International Civil Aviation Organization

The Tenth Meeting of the Aerodromes Operations and Planning Sub-Group (AOP/SG/10)

Bangkok, Thailand, 10 to 14 August 2026

Agenda Item 5: State's/Aerodrome Operator's update and best practices

RUNWAY MISALIGNMENT DURING NIGHT AND LOW-VISIBILITY OPERATIONS: HUMAN FACTORS, AERODROME GEOMETRY AND VISUAL GUIDANCE MITIGATION

(Presented by AIRPORTS AUTHORITY OF INDIA, INDIA)

SUMMARY

This paper consolidates operational evidence from India and other States concerning runway misalignment during night-time and low-visibility line-up operations. The reviewed occurrences demonstrate that flight crews may incorrectly acquire runway edge lighting or markings as the runway centerline, notwithstanding the serviceability and regulatory compliance of the visual aids. The paper analyses the contributing human-factors, runway-entry geometry and visual-guidance characteristics and proposes a layered risk-mitigation framework comprising aerodrome safety assessment, improved continuity and differentiation of visual cues, enhanced flight-crew runway alignment verification and the safety-assessed use of supplementary retro-reflective cat's-eye lead-in markers at suitable aerodromes operating up to CAT-I conditions.

1. INTRODUCTION

1.1 Runway centreline and edge lights provide essential visual guidance for accurate aircraft alignment during runway entry, line-up and take-off, particularly at night and in reduced visibility. Given the low cockpit viewing angle, pilots must correctly interpret these lighting and marking cues before commencing take-off.

1.2 Although existing Standards and Recommended Practices are followed, operational experience shows that human factors and aerodrome geometry can still affect pilot visual perception and lead to incorrect runway alignment. Reports from airline operators and investigation authorities confirm that the issue is not limited to a particular aircraft type, operator or aerodrome.

1.3 Investigation and safety reports from several States show a recurring pattern in which flight crews confuse runway edge lights or markings with the runway centreline lights/markings. As a result, the aircraft may begin the take-off roll while offset from the centreline and strike runway edge lights before the crew corrects the alignment or rejects the take-off.

1.4 These events have involved jet and turboprop aircraft and have occurred during curved or acute-angle runway entries, backtrack and turnpad operations and in both good and reduced visibility. This indicates a wider vulnerability during the taxiway-to-runway transition.

1.5 This paper consolidates the available operational evidence, identifies common human-factors and design issues and proposes a layered mitigation approach, including enhanced visual

guidance and supplementary retro-reflective lead-in markers for suitable aerodromes operating up to CAT-I conditions.

2. DISCUSSION

Chennai Airport Occurrence and Safety Learning

2.1 On 25 February 2025, during night operations, an Embraer EMB-170 entered Runway 07 at Chennai International Airport via Taxiway K. During line-up, the aircraft deviated from the designated lead-in guidance, aligned close to the right-hand runway edge and commenced the take-off roll while laterally displaced from the runway centreline. ASMGCS data, tyre marks and flight-recorder data showed that the aircraft travelled approximately 360 meters before its alignment was corrected towards the runway centreline. Seven runway edge lights were damaged. The aircraft continued the flight and landed safely at its destination, with no injuries and aircraft damage.

2.2 The investigation found that the runway lighting and markings complied with the applicable requirements and that weather was not a factor. The sequence nevertheless exposed several human performance vulnerabilities. The Pilot Monitoring was conducting the before-take-off checklist during line-up. The Pilot Flying was steering and handling the take-off clearance. The aircraft began rolling before the Pilot Monitoring had fully returned attention outside. He detected the edge lights through peripheral vision and called for a correction after the take-off roll had commenced. The commander was also operating to Chennai for the first time and had not received the airport familiarisation required by the operator. Crew feedback indicated that the before-take-off checklist was being completed during line-up and that the lateral displacement was detected only after the take-off roll had commenced.

Figure 1. A-SMGCS playback showing the aircraft path from Taxiway K to the right edge of Runway

2.3 Airline operators had previously reported concerns about the conspicuity of the lead-in guidance at this entry. Following the occurrence, the aerodrome operator realigned the lead-in marking, used retro-reflective material and assessed additional centre line lighting. The before-and-after geometry shown in Figure 2 also illustrates a broader lesson. Erased or displaced lines, residual shadows, and adjacent guidance paths can continue to influence perception even after a marking has

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

— END —

been changed. The operational effect must be checked from the cockpit view, not only from an engineering plan or a vehicle inspection.

