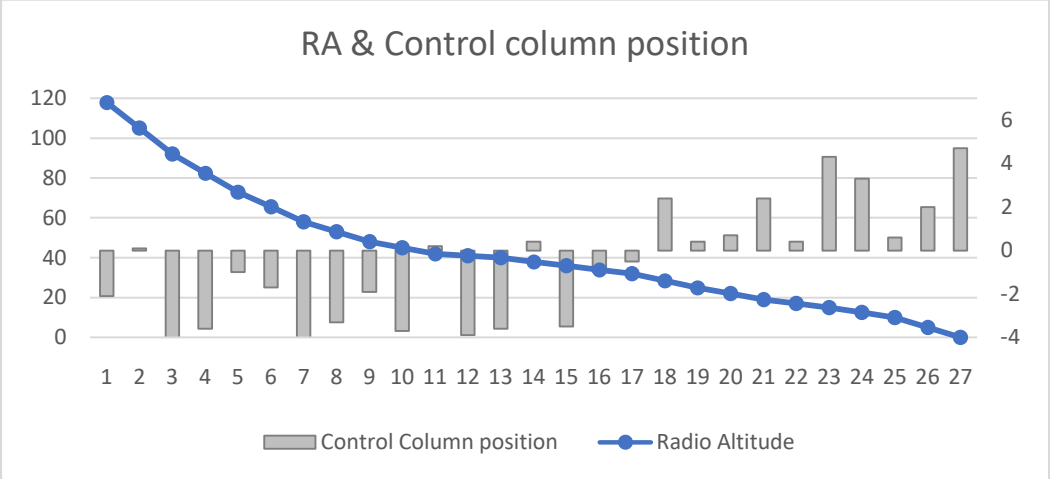
Figure below gives the landing performance under conditions at the time of accident.



Taking into consideration the point of touch down as perceived by the flight crew, the landing distance available to stop the aircraft on runway 27 was 9727 feet. The required landing distance (for the flight) as computed by the Electronic Flight Bag (EFB) for “landing weight of 64,000 Kgs with flaps 30 and auto-brakes 3” was 8810 feet in reported weather and wet runway conditions. So the flight crew had a landing distance margin of about 917 feet. For the given conditions, auto-brake selection, lower than 3 would have been inadequate for the landing.

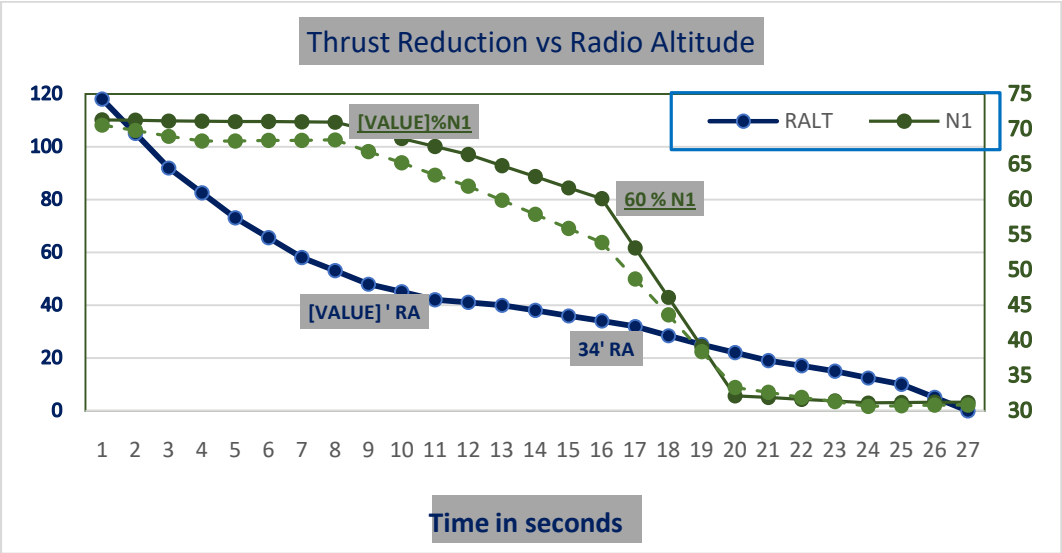
2.4.2 Auto Flight System

The crew did not factor the effect of the “autopilot trim bias”, which gets applied during the approach, on the actual flare technique of the crew carrying out the manual flare and landing. This required the pilot input in the pitch moment to be reduced or even occasionally reversed during the flare in order to achieve the touchdown within the touchdown zone of the runway.

