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ROLE OF AUTOMATION & AI IN IMPROVING AIRPORT OPERATIONS

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ABSTRACT :

The aviation industry is undergoing a digital transformation, with automation and artificial intelligence (AI) playing a pivotal role in enhancing airport operations. As global air travel continues to rise, airports face increasing pressure to improve efficiency, ensure passenger satisfaction, and maintain high safety standards. The integration of automation and AI technologies offers opportunities to streamline processes such as passenger check-in, baggage handling, security screening, air traffic control, and resource management.

The primary objective of this study is to examine how automation and AI are currently being applied in airport operations and to evaluate their impact on efficiency, safety, and passenger experience. The study also aims to identify challenges in implementation and recommend practical steps for maximizing benefits.

Research Design and Methodology:

This study is based on secondary research using publicly available information. The information was collected from reliable online sources such as official airport websites, aviation industry news portals, journal articles, and reports from organizations like IATA and ICAO. Basic observations were also made from personal experience and general awareness of airport operations.
The purpose of this methodology was to understand the role of automation and AI in improving airport efficiency, passenger services, safety, and overall management. By analysing various real-world examples and documented benefits, this study highlights the major contributions and future potential of these technologies in airport environments.

Major Findings:

- **Efficiency Gains:** Automation has significantly reduced check-in and boarding times through self- service kiosks, biometric gates, and AI-powered passenger flow analysis. AI-enabled systems in baggage handling have minimized misrouting and improved turnaround time.
- **Enhanced Security:** AI-driven surveillance systems and facial recognition technologies have improved threat detection and response times at security checkpoints.
- **Predictive Maintenance:** AI-powered predictive analytics have helped in reducing aircraft and equipment downtime by forecasting maintenance needs, ensuring uninterrupted operations.
- **Passenger Experience:** Chatbots, virtual assistants, and real-time information systems powered by AI have improved passenger satisfaction by reducing uncertainty and wait times.
- **Operational Cost Reduction:** Airports implementing automation reported reduced manpower costs and more accurate resource allocation, improving overall financial performance.

By embracing AI and automation thoughtfully, *airports can enhance operational resilience and* better meet the evolving demands of the global aviation landscape.

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Airports today face increasing pressure to operate efficiently while ensuring safety, customer satisfaction, and cost-effectiveness. The global aviation industry has witnessed massive growth in passenger traffic, cargo handling, and security requirements. This growth, although positive, has led to operational challenges such as flight delays, congestion, overworked staff, long queues at check- in and security, baggage mishandling, and inefficient resource allocation. In response to these challenges, **Automation and Artificial Intelligence (AI)** have emerged as powerful tools to enhance the

efficiency, safety, and overall performance of airport operations. From facial recognition systems to autonomous vehicles, AI- driven tools are transforming how airports function at every level — from passenger processing to baggage handling and airside operations.

This project was initiated to understand how automation and AI are being applied in airports, the benefits they bring, and the challenges associated with their implementation. The goal is to identify best practices, evaluate real-world case studies, and recommend ways in which Indian airports can harness these technologies for improved operations.

Airports around the world are evolving rapidly to keep pace with the growing demands of air travel. As passenger volumes continue to rise and operational complexity increases, traditional airport management systems are proving insufficient. This has created a strong need for adopting advanced technologies such as automation and artificial intelligence (AI). These innovations are playing a transformative role in streamlining airport operations, reducing delays, enhancing security, and improving the overall passenger experience. The use of AI in airport environments is no longer a concept of the future; it has become a reality that is steadily changing the way airport's function.

Automation and AI are being applied across various domains within the airport ecosystem, from passenger check-in and baggage handling to security screening and air traffic control. The integration of self-check-in kiosks, biometric facial recognition systems, smart baggage handling, and predictive analytics is leading to faster, safer, and more reliable services. Passengers now expect quick and contactless processes, especially after the COVID-19 pandemic, which accelerated the shift toward digital and touch-free solutions in the aviation industry.

