



RE200 Airport Research

**In Partial Fulfillment of the Requirements of the
Course AR147-1 *Design 7:*
*Community Architecture and Urban Design***

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I. HISTORICAL AND CONCEPTUAL BACKGROUND

A. Origin and Evolution of Airports

The roots of Philippine aviation trace back to the 1930s with Nielson Field in Makati, which opened in July 1937 as one of the most advanced airports in Asia at the time. Following World War II, Manila International Airport (now NAIA) took center stage, transitioning from a US airbase to the country's primary civilian hub by the late 1940s.

The 1950s and 1960s marked a wave of airport expansion, most notably the conversion of Clark Air Base into Clark International Airport in 1996, and the gradual growth of Cebu's airport. This reflected the post-war surge in travel and economic activity. These developments were considered the precursor for modern airport infrastructure that supports today's travel and tourism demands.

B. Legal Definitions and Governance Structures

There have been laws that regulate and provide clarification on the standards of airport design & systems here in the Philippines.

Early Legal Foundations:

- *Legislative Act No. 3909 (1931)* and *Commonwealth Act No. 168 (1936)* laid the foundation for aviation regulation in the Philippines.
- These acts established the government's role in civil aviation operations.

Institutional Evolution:

- Creation of the **Civil Aeronautics Administration (CAA)** to oversee civil aviation.
- The CAA transitioned into the **Bureau of Air Transportation**, and later the **Air Transportation Office (ATO)**.
- In 2008, the **Civil Aviation Authority of the Philippines (CAAP)** was established under *Republic Act No. 9497*.

Airport Management and Oversight:

- The **Manila International Airport Authority (MIAA)** was established in 1982 to manage NAIA.
- The **Mactan–Cebu International Airport Authority (MCIAA)** followed in 1990 for Cebu's airport.
- Both authorities operate under the supervision of the **Department of Transportation (DOTr)**.

C. Global Trends in Airport Planning and Development

Airports around the world are no longer just transit points—they are evolving into complex, multi-functional “aerotropolises” or “cities within cities” that integrate transportation, commerce, and lifestyle functions. This evolution is largely driven by rapid technological advancement, increasing environmental concerns, and shifting passenger expectations, particularly in the aftermath of the COVID-19 pandemic. The following trends characterize global airport development today:

Smart Technology Integration: Industry 4.0 technologies, artificial intelligence (AI), big data, and automation are being widely adopted to optimize operations, manage security systems, and improve the passenger journey. Biometric

screening, contactless check-ins, and predictive maintenance systems are now standard in many international hubs.

Sustainability and Climate Resilience: Airports are increasingly adopting green building practices, aiming for carbon neutrality through solar power, energy-efficient terminal designs, and sustainable water management systems. ICAO and ACI have encouraged airports to align with the global aviation sector's long-term environmental goals.

Transit-Oriented and Adaptive Infrastructure: Modern airports are planned with integrated transport networks (rail, bus, expressways) and are designed to be flexible, allowing adaptation to changing passenger volumes, technology needs, and health protocols.

Passenger Experience as Priority: The post-pandemic era has accelerated the demand for seamless, contactless travel. Airports now focus on enhancing comfort, efficiency, and health safety through digital wayfinding, wellness zones, and automated services.

D. Comparative Study: Local vs International Airport Design

Compared to international airports in Singapore, Dubai, or Seoul, Philippine airports are rapidly upgrading but still lag in capacity, infrastructure quality, and technological integration. NAIA, for instance, is under a PPP-driven modernization to raise passenger throughput from 42 to 62 million annually, addressing inefficiencies and operational delays. Regional hubs like Mactan–Cebu and Clark reflect hybrid models: while Cebu has implemented a modern terminal and added a second runway (to launch mid-2025), Clark leverages smart planning and PPP frameworks but faces challenges in scaling airline networks.

In contrast, future greenfield projects like the Bulacan New Manila International Airport and the Panglao International Airport demonstrate early adoption of sustainable, smart design principles.

II. DESIGN AND PLANNING CONSIDERATIONS

A. Site Selection and Strategic Land Use

Selecting a site for a new airport involves evaluating environmental impact, noise exposure zones, access to urban centers, and expansion potential. Land use planning must address zoning compatibility, buffer zones, and connectivity to major transport corridors. In the Philippine context, low-lying coastal sites (e.g., Bulacan airport) pose challenges in climate resilience and require significant mitigation strategies.

Provided are examples of key considerations when it comes to site selection and strategic land use:

- **Accessibility and Proximity to Urban Centers**
 - Must be reachable within a reasonable time by road, rail, or water transport.
 - Supports intermodal connectivity (e.g., integration with MRT, highways, bus routes).
- **Environmental Impact**

- Assessment of ecological sensitivity, biodiversity disruption, and carbon footprint.
- Compliance with Environmental Impact Assessment (EIA) and ECC (Environmental Compliance Certificate) in the Philippines.
- **Topography and Geotechnical Conditions**
 - Flat, stable land preferred for runways; avoids excessive grading or filling.
 - Consideration of soil bearing capacity and flood risk (especially for coastal sites like Bulacan).
- **Airspace Availability and Obstacle Clearance**
 - Avoidance of high-rise obstructions, mountain ranges, and conflict with other airports' airspace.
 - Compliance with ICAO's Obstacle Limitation Surfaces (OLS).
- **Expansion Potential & Socio-Political and Economic Factors**
 - Site should accommodate future runway extensions, new terminals, and logistics zones.
 - Land banking strategies may be used to preserve space for long-term growth.
 - Land acquisition feasibility and potential for displacement or resettlement.
 - Economic viability and impact on regional development and job creation.
- **Zoning and Land Use Compatibility**
 - Must align with comprehensive land use plans (CLUP) and zoning ordinances.
 - Avoidance of conflicting land uses (e.g., residential, heritage zones, protected areas).
- **Climate Resilience**
 - Consideration of sea-level rise, typhoons, and earthquake risks in site selection.
 - Elevated platforms, sea walls, or drainage infrastructure may be required.

