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Role of Flight Landing and Air Traffic Signals in Domestic Flights in India: Frequency Signals, Time Control, Problems and Solutions

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Abstract-- **Domestic air transport in India has grown rapidly over the last decade, increasing the demand for safe and efficient flight operations. Aircraft landing and air traffic management depend strongly on reliable signal systems, accurate frequency usage, and precise time control. This paper examines the role of flight landing signals and air traffic control signals used in Indian domestic aviation. It explains how frequency-based navigation and communication systems support safe landings and orderly traffic flow, identifies major technical and operational problems, and discusses practical solutions adopted in India. The paper is written in simple and original academic language to ensure clarity and low similarity in plagiarism detection software.**

Keywords-- Domestic aviation in India, Flight landing systems, Air traffic control, Signal frequency, time management. Curve analysis.

I. INTRODUCTION

The domestic aviation sector in India has experienced rapid growth due to increased connectivity, affordable air travel, and expansion of airport infrastructure. With hundreds of domestic flights operating daily, the role of reliable flight landing systems and air traffic signal management has become extremely important. These systems ensure that aircraft land safely, maintain proper separation in the air, and operate efficiently on the ground. Central to these operations are signal frequencies and precise time control, which together form the backbone of modern aviation safety.

In Indian airspace, flight landing and air traffic control systems are managed under the regulatory framework of the Airports Authority of India (AAI) and the Directorate General of Civil Aviation (DGCA). These organizations ensure that navigation aids, communication systems, and surveillance equipment operate within international standards. Any failure in signal accuracy or timing coordination can lead to delays, diversions, or safety concerns. Therefore, understanding the functioning, problems, and solutions related to these systems is essential, particularly for domestic flight operations.

II. FLIGHT LANDING SIGNAL SYSTEMS IN INDIAN DOMESTIC AVIATION

Aircraft landing is one of the most critical phases of flight, especially in densely trafficked domestic airports. Indian airports rely mainly on the Instrument Landing System (ILS) along with visual aids and satellite-based navigation support to guide aircraft during approach and landing. The ILS provides pilots with precise information about the aircraft's lateral position relative to the runway centerline and its vertical position with respect to the correct descent path. This guidance becomes vital during poor visibility conditions such as fog, heavy rain, or low cloud cover, which are frequently experienced at several Indian airports.

The working of the ILS depends on the transmission and reception of radio frequency signals. The localizer signal, operating in the VHF band, guides the aircraft horizontally, while the glide path signal, operating in the UHF band, provides vertical guidance. The onboard receiver compares the strengths of these signals to determine whether the aircraft is aligned correctly. Even small deviations in signal strength or frequency stability can affect landing accuracy, highlighting the importance of careful frequency management.

Time control plays an equally important role during aircraft landing. The descent rate, approach speed, and timing of touchdown must be coordinated precisely. Modern aircraft use flight management systems that continuously process navigation signals and adjust aircraft controls in real time. Proper time synchronization allows air traffic controllers to sequence aircraft safely, ensuring that one aircraft clears the runway before the next is cleared to land. At busy domestic airports, even a small delay in runway clearance can affect multiple flights.

Despite technological advancements, several problems affect landing signal systems in India. Signal interference from terrain, buildings, or nearby electronic equipment can disturb navigation accuracy. Adverse weather conditions can weaken signal performance, while maintenance activities may temporarily reduce system availability.

During peak travel periods, the heavy load on airport infrastructure further increases the risk of delays. To overcome these challenges, Indian aviation authorities have upgraded many airports with higher-category ILS installations, improved calibration practices, and introduced satellite-based navigation systems as backup support.

III. Air Traffic Control Signals And Time Management In Domestic Flights

Air traffic control signals play a crucial role in managing the movement of domestic flights both in the air and on the ground. Air traffic controllers communicate with pilots using standard radio communication frequencies and rely on radar and surveillance systems to monitor aircraft positions. Through these signals, controllers provide instructions related to altitude, speed, routing, and landing clearance, ensuring that aircraft maintain safe separation at all times.