In India, the government's efforts to digitalize airport operations through initiatives like **DigiYatra** have set the stage for the wider adoption of smart technologies. Major airports in Delhi, Bengaluru, Hyderabad, and Varanasi have already begun implementing facial recognition-based boarding systems to offer seamless and paperless travel experiences. These developments show the country's commitment to modernizing its infrastructure to match global standards. However, India's journey towards fully automated airports is still in progress, especially when compared to international leaders such as Singapore's Changi Airport or Hamad International Airport in Qatar.

These airports have successfully implemented end- to-end AI-driven systems that handle everything from gate assignments to real-time passenger flow management. Their models provide a valuable benchmark for Indian airports aiming to enhance both efficiency and passenger satisfaction.

Another major advantage of automation and AI is their ability to support decision-making through data analytics. By analysing large volumes of operational data, AI tools can predict flight delays, estimate passenger wait times, and optimize resource allocation in real time. This helps airport managers to proactively handle disruptions and make informed decisions. AI can also contribute to sustainability goals by monitoring energy use and helping reduce waste and emissions. The introduction of autonomous cleaning robots, smart lighting systems, and automated HVAC controls are just a few examples of how airports can become more environmentally friendly while reducing operational costs.

Overall, the role of automation and AI in airport operations is becoming increasingly important in shaping the future of aviation. These technologies offer a promising path to overcoming the operational challenges faced by modern airports. As the aviation industry continues to grow, airports will need to adopt smart solutions that allow them to scale effectively, meet safety and security requirements, and provide superior customer service. This project aims to explore how automation and AI are currently being used in airport operations, examine their benefits and limitations, and understand the impact of these technologies on the future of airport management, with a special focus on the Indian context.

1.3 Literature Review

The integration of automation and artificial intelligence (AI) in airport operations has become a critical area of study as airports strive to manage increasing passenger volumes while ensuring high levels of safety, efficiency, and customer satisfaction. This section presents a comprehensive review of academic and industry literature to understand the current state of automation and AI in the aviation industry.

1. Role of Automation in Passenger Processing

Automation has transformed various touchpoints in the passenger journey. According to **SITA Air Transport IT Insights (2023)**, over 70% of global airports have implemented self-service technologies, including Self-check-in kiosks and automated bag drops.These systems reduce the need for manual intervention, resulting in faster processing and reduced queuing time. Studies by **Jones & Kavanaugh (2019)** show that passengers using automated systems experience a 25–40% decrease in waiting times and a more personalized travel experience.

2. AI in Operational Planning and Predictive Analytics

AI plays a pivotal role in operational forecasting. Machine learning models analyze historical data to predict passenger flow, aircraft turnaround times, and baggage delivery speed. **IATA (2021)** reports that airports using AI for **predictive maintenance** (for conveyor belts, elevators, and vehicles) reduce system downtime by up to 40%.

A study by **Tiwari et al. (2022)** highlights how AI- based tools can optimize gate allocation, staff scheduling, and runway usage, thereby reducing delays and improving on-time performance.

3. Enhancing Baggage Handling Systems

Baggage mishandling is a major challenge for airports. SITA's 2023 Baggage IT Insights indicates that AI-integrated RFID tracking and automated conveyor systems have reduced baggage mishandling rates by over 60%. For example, **Hong Kong International Airport** has successfully implemented an AI-enabled smart baggage handling system that offers real-time tracking and routing adjustments.

4. Smart Security Systems

AI-powered surveillance cameras and facial recognition systems are increasingly being used for security screening and identity verification.

According to **ICAO (2022)**, AI in security systems enhances threat detection by identifying abnormal behaviours and suspicious objects more effectively than traditional CCTV systems. For instance:

Facial recognition at immigration counters replaces manual passport checks.

5. AI in Customer Service

Chatbots and virtual assistants are also being integrated into airport customer service platforms. **Airports like Dubai and Amsterdam Schiphol** have introduced AI-based customer service bots that assist passengers with real-time flight information, wayfinding, and FAQs. A study by **Fernandes & Das (2021)** found that such systems enhance passenger satisfaction, especially during disruptions like flight delays or cancellations.