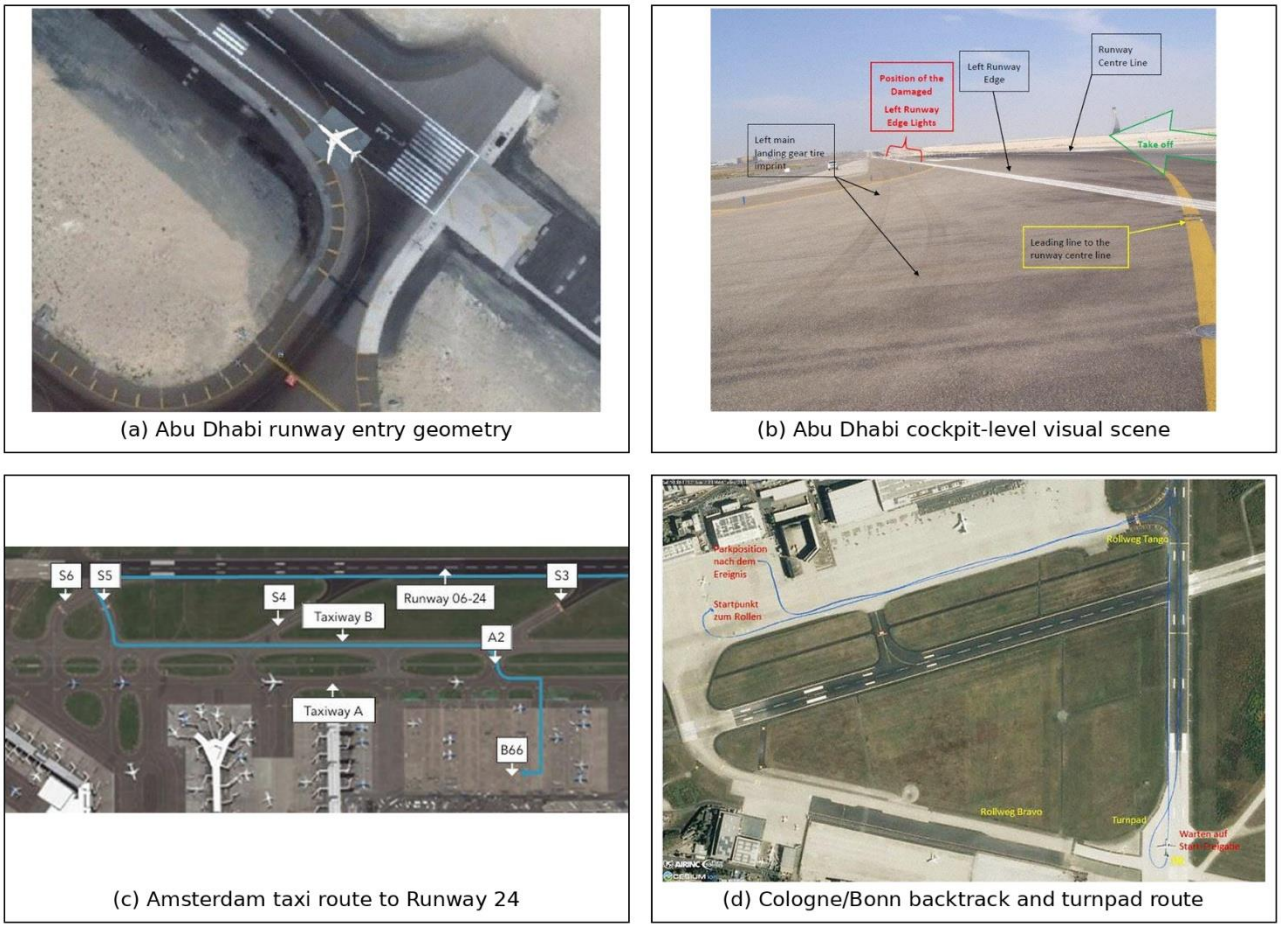
Figure 2. Previous and revised Taxiway K lead-in marking connecting to Runway 07.

Recurring International Pattern

2.4 The Chennai occurrence is consistent with a recurring international pattern. The selected investigations in Table 1 involved different aircraft types, States and operating conditions. In each case, the crew followed a plausible but incorrect line of guidance. The events also show that the hazard can occur in low visibility or in otherwise good night weather, and during direct runway entry, a large-angle turn, backtrack or turn pad operations.