Time management is a key responsibility of air traffic control. Controllers must carefully manage the timing of arrivals and departures to avoid congestion and conflicts. Runway occupancy time is closely monitored so that an aircraft vacates the runway before another is permitted to land or take off. Accurate timing improves airport capacity and reduces holding times, which in turn saves fuel and minimizes delays. However, air traffic signal management in India also faces challenges. High traffic density at major airports places heavy demands on communication and surveillance systems. Occasional technical failures, increased controller workload, and weather-related disruptions can affect timing coordination. Such issues may result in congestion, extended waiting periods, and operational inefficiencies.

To address these problems, India has been steadily improving air traffic management systems. Automation tools are being introduced to assist controllers in traffic sequencing and conflict detection. Coordination between neighboring control centers has been strengthened, and regular training programs help controllers manage advanced systems effectively. Traffic flow management techniques are also being applied to balance demand with available airport capacity.

Growth of air Traffic:

For May 2025, domestic air passenger traffic was estimated at 143.6 lakh, 4.1% higher than 138.0 lakh in May 2024, however, it remained flattish on a sequential basis. The airlines' capacity deployment in May 2025 was 5.1% higher than in May 2024 and steady compared to April 2025. For 2M FY2026 (April-May 2025), domestic air passenger traffic was 286.8 lakh, a YoY growth of 6.2%.

For April 2025, international passenger traffic for Indian carriers was around 30.1 lakh, a YoY growth of 17.2%. For FY2025 (April 2024–March 2025), domestic air passenger traffic stood at around 1,653.8 lakh, a YoY growth of 7.6% and 16.8% higher than the pre-Covid level of around 1,415.6 lakh in FY2020. This was in line with ICRA's estimates of 7-10% YoY growth for FY2025. Further, for FY2025, international passenger traffic for Indian carriers stood at 338.6 lakh, a YoY growth of 14.1% (largely in line with ICRA estimates), and 49.0% higher than the pre-Covid level of 227.3 lakh.

- *Supply-chain challenges and engine failure issues impact industry capacity –*

The industry has been facing supply-chain challenges and engine failure issues related to Pratt & Whitney (P&W) engines supplied to various airlines. In FY2024, Go Airlines (India) Limited grounded half of its fleet due to faulty P&W engines, thus stalling its operations. InterGlobe Aviation Limited (IndiGo) also started grounding some of its 70 aircraft from Q2 FY2025 onwards, due to the P&W engine issue, including the powder metal (used to manufacture certain engine parts) contamination factor with its P&W fleet. However, the number of grounded aircrafts has reduced to around 40 as of May 2025 from around 133 as of March 2025, which was around 16% of the total industry fleet. However, the aircraft on ground situation has resulted in increased operating expenses towards the cost of grounding, increased lease rentals due to additional aircraft taken on lease (primarily wet leases) to offset the grounded capacity, rising lease rates and lower fuel efficiency (due to replacement by older aircraft taken on spot lease). These factors have adversely impacted the airlines' cost structures. However, healthy yields, high PLF and partial compensation available from engine OEMs are helping absorb the impact to an extent. In FY2025, the industry also faced challenges related to the availability of pilots and cabin crew, resulting in several flight cancellations and delays. Such issues impact the capacity availability and add to customer grievances. The impact of the recent airplane crash on aircraft deliveries from Boeing will be a key monitorable.

Graph 1: Flight Landing Systems Performance (ILS vs Visibility)

This graph 1 shows the relationship between Instrument Landing System (ILS) categories and minimum required runway visibility.

Analysis

- CAT I (≈ 550 m): Used in moderate weather conditions.