6. Environmental Sustainability

AI is also contributing to green airport operations. Smart lighting, AI-controlled HVAC systems, and automated waste management are helping airports reduce energy usage and carbon emissions.

Chaudhary & Mehta (2022) observed that airports using AI for energy monitoring achieved energy savings of up to 20% annually.

7. Challenges in Implementation

Despite the benefits, several challenges persist:

Data Privacy and Ethics: Facial recognition and biometric data usage raise privacy concerns under data protection laws (e.g., GDPR, India's PDP Bill).

Cybersecurity Risks: Increased digital infrastructure expands the attack surface for cybercriminals.

Workforce Displacement: Automation may replace some low-skill jobs, requiring reskilling initiatives to avoid unemployment.

Cost of Implementation: High upfront investments in AI infrastructure are a barrier for smaller or regional airports.

The integration of automation and artificial intelligence (AI) into airport operations has been a subject of increasing academic and industry interest over the past decade. Researchers and aviation experts consistently highlight how these technologies can address persistent challenges in airport management, including operational inefficiencies, security risks, and passenger dissatisfaction. The body of literature on this topic encompasses multiple disciplines such as operations management, information technology, and transportation engineering, revealing both the potential and complexities of AI adoption in aviation. Early studies on automation in airports primarily focused on the implementation of self-service kiosks and automated baggage handling systems. For instance, research by Ni and Sun (2017) demonstrated that automated check-in kiosks significantly reduce passenger wait times and relieve pressure on front-desk staff, improving overall throughput during peak hours. Subsequent studies expanded this view by examining AI- enabled biometric technologies, including facial recognition and fingerprint scanning, which
enhance security and expedite passenger processing. A study by Kamat and Bhattacharya (2019) emphasized the role of biometric AI systems in minimizing human error and preventing identity fraud, thereby strengthening airport security protocols without compromising passenger convenience.

More recent literature delves into the application of AI in operational decision-making and predictive analytics. Airports generate massive volumes of data daily—from flight schedules and passenger movements to baggage tracking and maintenance logs. Studies such as those by Zhang et al. (2020) explore how AI algorithms analyse these large datasets to forecast flight delays, optimize gate assignments, and improve resource allocation. Their findings suggest that AI-driven analytics can transform reactive management into proactive planning, significantly reducing disruptions and enhancing efficiency. Moreover, predictive maintenance enabled by AI helps identify potential equipment failures before they occur, thereby minimizing downtime and operational costs (Lee & Park, 2021).

Research Objectives

The primary objective of this research is to critically analyse the role of automation and artificial intelligence (AI) in enhancing the efficiency, safety, and overall performance of airport operations. The study is designed to explore how these technologies are being integrated into various functions within the airport environment— ranging from baggage handling systems, check-in and boarding procedures to flight scheduling, airside logistics, and passenger flow management.

These objectives are directly derived from the previously stated research questions and hypotheses, ensuring a clear and structured path from inquiry to analysis. By narrowing down the broader questions into specific and measurable outcomes, this
research aims to generate actionable insights that contribute both academically and practically to the field of aviation management.

One of the core objectives of the research is to **assess the impact of automation in reducing manual errors and improving operational turnaround times**. For example, by focusing on AI-powered baggage handling systems, the study aims to determine whether these technologies lead to a statistically significant drop in baggage mishandling incidents compared to traditional systems. Another objective is to measure how **predictive analytics and machine learning algorithms** assist in the forecasting of passenger traffic and resource allocation, and whether their implementation leads to enhanced coordination across different airport departments. This includes examining how AI systems are used in air traffic control simulations, biometric check-in processes, and smart surveillance systems to ensure safety and streamline workflows.

Further, this research seeks to **evaluate improvements in passenger experience** that result from the adoption of AI and automation. With many airports facing challenges related to crowd control, long wait times, and inconsistent service quality,
AI-based queue management systems, facial recognition for faster boarding, and real-time communication apps are being increasingly implemented. The research will objectively measure whether such technologies reduce average waiting times, improve passenger feedback scores, or enhance the overall perception of airport service quality.