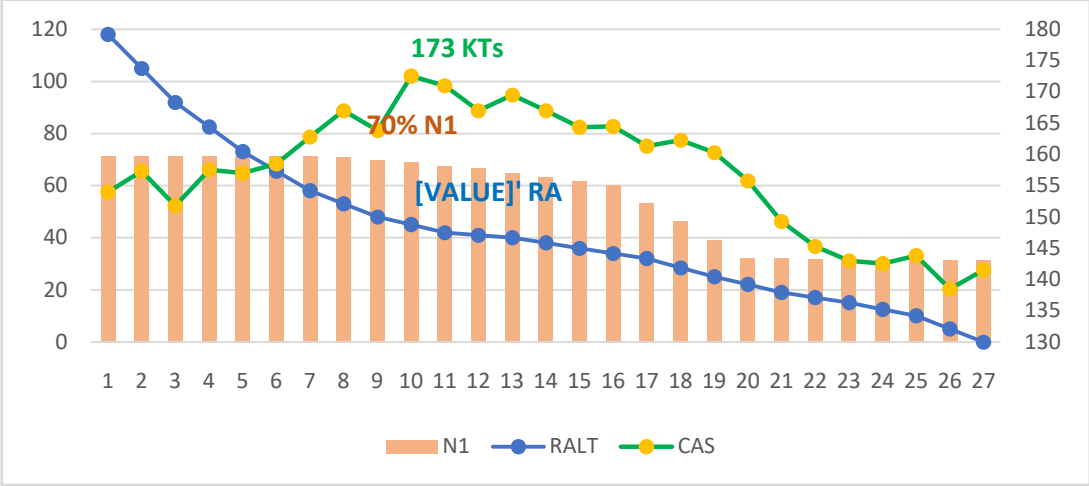


2.4.3 Delayed Thrust Reduction during the Flare

The pilots disconnected the autopilot and the auto thrust at 118 feet radio altitude. When the auto throttle was disconnected, the thrust setting was approximately 70% N1 for both engines. The Thrust was maintained at approximately 70% N1 from 120’ RA to 53’ RA leading to an increase in CAS from 154 to 172 Knots.



The thrust levers were reduced from 71% N1 to 60% N1 at 53' RA over 9 seconds. The thrust levers were further reduced from 60% N1 to idle at 34' RA over 4 seconds.



2.5 Crew Resource Management (CRM)

The crew task sharing, and coordination was assessed using the CVR recording and discussions with the flight crew.

The flight crew had an IAS disagree (CVR) at about 25 nm on approach (DFDR does not have individual IAS parameters for the PF and the PM). The PF calls for the Non-Normal checklist. While the PM is reading the checklist, the PF verifies that the airspeeds are now indicating correctly for all 3 indications, though the PM continues to read the checklist. The PM carries out the reading of the checklist, however, no action was taken to verify the same by PF.