B. Master Planning and Airport Layouts

A well-crafted airport master plan defines the short-term and long-term development of all airport components. It includes the spatial arrangement of terminals, runways, taxiways, support facilities, and commercial zones. (*Refer to Figures 1 & 2*). Flexibility and phasing are vital to accommodate future expansions without disrupting operations. Philippine airports like Clark and Mactan–Cebu have updated master plans to reflect long-term passenger growth and airline activity.

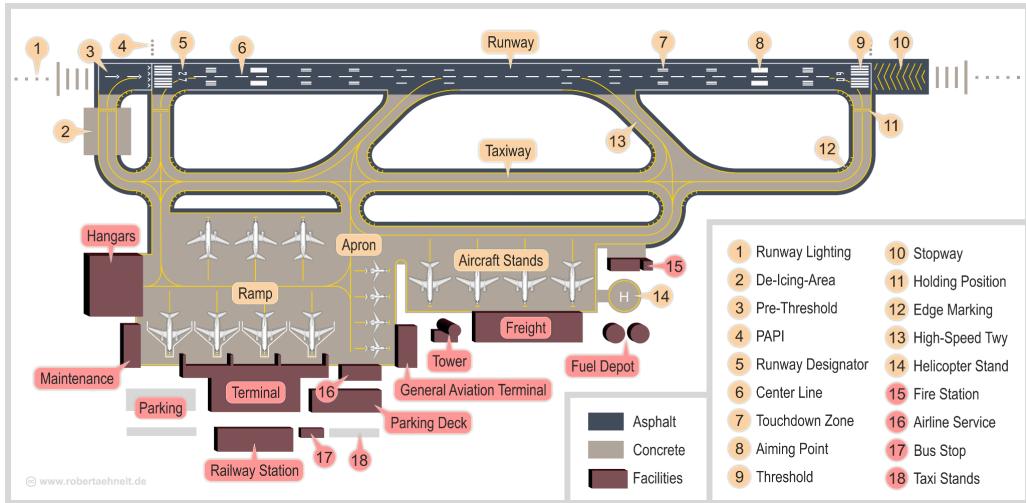


Figure 1. Airport Terminal & Runway Sample Layout

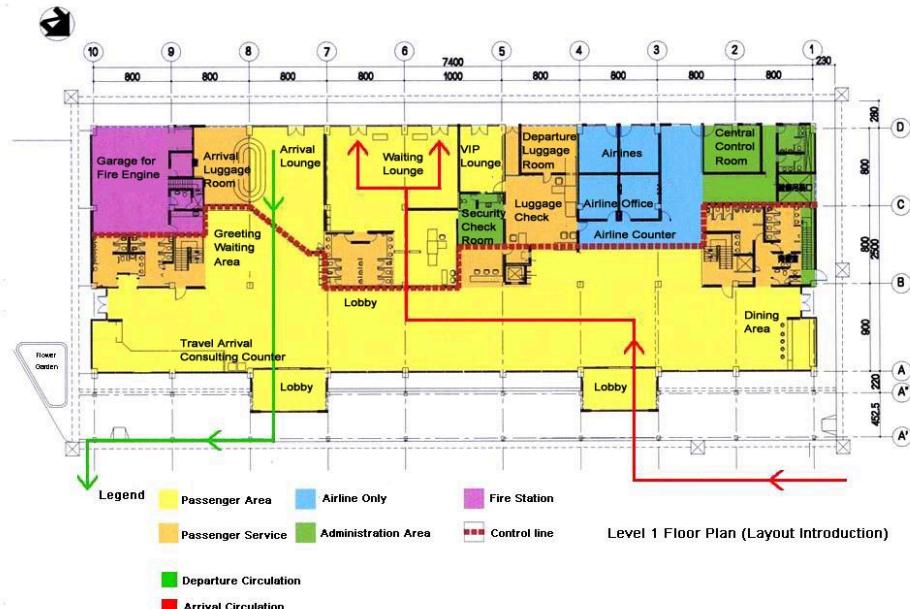


Figure 2. Henchun Airport Terminal Interior Layout

1. Zoning of Functional Areas (Airsideside, Landside, Terminal Core)

- The site is divided into zones: **airsideside** (runways, taxiways, aprons), **landsideside** (parking, public transport, access roads), and **terminal core** (passenger processing).
- Efficient transitions between these areas reduce congestion and optimize passenger and baggage flow.
- Zoning should include **non-aeronautical areas** like commercial districts, hotels, logistics parks, and administrative zones for revenue diversification.
- Best practices from Changi and Incheon airports include extensive non-aeronautical zoning to improve profitability.

2. Terminal Building Placement and Modularity

- The terminal is usually placed between runway and landside access roads to optimize passenger movement and reduce curb-to-gate distances.
- Modular or pier-finger terminal configurations are preferred for scalability and efficient gate allocation.

- Concourses and satellite terminals must allow for incremental expansion without disrupting core operations.