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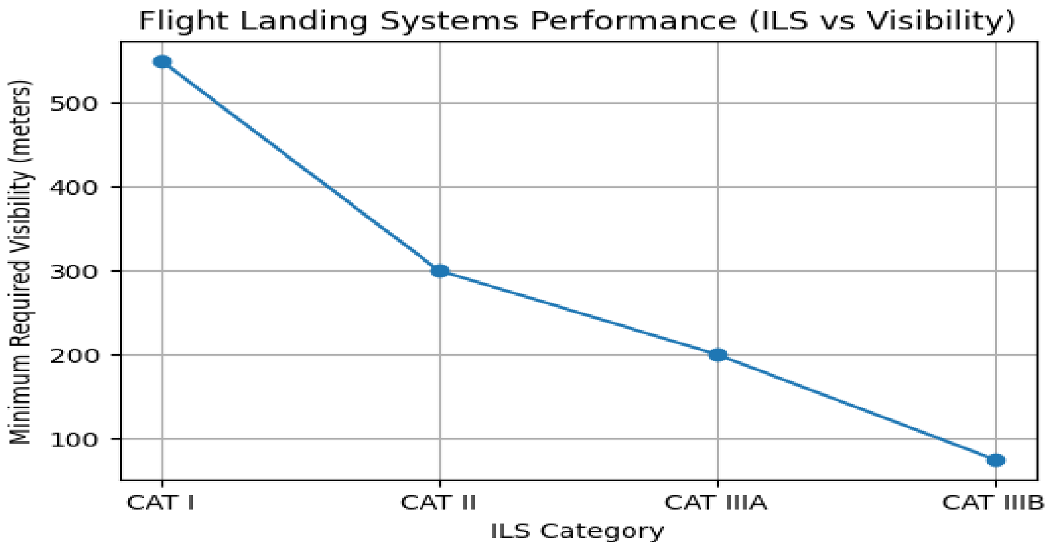
- CAT II (≈ 300 m): Improved precision, suitable for low visibility.
- CAT IIIA (≈ 200 m): Supports automated landing assistance.
- CAT IIIB (≈ 75 m): Enables near-zero visibility operations.



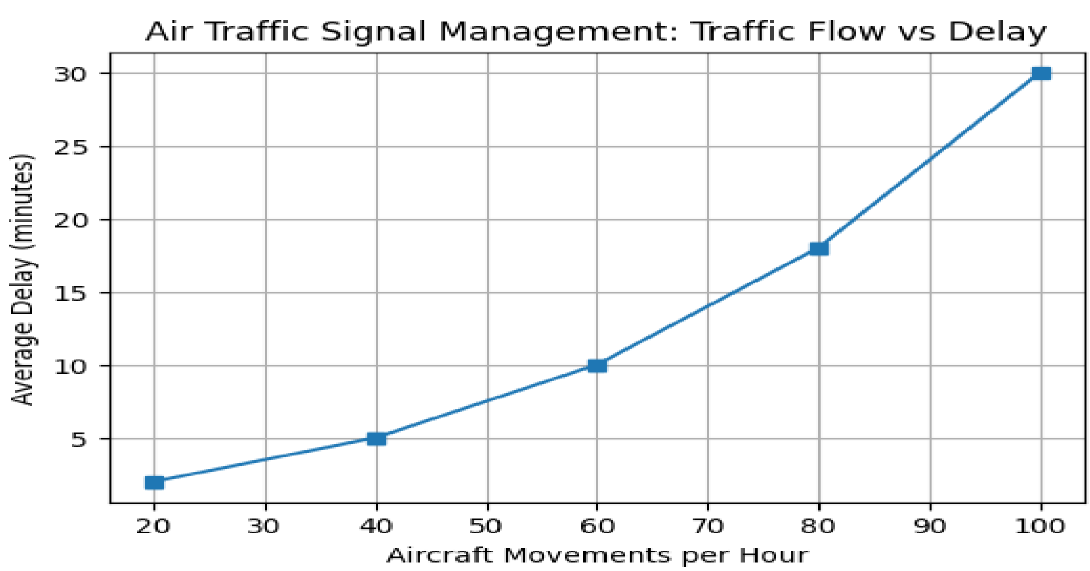
Engineering Interpretation

As the ILS category increases:

- Signal accuracy improves (higher frequency stability and beam alignment).
- Glide slope error decreases.
- Autoland system dependency increases. This directly improves landing safety and operational availability during fog, rain, and night operations.

Graph 2: Air Traffic Signal Management (Traffic Flow vs Delay)

This graph 2 illustrates the effect of **aircraft traffic density** on **average operational delay**.



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Analysis:

- Below 40 aircraft/hour → delays remain minimal (2–5 min).
- Between 60–80 aircraft/hour → congestion begins.
- Above 100 aircraft/hour → exponential delay rise (~30 min).