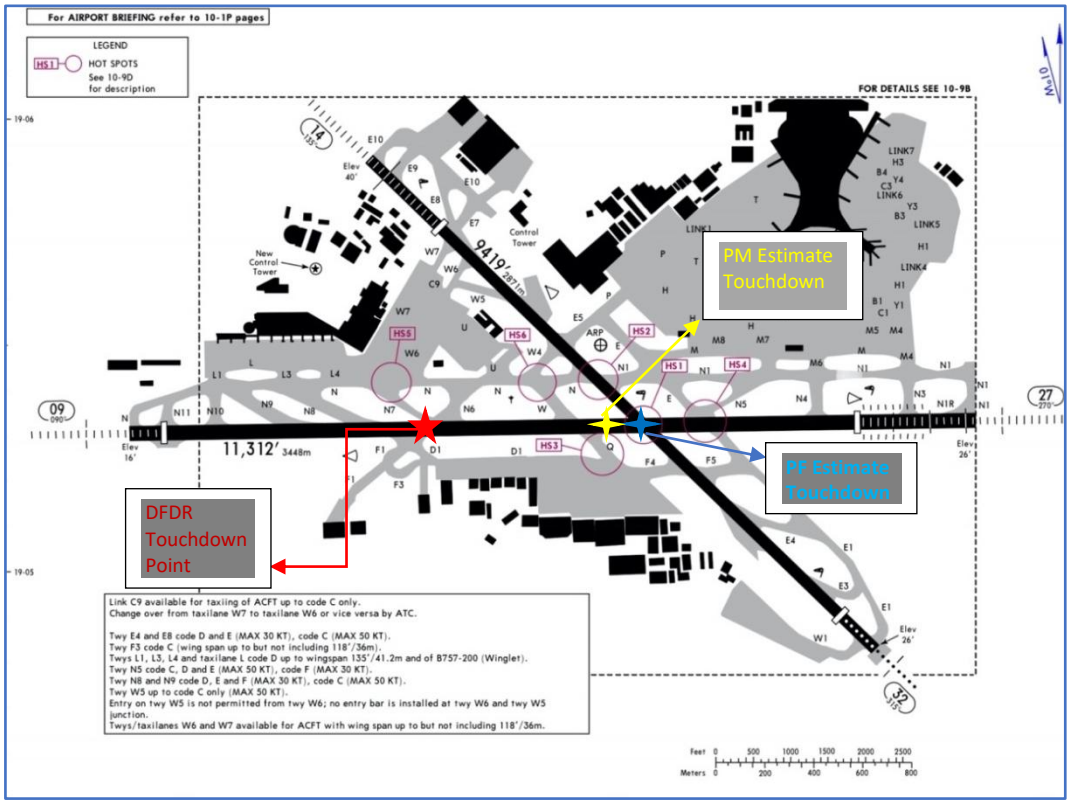
For intermittent indications, a 'Non-Normal Checklist' is usually not required. If the crew decides to carry out a checklist then the same must be done prior to commencing the approach. While this had no impact on the continued approach, configuration of the aircraft and achieving the stabilized criteria, the crew task management and workload management appears to be sub optimal.

After a late touchdown, the PM elected to move the auto-brake selection to MAX which is not done. Both flight crew members subsequently applied

maximum brake effort after realizing that the remaining runway was very less. After the aircraft stopped beyond the runway, the crew coordination improves while the evacuation checklist is being read. Both of them remained composed and the coordination between them was well established.

2.6 Crew Perception

Both pilots have stated that the visibility was such that they could only see the centerline lights which appeared to be blurred due to the refraction from water droplets. Both Pilots have stated that they believed the primary cause of the overrun was the runway surface friction being inadequate and the same not reported to the crew prior to approach and landing. Both crew members' assessment of approximate point of touchdown achieved was inaccurate (marked on the runway). The actual touchdown was outside the touchdown zone.



2.7 Cockpit Display vis-a-vis Actual Aircraft Position

The Image below shows the 50 feet radio altitude position. This was achieved just after crossing the landing threshold at a speed of 165 Kts (12 Kts above Target Approach Speed) and the thrust was (L) 70.1% N1 & (R) 67.2% N1. The auto throttle and Autopilot are both disengaged. The aircraft is on the Localiser and above the Glideslope.

The Image below shows the touchdown slightly to the left of centreline with a slight bank to the right at 144 Kts. This position is 5807 feet past the landing threshold with 3881 feet of runway remaining. The location is abeam Taxiway N7.

The Image below shows the runway exit from the paved surface at 63 KIAS. The aircraft is to the left of centreline with maximum reverse thrust and maximum brake effort.

The Image below shows the aircraft stop position. The aircraft has a 2.5^0 nose down attitude. The engines have been shut off and speed brakes retracted 31 seconds after the aircraft had reached this position. The landing gear sensors are not indicated due to extensive damage to the aircraft. The aircraft remained intact.

2.8 Evacuation Process

The evacuation of passengers at the site of accident was very unique. The passengers de-boarded from the forward exit using a metal step ladder (approximately 7 feet high). This procedure is neither documented in the operator's manuals nor was the cabin crew ever taught or briefed about this earlier. The procedural deviations identified below might have aggravated the situation if the situational dynamics would have changed (subsequent fire, evacuation).