C. Passenger Terminal, Runway, and Taxiway Design

Airport infrastructure is primarily composed of three interconnected systems: the passenger terminal, the runway, and the taxiway. Each of these components must be carefully designed to ensure safe, efficient, and seamless operations that accommodate both current demands and future growth. Below are key considerations for each component:

Passenger Terminal Design Considerations

- Areas for arrivals, departures, immigration, and baggage should be clearly separated.
- Layouts should reduce walking distances and waiting times.
- Terminals should be designed so they can be expanded easily over time.
- Must follow international safety rules (ICAO standards).
- Include cameras, controlled access, and secure zones.
Should offer lounges, shops, restaurants, and other amenities.
- Should connect well with buses, trains, taxis, and parking.
- Must be accessible for persons with disabilities (BP 344 compliance).
- Should include natural ventilation, shading, and flood protection.
- Use of green and energy-efficient materials is encouraged.

Runway Design Considerations

- Runways must line up with common wind directions to reduce risk.
- ICAO suggests 95% wind coverage to be safe for most flights.
- Runway length depends on the airport's location and aircraft type.
- Surfaces must be strong enough for heavy jets (PCN/ACN system).
- Includes extra space at both ends in case of emergencies.
- Proper lighting and markings help pilots land safely.
- Having more than one runway improves efficiency and avoids delays.
- Crosswind runways are useful in areas with variable wind directions.

Taxiway Design Considerations

- Layout should let planes move without crossing runways unnecessarily.
- Fast-exit taxiways help clear runways quicker.
- Must support the turning radius and wingspan of large aircraft.
- Adequate side clearance ensures safety.
- Pavement must handle frequent, heavy use.
- Lighting and markings should help guide planes, especially at night.
- Planes wait here before takeoff.
- Must follow international standards for signs and markings.

Terminal & Runway Configurations

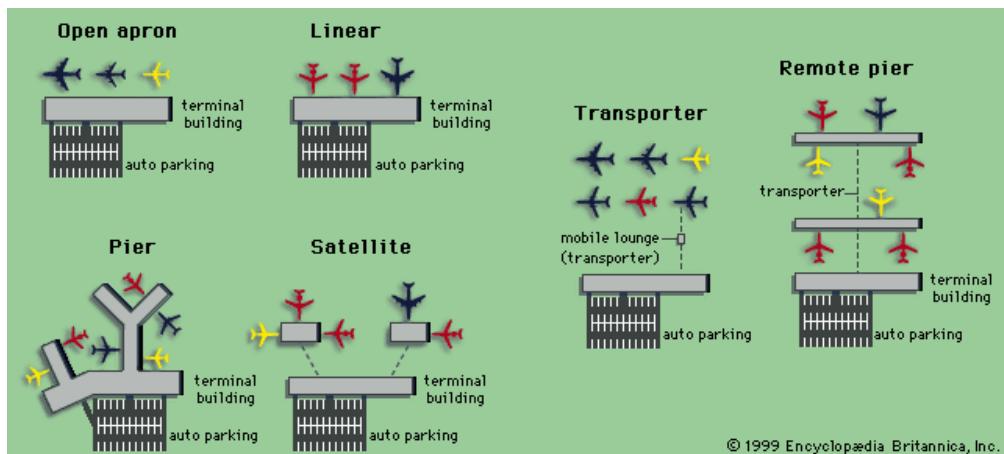


Figure 3. Airport Terminal Configurations

1. Open Apron Design

- Oldest and simplest layout.
- Planes park right next to the terminal; passengers walk across the tarmac to board.
- Works for small airports but is not suitable for large passenger volumes.

2. Linear Design

- Planes park directly next to the terminal with gates and air bridges.
- Easier and safer for passengers, but buildings can get very long (up to 800m), leading to long walks.
- Used in airports like Kansas City, Munich, and Charles de Gaulle.

3. Pier Design

- Long corridors (piers) extend from the main terminal, with planes parked along them.
- Handles more gates than linear design but can mean long walking distances.
- Seen at Frankfurt and Schiphol.

4. Satellite Design

- Aircraft park around separate satellite buildings away from the main terminal.
- Passengers ride automated trains or people movers to reach them.
- Used in Orlando and Tampa. Once popular, but less favored now due to space inefficiency.

5. Transporter Design

- Uses movable lounges or buses to take passengers directly to the plane.
- Example: Dulles Airport (Washington D.C.).
- Reduces walking but causes delays and potential aircraft damage. Not widely liked.

6. Remote Pier Design

- Similar to satellite design but uses long piers accessible by people movers.
- Efficient for connecting passengers but needs advanced transport systems.
- Example: Atlanta (Hartsfield) and Stansted (London).

Terminal Runway Markings

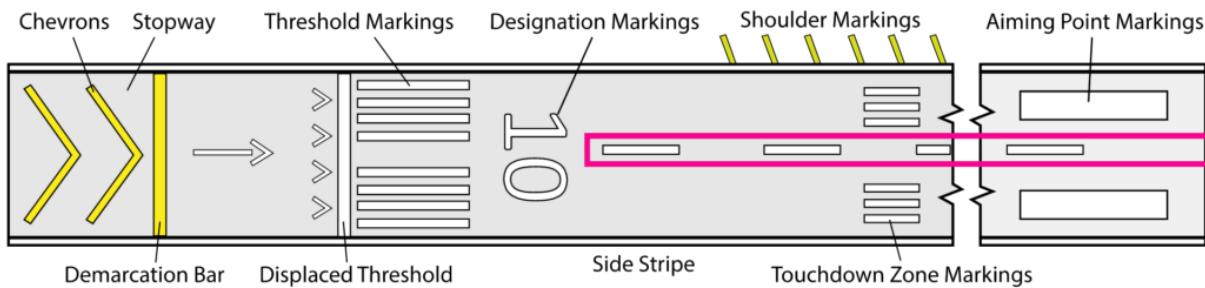


Figure 4. Runway indicators & markings

Marking Color Symbolism

Marker	Colour
Runway marker	white
Taxiway marker	yellow
Apron edge marker	yellow
Runway strip marker	white
Helicopter apron edge marker	blue
Unserviceability marker	white, with central 25 cm red band
Runway strip marker (displaced threshold.)	split white and suitable background colour