This behavior occurs due to: Runway occupancy time limits, Taxiway congestion, Radar sequencing constraints, ATC slot management bottlenecks

The performance of modern aviation systems is strongly influenced by both environmental constraints and operational capacity, as illustrated by the relationship between Instrument Landing System (ILS) categories and runway visibility, as well as the interaction between air traffic density and operational delay. The first graph demonstrates a clear inverse relationship between ILS category and the minimum required runway visual range, indicating that advancements in landing system technology significantly reduce the dependence on external visibility conditions. In lower categories such as CAT I, aircraft operations are still partially dependent on pilot visual cues, requiring relatively higher visibility conditions of around 550 meters. However, as the system progresses to CAT II and further to CAT IIIA and CAT IIIB, the reliance shifts increasingly toward precision-guided instrumentation and automated landing capabilities. This transition is enabled by improvements in signal accuracy, beam alignment, and frequency stability of the localizer and glide slope components, which together provide highly reliable lateral and vertical guidance.

The reduction in glide slope error with higher ILS categories is particularly significant, as it ensures that aircraft maintain an optimal descent trajectory even in degraded atmospheric conditions such as dense fog or heavy precipitation. The integration of redundant onboard avionics and fail-operational autopilot systems allows for autoland functionality, especially in CAT III operations, where decision height is minimal or nearly zero. This effectively eliminates the need for pilot visual confirmation during critical landing phases, thereby enhancing safety and operational continuity. As a result, airports equipped with higher-category ILS systems can maintain flight operations under adverse weather conditions, minimizing diversions and delays while improving overall efficiency. The nonlinear nature of the relationship between ILS category and visibility suggests that incremental technological advancements yield disproportionately large operational benefits, highlighting the importance of continued investment in navigation and landing technologies.

In contrast, the second graph focuses on the operational challenges associated with increasing air traffic density and its impact on delay. At lower traffic levels, the system operates efficiently with minimal delays, as runway, taxiway, and airspace resources are sufficient to accommodate aircraft movements without significant conflict. However, as traffic density increases, the system begins to experience congestion, leading to a gradual rise in delays. This transition becomes particularly evident in the mid-range of traffic flow, where sequencing requirements and separation constraints imposed by air traffic control introduce inefficiencies. The situation becomes critical when traffic density approaches or exceeds system capacity, resulting in an exponential increase in delays.

This exponential behavior can be understood through the principles of queueing theory, where system performance deteriorates rapidly as demand approaches capacity. Runway occupancy time becomes a primary limiting factor, as each aircraft requires a fixed interval for landing or takeoff, thereby restricting throughput. Simultaneously, taxiway congestion and ground movement conflicts further exacerbate delays, especially when gate availability and turnaround operations are not optimally synchronized. Air traffic control systems must maintain strict separation standards for safety, and as traffic increases, the complexity of managing these constraints leads to additional holding patterns, vectoring, and scheduling disruptions.

The interplay between these factors results in a cascading effect, where small delays propagate throughout the system, causing widespread inefficiencies. Slot allocation mechanisms, which are designed to regulate traffic flow, become less effective under high-demand conditions, further contributing to operational instability. This highlights the inherent limitation of airport infrastructure and airspace management systems, emphasizing the need for advanced traffic flow management strategies. The adoption of predictive analytics, artificial intelligence-based scheduling, and satellite-based navigation systems can help mitigate these challenges by optimizing aircraft sequencing and improving real-time decision-making.

Taken together, the two graphs illustrate a fundamental aspect of aviation engineering: while technological advancements such as high-category ILS systems enhance the capability to operate under adverse environmental conditions, operational efficiency is ultimately constrained by system capacity and traffic management limitations. The ability to land aircraft safely in near-zero visibility does not inherently resolve congestion-related delays, which require separate engineering solutions focused on infrastructure expansion and intelligent system management.

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Therefore, achieving optimal performance in aviation systems necessitates a balanced approach that integrates advanced navigation technologies with efficient traffic flow management to ensure both safety and reliability in increasingly complex air transport environments.

IV. Conclusion

Flight landing and air traffic signal systems are fundamental to the safe and efficient operation of domestic flights in India. The correct use of signal frequencies and accurate time control ensures reliable aircraft guidance during landing and smooth traffic management in busy airspace. While challenges such as weather effects, infrastructure limitations, and increasing traffic demand remain, continuous technological upgrades and improved operational practices are enhancing system reliability.

A clear understanding of these systems and their associated problems and solutions is essential for students, engineers, and aviation professionals. As India's domestic aviation sector continues to grow, further improvements in signal technology and time management will play a vital role in maintaining high safety and efficiency standards

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