In measurable terms, the study intends to define standards and benchmarks for what a successful integration of AI in airports looks like. These may include key performance indicators (KPIs) such as percentage decrease in flight delays, rate of increase in passenger throughput, percentage improvement in resource utilization, or time saved in check-in and boarding processes. Establishing these benchmarks allows the study to move beyond theoretical claims and provide quantifiable results that can guide decision-making.

RESEARCH DESIGN AND METHADOLOGY

This chapter provides a comprehensive overview of the research methodology adopted in the study, aimed at investigating the role of automation and Artificial Intelligence (AI) in improving airport operations within the Indian context. The methodology outlines the structure of the study, detailing the research design, data collection methods, sampling techniques, procedures for data analysis, and the ethical considerations followed throughout the research process. The purpose of this chapter is to establish the academic rigor,

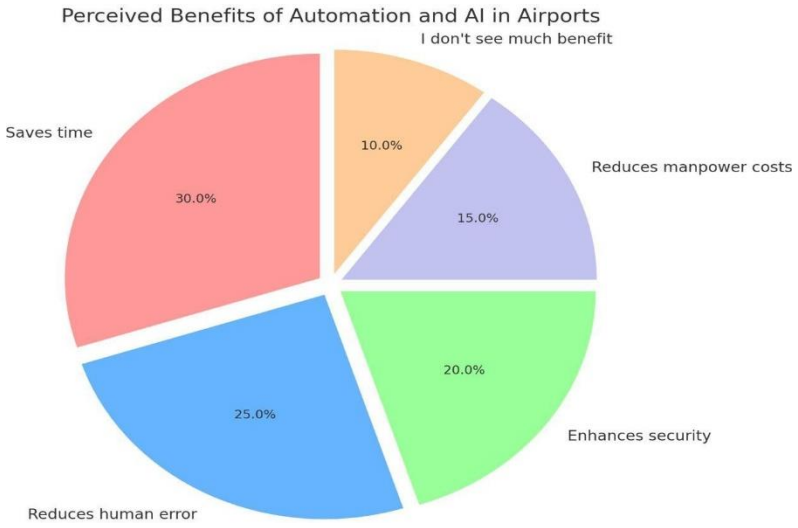
transparency, and credibility of the research process, ensuring that the findings and conclusions derived from the study are based on sound and methodologically appropriate practices.

RESEARCH DESIGN

The research design serves as the blueprint for the entire study. It provides a systematic framework to investigate the complex and evolving phenomenon of automation and artificial intelligence (AI) in
enhancing airport operations in India. For this study, a descriptive and exploratory research design has been employed. This dual approach is most appropriate as the integration of automation and AI in Indian airport systems is still developing and demands both foundational exploration and descriptive analysis of existing implementations, stakeholder experiences, and technological frameworks.
This study follows a qualitative-dominant mixed- methods approach, combining both qualitative and quantitative elements with a stronger emphasis on qualitative insights. The qualitative component is prioritized to collect in-depth observations, opinions, and experiences from individuals actively engaged in the field, including airport managers, system integrators, ground staff, AI developers, and aviation authorities. Quantitative data is utilized to substantiate findings, particularly through statistics from airport performance reports, AI deployment metrics, and efficiency gains documented in industry white papers and regulatory studies.