Colour	AS Colour Code	AS Colour Name
Blue	B41	Blue Bell
Green	G35	Lime Green
Orange	X15	Orange
Red	R13	Signal Red
Yellow	Y14	Golden Yellow
White	N14	White
Black	N61	Black

Figure 6. Runway marking symbolism

D. Airside vs Landside Planning

The division between airside (runways, taxiways, aprons, gates) and landside (check-in, parking, retail, baggage claim) areas is essential for operational clarity and safety. Efficient design ensures smooth transitions for passengers and aircraft, minimizing delays and enhancing security. Airports must consider congestion points in both areas and apply appropriate spatial and traffic flow strategies.

E. Structural and Engineering Systems in Airports

Airports demand robust structural systems to accommodate long-span roofs, large crowds, and seismic resilience, especially in earthquake-prone countries like the Philippines.

Engineering systems include:

- HVAC
- baggage handling
- fire protection

- ICT networks

Sustainable engineering is now integral to airport design, using passive cooling, daylighting, and smart grid integration to reduce energy loads.

F. Compliance with Aviation, Building, and Safety Codes (e.g., ICAO, IATA, NBC)

The planning and construction of airport facilities must be guided by a rigorous framework of international and national regulations to ensure operational safety, structural integrity, and efficient user experience. This compliance landscape includes a layered set of standards that range from general building codes to highly specialized aviation safety protocols.

1. International Civil Aviation Organization (ICAO) Standards

The International Civil Aviation Organization (ICAO) issues global Standards and Recommended Practices (SARPs) found in its Annexes to the Convention on International Civil Aviation. These address virtually every aspect of airport planning, including:

- Annex 14 – Aerodromes, which defines the design and operational criteria for runways, taxiways, lighting systems, obstacle limitations, and rescue/firefighting services.
- Annex 9 – Facilitation, which covers customs, immigration, and passenger processing standards.
- Annex 11 – Air Traffic Services, which governs the layout of air traffic zones and control towers.
- Aerodrome Design Manual (Doc 9157), which supplements Annex 14 with best practices and detailed design parameters.

2. International Air Transport Association (IATA) Guidelines

While ICAO provides minimum standards, IATA promotes operational efficiency, passenger satisfaction, and safety. IATA guidelines are not binding like ICAO SARPs, but they are widely adopted for design excellence and customer-focused functionality. Key IATA contributions include:

- Airport Development Reference Manual (ADRM) – outlines capacity planning, terminal design, and level of service standards.
- Guidance on baggage handling, passenger flow simulation, wayfinding, and retail integration in terminal design.

3. National Building Code of the Philippines (NBC)

Locally, all airports must conform to the National Building Code (Presidential Decree No. 1096), which outlines the minimum requirements for structural design, safety, health, and sanitation. Specific implications for airport facilities include:

- Fire safety and egress: Minimum widths and clearances for exits, firewalls, and protected paths of travel.
- Occupant loading and assembly areas: Important in high-density airport terminals.

- Accessibility (BP 344): Airports must comply with accessibility laws, ensuring barrier-free access for persons with disabilities, including ramps, tactile strips, and Braille-enhanced signage.
- Mechanical, electrical, and sanitary systems: Subject to compliance with the Philippine Electrical Code, Plumbing Code, and Fire Code.

4. Civil Aviation Authority of the Philippines (CAAP) Regulations

CAAP serves as the regulatory body overseeing airport safety, airworthiness, and air navigation systems in the Philippines. It issues permits, certifies aerodromes, and ensures that Philippine airports conform to ICAO standards through local adaptation.

CAAP:

- Conducts aerodrome certification inspections (per CAAP Memorandum Circulars).
- Requires Obstacle Limitation Surfaces (OLS) analysis for any new structure near flight paths.
- Enforces Aerodrome Manual submission for airport operators covering firefighting, maintenance, and emergency planning.
- Monitors environmental impact compliance in coordination with DENR for runway extensions or airport expansions.

5. Integration and Coordination Across Codes

Design teams must integrate all these standards early in the planning phase to avoid costly redesigns or regulatory rejections. For example:

- Runway orientation and placement must meet ICAO wind coverage and OLS while minimizing community disruption per local zoning codes.
- All major airport construction requires an Environmental Compliance Certificate (ECC) from DENR under Philippine EIA guidelines.

III. FUNCTIONAL AND OPERATIONAL ASPECTS

A. Airport Operations and Terminal Management

Airport operations refer to everything that needs to happen to keep an airport working efficiently, safely, and on time. This includes both airside operations (the areas where aircraft move, such as runways, taxiways, and aprons) and landside operations (the parts of the airport where passengers arrive, check-in, shop, eat, and wait).

Terminal management focuses on how the building itself is run. This includes scheduling gates for incoming and outgoing flights, keeping terminals clean and organized, maintaining heating and air-conditioning, managing food and retail spaces, and ensuring that announcements and flight displays are accurate. Airports often have Airport Operations Centers (AOC) that monitor weather, flights, and crowd movement in real-time, like a mission control room.