2.8.1 The PF Command of Crew at Stations

PF announced "crew to stations" shortly after the aircraft came to stop. As there was no further communication from the cockpit, after some time the cabin crew, of their own visited the cabin to inspect the condition of passengers. This was initiated out of genuine concern but might have impeded a subsequent immediate evacuation command issued by the flight crew.

2.8.2 The Consideration for an Evacuation

The cabin crew was not aware of the requirements for an evacuation involving a very steep nose down attitude. The only factors that would warrant an evacuation in their opinion would have to be a catastrophic event, fire or smoke, break up of fuselage etc. The cabin crew believed that there was no risk of fire to the external areas of the aircraft since it was raining. While the cabin crew followed all instructions issued by the flight crew, there was no attempt to communicate a concern to the flight crew. This was in part due to the training received emphasizing that only catastrophic events required evacuation.

2.8.3 Exits Considered for Evacuation

The cabin crew was of the opinion that the rear exits would be unusable due to nose down attitude of the aircraft. Given the situation, the use of slide chutes should have been considered and definitely utilized for evacuation. Probably, this was not done because of lack of understanding in respect of the use of slides for evacuation.

2.8.4 Cockpit - Cabin Communication

Since the cabin crew was unaware of the requirements for evacuation, they did not provide any feedback to the flight crew suggesting that immediate evacuation be considered. While, each cabin crew found that the ladder used for deplaning the passengers was having certain element of risk, however, this issue was neither communicated between other crew members nor with the flight crew.

2.8.5 The Role of Fire Rescue Team

While the cabin crew was onboard and fully capable to carry out their functions, however, the Fire services team boarding the aircraft for inspection caused unnecessary delay in the passengers exiting the aircraft. This not only resulted into a situation for which the cabin crew was not trained for, but coupled with no communication from cockpit, stopped the cabin crew from thinking about evacuation. There was no clarity on whether the Fire Services Personnel were in charge for evacuation. Also, or the cabin crew should have waited for the orders from flight crew. The situation lacked leadership on the part of the cabin crew and was a deviation from established procedures they were accustomed to.

2.9 Circumstances Leading to the Accident

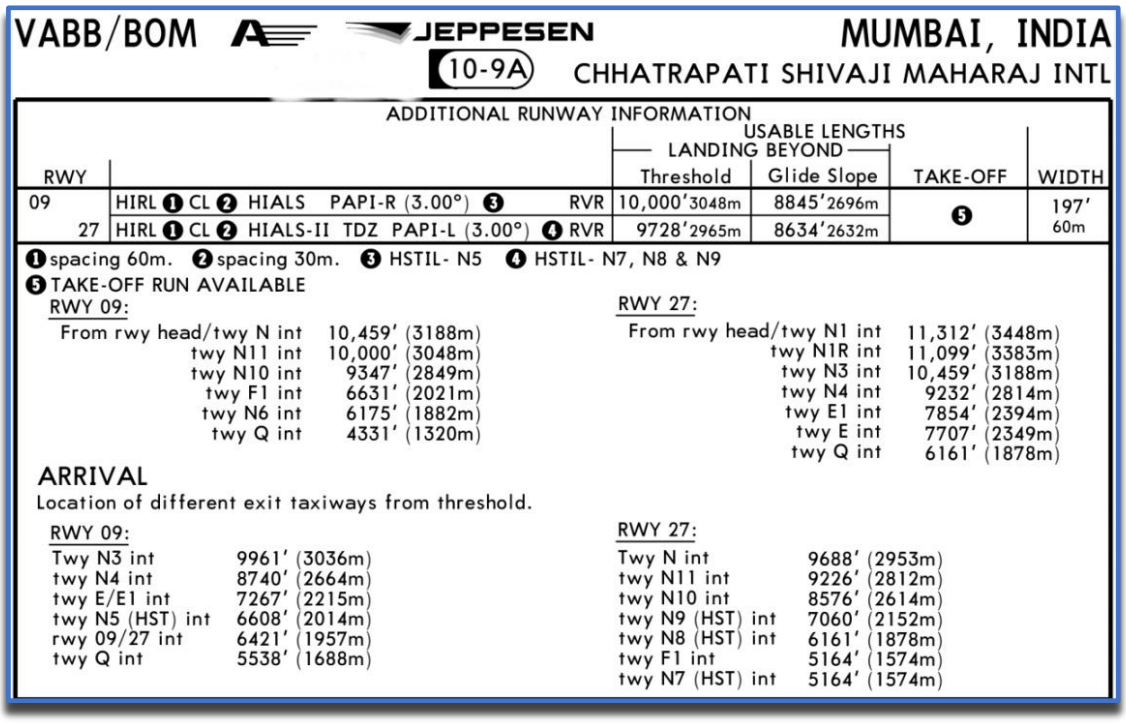
The flight from Jaipur till descent at approximately 7000' Pressure Altitude was uneventful. At that time, flight crew observed an indication for "IAS disagree" for which Non-Normal Checklist was carried out. The indication discrepancy did not recur for the remainder of the flight.