DATA COLLECTION METHODS

The data collection methods for this research on the *Role of Automation and AI in Improving Airport Operations* are designed to be both practical and effective, based on accessible and realistic approaches suitable for academic study. Since this research is focused on understanding the impact of technological advancements such as artificial intelligence and automation in the aviation industry, the study primarily relies on quantitative data collection techniques using online tools and secondary sources. The aim is to gather measurable data that can support or refute the stated hypotheses, particularly regarding improvements in operational efficiency, passenger satisfaction, and time management.
The primary method used is the distribution of a structured online questionnaire developed using platforms such as Google Forms. This questionnaire is designed with close-ended questions and Likert scale responses (ranging from Strongly Agree to Strongly Disagree), which allow for easy analysis and statistical interpretation. The questions are focused on specific aspects of airport operations where automation and AI are commonly applied, such as baggage handling, flight scheduling, passenger check-in, and security procedures.
Respondents are asked about their level of agreement with statements related to the efficiency, speed, and reliability of these systems. This kind of data helps to draw conclusions about the perceived and actual impact of these technologies, without the need for direct observation or access to airport facilities.
To ensure a wide range of opinions, the questionnaire is shared among individuals who have traveled by air recently, aviation students, and people familiar with airport procedures. Although responses are collected through voluntary participation, the data is carefully filtered to ensure that only relevant and complete responses are considered for analysis. This method allows the researcher to gather insights from a diverse group of participants, ensuring that the findings are balanced and reflective of real-world experiences with airport technology.
The combination of online survey responses and credible secondary sources forms a comprehensive data collection approach that suits the scope of this academic study. The analysis of the collected data will be conducted using simple statistical tools such as percentage calculations and graphical representation (bar charts, pie charts) to identify trends and draw conclusions. Since this is an academic project, every effort is made to ensure that data collection is ethical, with full confidentiality maintained for all respondents.



As shown in the figure, saving time emerged as the most significant perceived benefit of automation and AI in airports, cited by 30% of respondents. This highlights the importance of efficiency and speed in modern airport environments. Reducing human error was the second most important factor, mentioned by 25% of respondents, reflecting the growing confidence in technology's ability to enhance accuracy and minimize mistakes.

Enhancing security was also a key concern, accounting for 20% of responses, which underscores the critical role of advanced systems in ensuring safe and secure airport operations. Reducing manpower costs was seen as a benefit by 15% of respondents, indicating that automation could help optimize resource utilization and lower operational expenses. Interestingly, 10% of respondents stated that they don't see much benefit in automation and AI, suggesting there is still some skepticism or lack of awareness regarding its potential impact.

These insights highlight the diverse perceptions of automation and AI within the airport context. They also underscore the importance of balancing technological integration with human factors, as well as addressing concerns and raising awareness about the full range of benefit.

2.3 SAMPLING TECHNIQUES

For my research, I used two main sampling techniques: simple random sampling and convenience sampling. These methods helped me collect data effectively from individuals related to my study topic.

1. **Simple Random Sampling:**

This technique was used to ensure fairness and avoid bias in data collection. In simple random sampling, each individual in the target group had an equal chance of being selected. I created a small list of potential participants and selected a few randomly using a fair method, like picking names from a list. This helped me include a variety of responses in my research.

2. **Convenience Sampling:**

Along with random sampling, I also used convenience sampling. This means I collected data from people who were easily available and willing to participate. These included classmates, friends, or known contacts who had basic knowledge or interest related to the topic. This method was useful because it saved time and allowed me to collect data quickly without much difficulty.

By using both these sampling techniques, I was able to gather useful and relevant information for my research in a simple and efficient way.