Every day, staff such as air traffic controllers, ground crew, janitors, customer service agents, and facility managers work together to make sure all parts of the airport are functioning properly.

B. Passenger Flow and Experience Optimization

A major goal of airport management is to make sure that passengers can move smoothly from arrival to boarding their plane. This process is called passenger flow. Airports are designed so travelers can easily move through stages like check-in, security, immigration, boarding, and baggage claim after landing.



Figure 7. Airport User Flow

To optimize the experience, airports use clear signs, digital displays, and helpful staff to guide passengers. More advanced airports use self-service check-in kiosks, e-gates (automated passport checks), and mobile apps that give real-time updates. This helps reduce wait times, avoid crowding, and lower stress.

A good passenger experience also includes clean restrooms, charging stations, fast Wi-Fi, comfortable waiting lounges, and access to food, drinks, and shopping. Some airports even have indoor gardens, massage chairs, and sleep pods to make long layovers more pleasant.

C. Security Screening and Access Control Systems

Keeping passengers, crew, and airport staff safe is a top priority. That's why airports have strict security systems and access control protocols. All passengers and their bags must pass through security screening before entering the boarding gates. This process includes metal detectors, X-ray scanners, and sometimes full-body scanners.

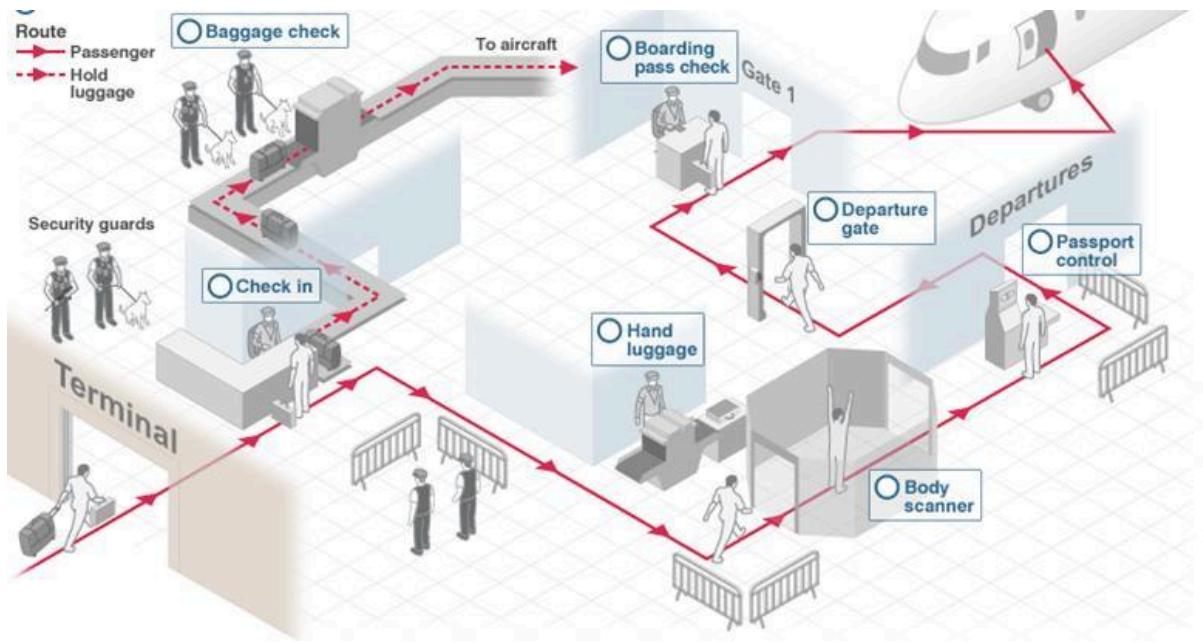


Figure 8. Airport Passenger Flow

Security officers may also use explosive trace detection (ETD) devices or swab checks to look for dangerous materials. Any suspicious item is pulled aside for manual inspection. At international airports, immigration officers also check travel documents and visas.

Only authorized personnel can access sensitive parts of the airport, like the control tower, aircraft parking areas, and baggage rooms. These areas are protected by access control systems, including ID badges, biometric scanners (such as fingerprints or facial recognition), and monitored security doors.

D. Baggage Handling and Logistics

Behind the scenes, there is a complex and carefully timed system that manages every checked suitcase and cargo package. When a passenger checks in their bag, it enters the baggage handling system (BHS), a network of high-speed conveyor belts and barcode or RFID scanners.

Bags are automatically sorted based on flight number and destination, then sent to the correct loading zone where ground staff place them in the aircraft's cargo hold. After landing, bags are unloaded, re-sorted, and sent to baggage claim areas for pickup.

Because thousands of bags are processed every hour, the system must be efficient and accurate to avoid delays or lost luggage. Advanced software tracks bags in real-time, and passengers can often check the status of their bags on airline apps.

E. Ground Transportation and Parking Facilities

Passengers need reliable ways to get to and from the airport. That's why airports have dedicated areas for ground transportation, including taxi stands, bus stops, train stations, ride-hailing pickup points, and rental car services. Some major airports are directly connected to city train or metro lines for fast public access.

Airports also provide parking lots and garages for passengers who drive. These can include:

- Short-term parking (for a few hours)
- Long-term parking (for several days)
- Employee parking (for airport staff)
- Premium or valet parking (closer and more convenient)

To make parking easier, airports often use electronic signs that show the number of available spaces, ticket machines at entrances, and shuttle buses that take travelers from far parking zones to the terminal entrance.