The aircraft was radar vectored for an ILS approach for Runway 27. The aircraft was configured for landing with the landing gear selected down and Flaps 30 by 3800 feet on the ILS approach. The autopilot was coupled to the ILS approach and the dual channel (Both Autopilots) was engaged. At 400 feet Radio Altitude, the aircraft commenced an automatic pitch trim up command and simultaneously compensated for the same with an elevator pitch down command. There was no deviation on the ILS till the aircraft approached 118 feet Radio Altitude.

At that point, both Autopilot and Auto-throttle were disengaged by PF in order to carry out a manual landing. With the autopilot disengaged, the elevator control was reverted to manual inputs by the pilot. The aircraft deviated above the vertical profile at 70 feet Radio Altitude while the pilot maintained forward pressure on control column at a reduced deflection. The aircraft descended 30 feet in the next 12 seconds. At approximately 30 feet Radio Altitude, the PF initiated a manual flare manoeuvre by applying aft control column deflection. From this point onwards the aircraft continued to remain in the flare for another 9 seconds. The total time in air from 50' to touchdown at an average speed of 169 Kts ground speed was 23 seconds and consumed 5807 feet of the usable runway. The aircraft touched down on the runway with 3881 feet of runway remaining. The speed brakes were deployed upon touchdown and thrust reversers were deployed 2 seconds after touchdown. 6 seconds later, the engines were producing max reverse.

As the crew realised that the remaining runway was inadequate, they applied maximum brakes 4 seconds after touchdown. Under the conditions, it was not possible to stop the aircraft on the runway and it overshot into the RESA

The useable length available at Mumbai, as per the Jeppesen is given below:-



VABB/BOM JEPPESEN MUMBAI, INDIA

10-9A CHHATRAPATI SHIVAJI MAHARAJ INTL

ADDITIONAL RUNWAY INFORMATION

RWY		USABLE LENGTHS LANDING BEYOND Threshold	Glide Slope	TAKE-OFF	WIDTH
09	HIRL ❶ CL ❷ HIALS PAPI-R (3.00°) ❸ RVR	10,000'3048m	8845'2696m	❺	197' 60m
27	HIRL ❶ CL ❷ HIALS-II TDZ PAPI-L (3.00°) ❹ RVR	9728'2965m	8634'2632m		

❶ spacing 60m. ❷ spacing 30m. ❸ HSTIL- N5 ❹ HSTIL- N7, N8 & N9

❺ TAKE-OFF RUN AVAILABLE

RWY 09:

From rwy head/twy N int	10,459' (3188m)
twy N11 int	10,000' (3048m)
twy N10 int	9347' (2849m)
twy F1 int	6631' (2021m)
twy N6 int	6175' (1882m)
twy Q int	4331' (1320m)

RWY 27:

From rwy head/twy N1 int	11,312' (3448m)
twy N1R int	11,099' (3383m)
twy N3 int	10,459' (3188m)
twy N4 int	9232' (2814m)
twy E1 int	7854' (2394m)
twy E int	7707' (2349m)
twy Q int	6161' (1878m)

ARRIVAL

Location of different exit taxiways from threshold.