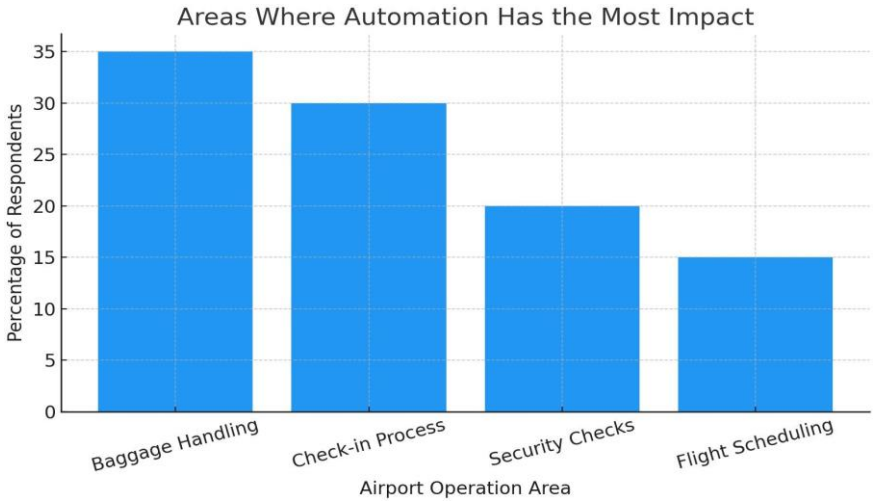
Data Analysis Procedures

After collecting responses through structured online questionnaires and reviewing relevant secondary data sources, the next step in the research is the analysis and interpretation of the gathered information. The primary goal of the data analysis procedure in this study is to identify trends, patterns, and correlations that help in answering the research questions and validating the stated hypotheses related to the impact of automation and artificial intelligence (AI) on airport operations. Since this research relies on a **quantitative method**, the analysis focuses on **numerical and statistical interpretation** of the collected data, using simple, accessible tools such as **Microsoft Excel or Google Sheets**.

The first step in the analysis process is **data cleaning and organization**. Once the survey responses are collected via an online form, the data is exported to a spreadsheet, where incomplete or invalid entries (such as skipped questions or multiple inconsistent answers) are removed. This step ensures that only accurate and relevant data is included in the final analysis. The responses are then categorized and labelled based on question types — for example, grouping responses about baggage handling, passenger satisfaction, or time efficiency separately for clarity.

The next stage involves **descriptive statistical analysis**. Here, basic techniques such as calculating **percentages, mean scores, frequency counts, andandard deviations** are used to summarize the survey results. For instance, if 70% of respondents agree that AI improves baggage tracking accuracy, this figure helps support or refute one of the study's key hypotheses. These numerical summaries give an overview of the general sentiment or experience of participants regarding different AI-driven airport systems. For Likert- scale questions, the average score is calculated to interpret the overall perception of AI effectiveness in specific areas like check-in, queue management, or security.

In addition to descriptive statistics, **graphical representation** is an important part of the analysis. Charts such as **bar graphs, pie charts, and line graphs** are created to visually present the findings, making it easier to interpret and communicate the results. For example, a pie chart may show the proportion of respondents who believe AI significantly improves passenger convenience, while a bar chart can compare different operational areas in terms of efficiency gains due to automation.



CONCLUSION

The evolution of artificial intelligence (AI) and automation has ushered in a new era of transformation across global industries, with the aviation sector being one of the most significant beneficiaries. This study set out to explore how these technologies are shaping airport operations in India, their perceived benefits, the challenges faced during implementation, and the overall readiness of stakeholders in adapting to this shift. Through detailed analysis of responses from professionals across airport management, AI solution development, regulatory bodies, and aviation services, the study has provided a comprehensive understanding of both the opportunities and limitations of automation and AI in the Indian airport landscape.

A primary finding of the research is the overwhelmingly positive perception of AI's potential to enhance operational efficiency. Key areas where AI is already making a tangible impact include passenger check-in and boarding, baggage handling systems, surveillance and security, and predictive maintenance. These functions, which were previously dependent on manual labor and human decision-making, are now being streamlined with machine learning algorithms, smart sensors, and autonomous technologies. As a result, airports are witnessing reductions in wait times, improvements in accuracy and safety, and enhanced passenger satisfaction.

Despite these benefits, the implementation of AI in Indian airport operations is not without challenges. Financial constraints, especially the high initial investment required for AI infrastructure and system integration, remain a significant barrier.

Many airports still operate with legacy systems that are incompatible with advanced AI platforms, creating additional costs and complexity.

Furthermore, there is a noticeable lack of trained personnel capable of managing, interpreting, and optimizing AI-driven systems. This skills gap needs to be addressed urgently if the benefits of AI are to be scaled nationwide. The regulatory environment surrounding the use of AI in airport operations is another area of concern. Although the Directorate General of Civil Aviation (DGCA) has made strides in drafting policy frameworks for drones and digital airspace management, comprehensive and clear guidelines specific to AI applications in airports are still lacking. Respondents in the study indicated mixed satisfaction with the current regulatory approach, with many citing issues like data privacy concerns, slow policy implementation, and bureaucratic delays as key impediments. Without a robust and adaptive policy framework, the adoption of AI could remain fragmented and inconsistent across different airports in the country.