Occurrence	Operational setting	Human performance and visual interaction	Outcome
Abu Dhabi, 2012	Low-visibility departure from Runway 31L	A more conspicuous line of edge lights was acquired after external reference was weakened. Distraction, expectation and ineffective crew challenge sustained the interpretation.	Eleven edge lights struck. Take-off rejected at about 86 kt.
Amsterdam, 2016	Night departure from Runway 24 after a large-angle entry	Discontinuous taxi guidance, no taxiway centre line lighting and clearance during the turn increased task demand. Edge lights were interpreted as centre line lights.	Seven edge lights destroyed. Aircraft damage discovered after landing.
Cologne/Bonn, 2020	Night backtrack and turn pad line-up	A brief cockpit distraction, wide paved area and difficult differentiation of the light patterns produced a shared but incorrect mental model.	Nine lights damaged. Take-off rejected.
Muscat, 2026	Night departure from Runway 26L after entering through Taxiway E7	The Boeing 737-800 reportedly aligned with the right-side runway edge instead of the runway centre line. The night-time visual environment and the apparent	Multiple runway edge lights were struck and the take-off was rejected. Reported consequences included tyre damage,

Occurrence	Operational setting	Human performance and visual interaction	Outcome
		continuity of the edge-light pattern may have contributed to the incorrect alignment. The crew recognised the abnormal situation only after a loud impact and a master-caution indication.	hydraulic leakage, engine damage, grounding of the aircraft and passenger disembarkation on the runway.



(a) Abu Dhabi runway entry geometry

(b) Abu Dhabi cockpit-level visual scene

(c) Amsterdam taxi route to Runway 24

(d) Cologne/Bonn backtrack and turnpad route

Figure 3. Selected runway entry geometries and visual scenes from international investigations.

Human Performance and System Interaction

2.5 **Visual similarity of lighting cues acquisition:** Runway edge lights and runway centre-line lights are both predominantly white along much of the runway. Their respective functions are therefore recognised not by colour alone, but through their pattern, spacing, symmetry and relationship with surrounding markings and lighting systems. At shallow cockpit viewing angles, these distinctions may become difficult to identify. Curved runway entries, wide pavement areas and discontinuities in visual guidance can further distort the expected visual pattern. Under such conditions, flight crews may unintentionally follow the first continuous and visually dominant line that appears to lead onto the runway.

2.6 **Operational Implications of Inset Runway Edge Lights at Intersections:** Runway edge lights are primarily installed as elevated fixtures to provide a distinct visual demarcation from inset runway centreline lights. However, at taxiway-runway intersections, inset edge lights are

necessary to accommodate taxiing aircraft without risking structural damage to lighting fixtures. At complex intersections featuring curved entry geometries and wide pavement areas, a significant longitudinal extent of inset edge lighting may be required. This can create visual ambiguity for flight crews during night or low-visibility operations. Specifically, long configurations of flush-mounted edge lights may be misidentified as runway centre-line lights, potentially leading to spatial disorientation, improper aircraft alignment, and an increased risk of runway excursion during the take-off roll.

2.7 **Attention and task competition:** Runway entry compresses several tasks into a short period. Steering, outside scanning, checklist completion, radio communication, configuration confirmation and receipt of take-off clearance may occur together. These tasks compete for attention. Example, in Chennai Airport, the Pilot Monitoring was completing the checklist and only recognised the lateral displacement after redirecting attention outside. In Amsterdam and Abu Dhabi, the timing of radio communication and clearance during the turn added to the demand on the crew.

2.8 **Expectation and shared mental models:** Once the aircraft appears to be aligned, subsequent cues may be interpreted in support of that belief. Both pilots can form the same incorrect mental model because both see the same scene and share the same expectation. Routine verbal confirmation may then repeat the initial assumption rather than provide an independent check. The Cologne/Bonn investigation showed that the aircraft was deliberately and precisely aligned, but with the wrong chain of lights. The operating technique was correct while the situation model was wrong.

2.9 **Crew coordination and challenge:** The Pilot Monitoring may be heads-down at the exact point when an independent external scan is most valuable. If the other pilot responds to a concern by making a small correction, the response can reassure the monitoring pilot even when the correction is insufficient. Effective challenge therefore requires more than agreement. Each pilot should verify alignment against several independent cues before take-off thrust is applied. These cues may include runway orientation, aircraft heading, the position of the painted centre line, symmetry of the runway edges and passage over expected threshold or touchdown-zone markings.

2.10 **Reduced recovery margin after thrust application:** Once the take-off roll begins, acceleration, vibration, engine noise and performance monitoring narrow the time available to diagnose and correct a lateral error. Impacts with elevated lights may initially be interpreted as surface irregularities or a technical problem. Early alignment verification before thrust application is therefore more reliable than recovery after the aircraft has accelerated.