RWY 09:

Twy N3 int	9961' (3036m)
twy N4 int	8740' (2664m)
twy E/E1 int	7267' (2215m)
twy N5 (HST) int	6608' (2014m)
rwy 09/27 int	6421' (1957m)
twy Q int	5538' (1688m)

RWY 27:

Twy N int	9688' (2953m)
twy N11 int	9226' (2812m)
twy N10 int	8576' (2614m)
twy N9 (HST) int	7060' (2152m)
twy N8 (HST) int	6161' (1878m)
twy F1 int	5164' (1574m)
twy N7 (HST) int	5164' (1574m)

3.0 CONCLUSION

3.1 Findings

3.1.1 The aircraft was having a valid Certificate of Registration and Certificate of Airworthiness.

3.1.2 All maintenance schedules, mandatory modifications and checks were carried out as per the requirements. There were no defects / snags pending rectification.

3.1.3 Flight crew had not reported any problem with the brakes. DFDR data also indicated appropriate functioning of brakes.

3.1.4 Both cockpit crew members were appropriately licensed to undertake the flight. The medical of both cockpit crew members was valid. Both had undergone pre-flight & post flight medical checks including BA test which was negative.

3.1.5 During approach, at approximately 7000' Pressure Altitude, flight crew observed an indication for "IAS disagree" for which Non-Normal Checklist was carried out.

3.1.6 Though the go around procedure and actions required on the part of PF and PM were discussed from coordination point of view but configuration with flaps 40 was not discussed which would have given a lower approach speed and would have provided maximum aerodynamic drag.

3.1.7 On ILS approach, at 3800 feet, the aircraft was configured for landing with landing gear down and Flaps 30. The autopilot was coupled to the ILS approach and the dual channel was engaged.

3.1.8 At 400 feet Radio Altitude, the aircraft commenced an automatic pitch trim up command and simultaneously compensated for the same with an elevator pitch down command. There was no deviation on the ILS till the aircraft approached 118 feet Radio Altitude.

3.1.9 At that point both Autopilot and Auto-throttle were disengaged. At 70 feet Radio Altitude, the aircraft went above the vertical profile while the pilot maintained control column forward pressure at a reduced deflection. The aircraft descended 30 feet in the next 12 seconds.

3.1.10 At approximately 30 feet Radio Altitude, the PF initiated a manual flare maneouver by applying aft control column deflection and the aircraft continued in flare for 9 seconds.

3.1.11 The total time in air from 50' to touchdown at an average speed of 169 Kts ground speed was 23 seconds and consumed 5807 feet of the usable runway. The aircraft touched down on the runway with 3881 feet of runway remaining.

3.1.12 Under the conditions, it was not possible to stop the aircraft on the runway and it overshot into the RESA with consequential damages to the aircraft.

In addition to the above findings, root cause analysis of the accident was carried out particularly taking into account the systemic deficiencies in the organization, unsafe supervision, preconditions to the unsafe act and lastly the unsafe act itself.

A. Organization Factor

In the past there have been occurrences (incidents and accident) to the aircraft operated by the organization under similar circumstances and more or less due to the same in- actions/ errors by the flight crew. The investigation of these occurrences and those to the aircraft operated by other organization had given recommendations to obviate these occurrences in future. It was observed that majority of the safety recommendations were either not implemented in true letter and spirit or the action taken has withered away with passage of time. It also appears that there was resistance to implement certain requirements indicating cultural aspect across the industry. One such aspect is "low drag approaches" and "not going around" when appropriate to do so.

At the time of accident, the organization was not having an active flight watch/ monitoring programme. Once the aircraft departed, no advice or update was sent to the flight crew. The investigation has observed the above aspects in other organizations also.

Though DGCA carries out audits of the organization as per the mandate given in the various regulations, yet none of the audit reports have pointed out to these serious safety weaknesses in the system. Had these serious safety

issues brought out and acted upon in a proactive manner under SSP/SMS or otherwise, there was definitely an opportunity to arrest the unwanted lapses before these culminated into serious incident/ accident.

The coordination between the critical personnel post-accident is not prescriptive. This includes the coordination between rescue services and the cabin crew. While all personnel had the best interest in mind however, there existed an element of uncertainty when the cabin crew had to coordinate with rescue services. The rescue services took the call of the method of deplaning which is under the authority of the PIC and cabin crew.