F. Cargo Operations and Freight Handling

Airports are also major hubs for air cargo, which includes mail, packages, fresh food, medical supplies, and goods from manufacturers and online sellers. Cargo handling is important for business, trade, and even emergency aid.

Cargo is moved through special freight terminals separate from passenger terminals. These areas include:

- Loading docks and warehouses where packages are sorted
- Cold storage rooms for perishable items like seafood, flowers, and vaccines
- Security screening areas for checking cargo contents
- Customs offices for importing and exporting goods legally

Cargo is packed into containers called unit load devices (ULDs) and loaded onto cargo aircraft or the cargo holds of passenger planes. Some airports operate 24/7 just to handle cargo flights from different parts of the world.

G. Waste Management and Environmental Systems

Airports generate large amounts of waste every day from food packaging, paper, and plastic to chemical waste from cleaning and aircraft maintenance. To keep the environment clean, airports set up waste management and sustainability systems.

These systems include:

- Recycling stations throughout the terminals
- Hazardous waste disposal facilities
- Sewage and water treatment systems
- Programs to reduce single-use plastics

Many airports are working to become more eco-friendly by installing solar panels, using energy-efficient lighting, and planting green roofs or trees to absorb carbon emissions. Some have even adopted LEED-certified building designs that reduce environmental impact.

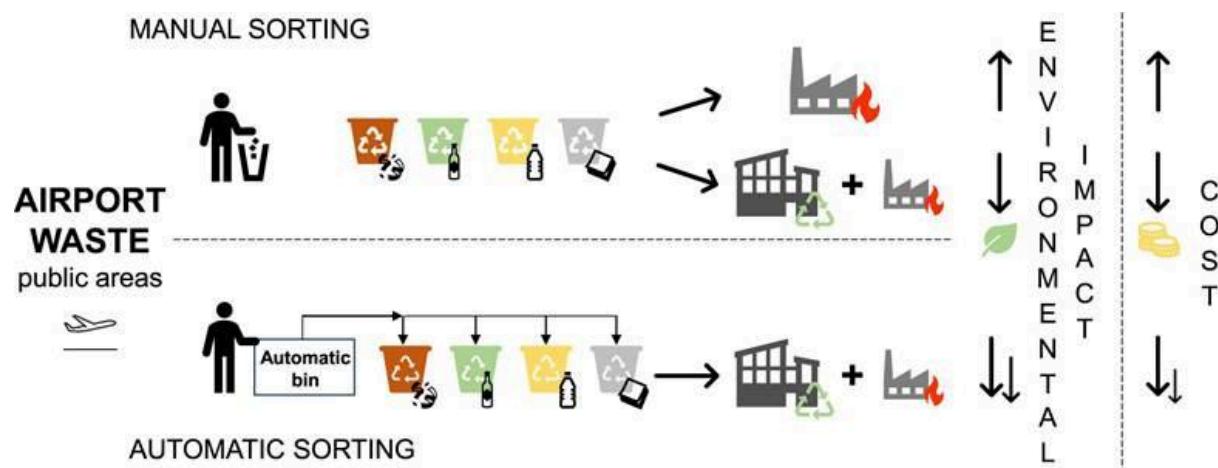


Figure 9. Airport Waste Management

Aircraft noise and air pollution are also concerns. Airports often schedule flights to reduce late-night noise and use special runways or sound barriers to protect nearby neighborhoods.

H. Emergency Planning and Disaster Resilience

Because airports handle large numbers of people and operate 24/7, they must be ready for any kind of emergency. These include aircraft accidents, fires, terrorist threats, natural disasters like earthquakes or typhoons, and public health emergencies (like disease outbreaks).

Airports have emergency response plans that include:

- Fire and rescue teams stationed at the airfield
- Medical teams and first aid stations
- Evacuation routes and emergency exits
- Backup generators in case of power failure
- Communication systems to alert staff and passengers

Airport staff regularly conduct emergency drills with airlines, police, fire departments, and local hospitals to practice how to respond quickly and safely. Some major airports also have Emergency Operations Centers (EOCs) that take over during crises and manage the situation from a central control point.

IV. ECONOMIC AND SOCIAL IMPACTS

A. Development Costs and Financing Models

Building an airport requires a huge amount of money. This includes buying or leasing land, constructing runways and taxiways, building terminals where passengers wait and check in, as well as facilities like control towers, parking lots,

and maintenance hangars. The bigger and more modern the airport, the higher the cost. For example, building a new international airport can cost billions of pesos or even billions of dollars.

To cover these costs, governments usually use a mix of funding sources. Sometimes they pay directly using taxpayer money, which means the government collects taxes and uses part of that money to build and maintain airports. Other times, governments invite private companies to invest and manage the airport through partnerships known as public-private partnerships (PPP). These companies help finance the construction and get a share of the airport's earnings. Additionally, loans from international banks or financial organizations like the World Bank are often used.

Different airports have different financing models depending on the country's economy, government policies, and the size of the project. For example, the New Manila International Airport in Bulacan is being built with heavy involvement from private investors, while smaller domestic airports may rely mostly on government funding.



Figure 10. Proposed New Manila International Airport in Bulacan

B. Economic Impact on Local and Regional Development

Airports have a big influence on the economy of the city or region where they are located. When an airport opens or expands, it can attract many businesses nearby. Hotels, restaurants, malls, and offices often develop close to airports to serve travelers and workers. This creates more jobs and encourages local businesses to grow.