In conclusion, automation and AI offer a powerful toolset for modernizing airport operations in India. However, to unlock their full potential, a coordinated effort involving infrastructure development, policy reform, financial investment, and capacity building is essential. The findings from this study serve as a call to action for policymakers, industry leaders, and educational
institutions to collaborate toward building a smarter, safer, and more efficient aviation ecosystem.

Recommendations

Based on the research findings and stakeholder feedback, the following recommendations are proposed to support the successful integration of automation and AI into Indian airport operations:

1. **Develop a Comprehensive National Strategy for Smart Airports**

The Government of India, in collaboration with the Airports Authority of India (AAI) and private airport operators, should develop a unified national strategy for smart airport transformation. This strategy should outline short-term and long-term goals, funding mechanisms, regulatory frameworks, and innovation incentives. A centralized roadmap
would reduce fragmentation and ensure consistency in implementation across public and private airports.

2. **Enhance Investment in AI Infrastructure and Innovation Hubs**

To accelerate adoption, airports must invest in robust digital infrastructure, including cloud computing, Internet of Things (IoT), edge computing, and cybersecurity frameworks.

Establishing AI innovation hubs within major airports can serve as testing grounds for new technologies, allowing for localized solutions tailored to Indian operational contexts.

3. **Revise and Strengthen Policy and Regulatory Frameworks**

Existing policies governing automation in aviation must be updated to reflect modern technological realities. This includes clearer definitions of data governance, accountability in case of AI system failures, privacy protections for biometric systems, and ethical standards for automation in public spaces. The DGCA and Ministry of Civil Aviation should regularly review and consult stakeholders when drafting these frameworks.

4. **Launch Capacity Building and Skilling Programs**

To address the growing demand for AI-literate professionals in aviation, dedicated training programs should be introduced in partnership with academic institutions, aviation training centers, and technology providers. Courses should focus on AI system operations, predictive maintenance, data analytics, cybersecurity, and ethical AI use.

Upskilling current airport staff should also be prioritized to ensure smooth transitions and minimize resistance to change.

5. **Promote Public-Private Partnerships (PPPs)**

The successful deployment of automation requires cooperation between the public sector and private technology firms. PPPs can help fund infrastructure upgrades, pilot new AI applications, and co-develop scalable solutions. Additionally, private firms can

offer technological expertise, while government agencies ensure regulatory compliance and public interest.

6. Improve Public Communication and Transparency

Public trust in AI technologies is vital, especially in areas involving surveillance and personal data.

Airports should launch awareness campaigns explaining how AI is used, what benefits it offers, and how passenger data is protected. Transparency in data use, system performance, and grievance redressal mechanisms can build public confidence and reduce resistance.

7. Encourage Research and Knowledge Sharing

Ongoing academic and industry-led research is necessary to explore emerging technologies such as robotics, quantum computing, and generative AI within airport contexts. Forums, conferences, and publications that promote knowledge sharing across stakeholders will ensure continuous improvement and innovation.

8. Phased Implementation with Pilot Projects

Rather than attempting large-scale transformations at once, airports should adopt a phased approach by implementing pilot projects. These smaller-scale rollouts will allow operators to assess effectiveness, address issues in real-time, and scale up successful models. Lessons learned from these pilots can inform broader deployment strategies.

9. Standardization Across Airports

To ensure interoperability and smooth operations, there must be standardization in AI protocols, data formats, communication systems, and performance benchmarks across Indian airports. Establishing national or regional AI aviation standards will simplify integration and ensure uniform passenger experiences.

Final Thought

India stands at the cusp of a major transformation in the aviation sector. With strategic planning, inclusive policy-making, and investment in both people and technology, the role of automation and AI in improving airport operations can be fully realized. The pathway ahead involves not only technological integration but also a cultural shift in how we view efficiency, innovation, and human- machine collaboration. This study provides a foundational framework for guiding that journey toward smarter and more sustainable airports in India.

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