2.11 **Air traffic control and external monitoring:** At night, tower personnel may be unable to recognise a small lateral displacement. Surface surveillance normally confirms runway occupancy and movement but may not present wheel-track alignment or aircraft heading with enough precision to provide a timely barrier. Clearance timing can also affect workload if a take-off clearance is issued while the aircraft is negotiating a complex turn.

2.12 **Aerodrome personnel and organisational learning:** Engineering inspections can confirm that lights and markings meet technical specifications while failing to identify how the complete scene appears from the cockpit. Repeated pilot reports of unclear guidance are weak safety signals and should not be closed solely because the equipment is serviceable. Aerodrome operators, airlines, ATC and Local Runway Safety Teams need a shared method for examining the entry under representative darkness, visibility and lighting intensity.

Proposed Layered Mitigation Measures

2.13 **Aerodrome risk assessment and layout review:** Aerodrome operators should identify runway-entry locations where complex geometry, turnpads, wide or sloped pavement, multiple lead-in paths, unclear markings may increase the risk of incorrect alignment. These locations should be reviewed through a safety assessment, followed by suitable corrective measures.

2.14 **Improved visual guidance and lighting:** Runway-entry guidance should provide a clear and continuous path from the taxiway to the runway centreline. Where required, aerodrome operators should improve markings, remove conflicting guidance lines, provide or extend taxiway centreline and lead-in lighting and enhance the visual distinction between runway centreline and edge lights.

2.15 **Supplementary cat's-eye lead-in guidance:** At suitable aerodromes operating up to CAT-I conditions, retro-reflective pavement markers may be used as supplementary lead-in guidance where taxiway centreline lighting is not available or where painted markings alone are insufficient. Their use should be supported by a safety assessment covering colour, spacing, frangibility, tyre interaction, FOD risk, wet-weather performance and compatibility with pavement maintenance. Cat's-eye markers should complement, and not replace, prescribed lighting systems.

2.16 **Pilot procedures, training and aerodrome familiarization:** Both pilots should positively confirm runway alignment before take-off thrust is applied, using more than one cue such as runway orientation, centreline markings, light spacing, symmetrical edge lights and aircraft heading. Airline Operators should also ensure completion of aerodrome familiarisation, while non-essential checklists and heads-down tasks should, as far as practicable, be completed before runway entry.

2.17 **Safety information, monitoring and follow-up:** Aerodrome operators should publish relevant runway-entry characteristics, hotspots and temporary taxi routes with proper information on the anticipated hazards through appropriate aeronautical information services. Reports of unclear or misleading visual guidance should be treated as early safety warnings and reviewed by the Local Runway Safety Team with airlines, ATC, engineering and regulators to monitor corrective actions and verify their effectiveness.

Need for ICAO-Level Consideration

2.18 Runway misalignment is a system interaction problem rather than a single act of pilot error. The occurrences reviewed in this paper show how a probable visual scene, divided attention, shared expectation and limited external detection can weaken several safety barriers at the same time. The risk may remain even when each visual aid is serviceable and compliant.

2.19 Existing provisions define the technical requirements for runway and taxiway visual aids. Additional guidance could help States assess whether runway-entry markings and lighting are clearly distinguishable from the cockpit, particularly where runway edge and centreline cues may appear similar.

2.20 Such guidance could cover human-factors assessment of runway-entry visual scenes, design considerations for complex entries and turnpads, performance requirements for supplementary lead-in guidance such as retro-reflective pavement markers, effective flight-crew runway alignment checks, and sharing of occurrence data and successful mitigation measures.

2.21 ICAO guidance should remain performance-based and should not prescribe a single solution for all aerodromes. The appropriate combination of geometry, markings, lighting, supplementary guidance, aeronautical information and operating procedures should be selected through a local safety assessment.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the recurring international pattern of night-time/low-visibility runway misalignment involving confusion between runway edge and centrelines visual cues, together with the associated runway-safety and human-factors concerns;

b) encourage States, aerodrome operators and aircraft operators to assess runway-entry layouts, visual guidance and operating procedures, and to implement suitable mitigation measures based on local safety assessments;

c) request ICAO to consider whether additional guidance is needed on the visual differentiation of runway edge and centreline cues, continuity of runway-entry guidance, human-factors assessment of complex runway entries, and the use of supplementary retro-reflective lead-in aids; and

d) encourage States to review and share relevant occurrences, hazard reports and effective mitigation measures through appropriate safety-management and ICAO runway-safety forums, including safety-assessed trials of cat's-eye lead-in guidance at suitable aerodromes operating up to CAT-I conditions.

— END —