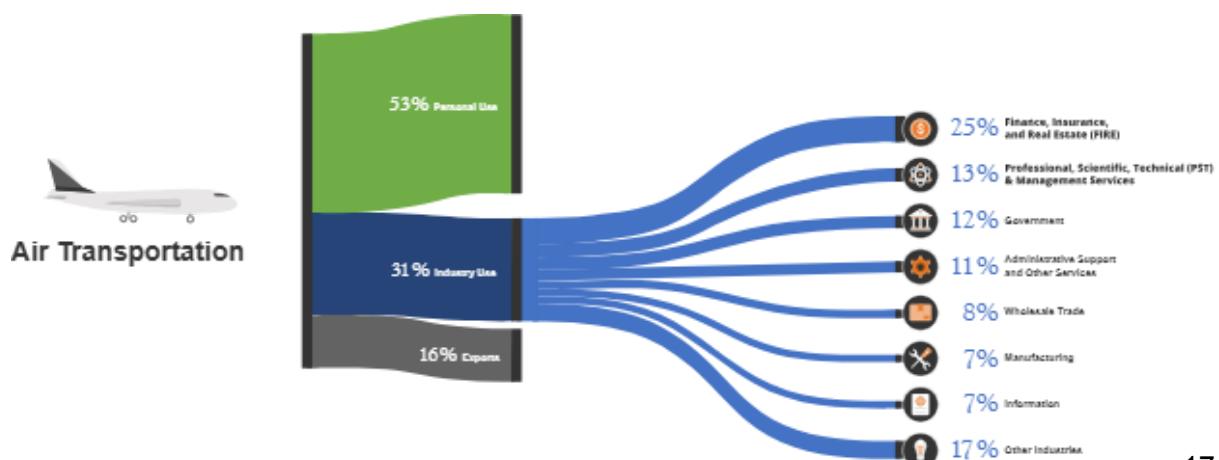


Figure 11. The Role of Aviation in Supporting Local Economic Activity

Airports also improve transportation links, making it easier and faster to move goods and people. This is especially important for industries that rely on fast delivery, such as electronics manufacturing or fresh food exports. As goods can be shipped internationally from the airport, local producers can sell their products to markets abroad, which boosts the regional economy.

Another important effect is that real estate prices near airports often increase. People want to live or invest in areas with good transport connections, which can raise property values and encourage urban development. However, this can also lead to gentrification, pushing out lower-income residents.

C. Airline-Airport Relationships and Business Models (e.g., hub-and-spoke)

Airlines and airports have a close working relationship to ensure smooth operations. Airlines pay airports fees for using their facilities, including landing fees for each plane, charges for using gates, and fees for passenger services. Airports, on the other hand, provide airlines with infrastructure like runways, terminals, and baggage handling.

Some airports serve as hubs in a network called the hub-and-spoke system. In this model, a central airport (hub) connects many flights from smaller airports (spokes). Passengers fly into the hub and then transfer to other flights to reach their final destinations. This system helps airlines operate efficiently by consolidating passengers and reducing the number of direct flights needed.

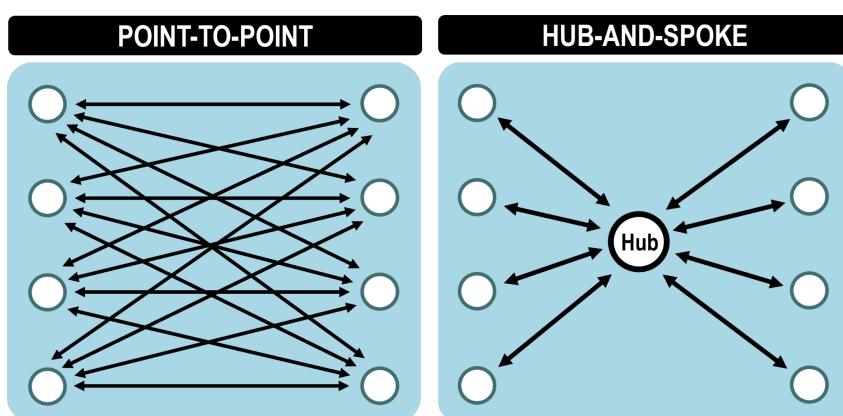


Figure 12. Point-to-Point versus Hub-and-Spoke Networks

Examples of major hub airports include Singapore Changi and Dubai International. These hubs attract many airlines and passengers, increasing business opportunities for the airport and the local economy.

D. Job Creation and Labor Dynamics

Airports are major job creators. They provide employment directly through jobs such as airline pilots, cabin crew, air traffic controllers, security personnel, baggage handlers, cleaners, and customer service staff. These direct jobs require different skills and training, from technical to hospitality.

Beyond direct employment, airports create indirect jobs in related sectors. Taxi drivers, hotel employees, restaurant workers, shop vendors, and logistics providers all benefit from airport operations. This broad job creation supports local communities and contributes significantly to the national economy.

However, airport jobs sometimes come with challenges. Many positions involve shift work, night shifts, or irregular hours due to 24/7 operations. Some roles, especially in ground handling or cleaning, may have low wages or limited benefits. Labor unions and government regulations play important roles in protecting workers' rights and improving conditions.

E. Impact on Tourism and Trade

Airports play a crucial role in supporting tourism, one of the biggest industries in many countries. By making travel easier and faster, airports encourage more tourists to visit. Tourists spend money on hotels, food, souvenirs, and tours, which boosts local businesses and creates more employment.

International airports open up countries to global visitors, increasing foreign exchange earnings. Domestic airports also help people explore different parts of their own country, supporting regional tourism development.