B. Unsafe Supervision

The organization does not have flight observation programme. The flight observation should have been further increased during monsoon season as required by the DGCA.

A standard “Compliance Based” Flight Data Monitoring program was run by the company. No proper information was exchanged between the Safety & Flight operations department for the Flight operations to act on the deficiencies or SPIs. Hence, crucial information as “Evidence” all though available in the form of “Flight Data”, was not used optimally. The program lacked addressing areas of weakness observed during flight data monitoring or data collected from occurrences.

The gaps were existing in the organization which could have been plugged by better supervision. Not disconnecting dual auto pilot channel in time, not taking full flaps & extended (long) flare, were also observed during investigation of the occurrences to the aircraft of the organization. There is lack of adequate risk management strategy in following the prescriptive CARs by the stakeholders in training of the flight crew, particularly for the monsoon conditions.

C. Pre-condition to the Unsafe Act

The weather (Environment) including tail wind conditions and reduced visibility acted as pre condition to the accident. There was no weather update from the company regarding the deteriorating weather condition in Mumbai. In deteriorating weather conditions, PF decided to continue the approach and there was no input given by the “PM”. Though weather was within the minima,

but the flight crew should have realized that the rapid decrease in visibility leading to loss of depth perception was an indication to have discontinued the approach. The flight crew should have gone around and there was no reason to continue the approach. Though ILS approach was carried out, PF flared the aircraft in manner (due to sudden reduction of visual cues), that ended up having an extended flare and floating over the runway. There was unintended and unrecognized longer flare.

D. Unsafe Act

Due to the pre conditions mentioned above, the aircraft landed at a distance much farther than the one perceived by the PF and there was no chance of stopping the aircraft on the runway.

3.2 Probable Cause

The runway excursion occurred because of combination of: -

- Disconnection of auto pilot at an altitude 118' RA with the nose up trim bias without adequate compensation.
- Disconnection of auto throttle at 118' RA at a higher thrust setting for that phase of flight.
- Late touchdown of the aircraft on the runway.
- Reduced visual cues due to heavy rain impacting depth perception and ascertaining of actual touchdown position.
- Tailwind conditions at the time of landing resulting in increasing the distance covered during the extended flare (float).
- Approach with lower flaps (30) than recommended (40).

4.0 SAFETY RECOMMENDATIONS

The recommendations given below are as a result of present investigation. As can be seen these are generic in nature and are applicable throughout the industry.

4.1 DGCA should review all safety critical recommendations given in the earlier accident/ serious incident investigation reports. Few of the occurrences are as follows:-

4.1.1 Boeing 737-700 / 2nd July 2019 / Landing into Mumbai
4.1.2 Q-400/30th June 2019/ Landing into Surat
4.1.3 Boeing 737/ September 2017/ Landing into Mumbai.

It should be ensured that action taken to implement the recommendations even now mitigates the risk for which the recommendations were made and has not lost its effect due complacency or otherwise.

4.2 All airlines must ensure that during the period of inclement weather, flight dispatch contacts the aircraft by available means (VHF/HF/ACARS/SATCOM) & relays the latest weather for destination and alternates. Operations Controller must give advice regarding weather trend. However, final decision regarding the flight shall remain with the Commander.

4.3 Operators should carry out risk reduction processes in a structured, proactive and systematic manner rather than relying on the crew's decision-making abilities when developing or updating procedures.

4.4 The airport license holder(s) should develop procedures in association with the aircraft operators, for disabled aircraft removal plan. Synergic and integrated efforts of all stakeholders at airports should be applied to make the closed runway operational ASAP.

4.5 All airports should take appropriate steps so as to ensure that the requisite information in desired format mentioned in Doc 9981 is available and provided to flight crew by 5th November 2020.

4.6 DGCA should ensure that the licensed airports provide the requisite information as mentioned in Doc 9981 to the crew for flight planning purposes by 5th November 2020.

4.7 DGCA should ensure that the standards and protocols of communication for post-accident duties are followed by all aerodrome and aircraft operators.

(R.S. Passi)
Investigator-In-Charge
Aircraft Accident Investigation Bureau

(Capt. Gaurav Pathak)
Investigator

(Dr. K. Nageshwar Rao)
Investigator

Place: New Delhi

Date: 21.03.2020