Airports also help trade by facilitating the export and import of goods. For products that need quick delivery, like fresh fruits, seafood, or electronics, air transport is essential. This allows producers to reach global markets and increases the competitiveness of local industries.

F. Community Integration and Noise Mitigation

While airports bring many benefits, they can also cause problems for nearby communities. One major concern is noise pollution. The loud sound of airplanes taking off and landing can disturb residents, affecting their sleep and overall well-being. Traffic congestion and air pollution from vehicles and planes are also common issues.

Challenges Faced by Communities:

- Noise pollution from airplanes taking off and landing
- Increased traffic congestion and air pollution
- Disruption to daily life and potential decrease in property values

To address these problems, airports work closely with communities and local governments. They may build noise barriers or soundproof homes to reduce the impact. Some airports implement flight curfews or restrictions on night flights to minimize noise during sleeping hours. They might also create green buffer zones with trees and parks around the airport to absorb noise and improve air quality.

In some cases, airports offer financial assistance or compensation to people affected by noise and other disruptions. Good community relations are important to balance airport growth with quality of life for residents.

G. Equity, Accessibility, and Social Inclusion

Airports should be accessible and welcoming to everyone, regardless of age, ability, or social status. This means designing facilities that help people with disabilities, such as ramps, elevators, braille signs, and special assistance services. It also includes making sure there are clear signs and information for senior citizens and non-native speakers.



Figure 13. Accessibility in Airports

Social inclusion means airports must provide affordable and reliable transportation options, like buses or shuttles, to connect low-income communities to the airport. This helps ensure that air travel is not only for the wealthy but available to more people.

By promoting equity, airports help create more inclusive societies where everyone can benefit from connectivity and economic opportunities.

V. ENVIRONMENTAL AND SUSTAINABILITY CONSIDERATIONS

A. Sustainable Airport Design and Green Certifications (e.g., LEED, BERDE, Envision)

Modern airport design is no longer just about functionality it must also consider sustainability. This means reducing environmental damage during construction and operation. Sustainable airport design involves using low-impact construction methods, choosing recyclable and non-toxic materials, and minimizing land disruption. Green roofs, natural ventilation, and the strategic placement of windows to maximize natural light are now standard practices in many new airport projects.

To validate these efforts, airports often seek green certifications. LEED (Leadership in Energy and Environmental Design) is one of the most widely recognized certifications globally. In the Philippines, BERDE (Building for Ecologically Responsive Design Excellence) serves a similar purpose, while

Envision is used to assess the sustainability of larger infrastructure projects. These frameworks provide strict criteria on energy use, water management, materials, site selection, and indoor environmental quality.

Earning a certification is more than a badge, it's a commitment to ongoing environmental responsibility. Certified airports must monitor their performance regularly and make improvements when needed. This approach pushes airports to reduce their carbon footprint and environmental harm over the long term. It also enhances their reputation with environmentally conscious travelers and investors.

In short, sustainable airport design isn't just about environmentalism, it's about future-proofing. As climate change and resource scarcity become more pressing, green-certified airports will be better equipped to meet new regulatory standards and societal expectations.

B. Energy Efficiency and Renewable Energy Integration

Airports consume massive amounts of energy daily from lighting and air conditioning to fueling ground support equipment. Improving energy efficiency is one of the most important ways to reduce environmental impact and operating costs. Energy-efficient systems include LED lighting, high-performance insulation, and motion-controlled lighting in seldom-used areas like storage rooms and restrooms.

One major advancement in sustainable airport energy use is the integration of renewable energy sources. Solar panels are becoming more common, especially in sun-rich areas like Southeast Asia. Some airports install solar farms on-site or on terminal rooftops, helping them generate clean electricity and reduce dependency on the grid. Other facilities explore wind turbines, geothermal heating, and even biofuels to power vehicles and support systems.

Smart energy management systems further optimize airport energy use. These systems use real-time data to monitor energy flows, detect waste, and automatically adjust settings like lighting or temperature based on activity and weather. AI-powered tools can even predict energy demands and schedule maintenance to avoid overconsumption or equipment failure.

Together, these efforts lower greenhouse gas emissions and contribute to global climate goals. For airports, it's also a practical choice investing in energy efficiency and renewables reduces long-term operational costs and shields them from rising fuel prices or power shortages.

C. Water Conservation and Drainage Management

Water conservation is essential in airport sustainability. Airports use thousands of liters daily for restrooms, food services, cooling systems, and landscaping. Sustainable airports now employ water-efficient technologies such as low-flow faucets, dual-flush toilets, and motion-activated systems to minimize wastage. These measures significantly cut down on water bills and reduce strain on local water supplies.

In addition to conservation, proper drainage management is crucial. Airports cover large paved surfaces, making them vulnerable to flooding during heavy rains or storms. Traditional drainage systems, like underground pipes, are now being replaced or supported by more natural methods, such as bioswales, retention basins, and green roofs. These systems slow down water runoff, allow for natural absorption, and help filter out pollutants before water enters local rivers or oceans.

Rainwater harvesting is another technique used in sustainable airports. Collected rainwater can be treated and reused for toilet flushing, cooling towers, and even irrigation. Some airports, like Changi Airport in Singapore, have large-scale water recycling systems that help them become more self-sufficient.

Ultimately, smart water management isn't just about being eco-friendly it also makes airports more resilient. With climate change increasing the risk of extreme weather, having effective water conservation and flood control systems protects both operations and surrounding communities.

D. Waste Management and Circular Economy Practices

Airports produce enormous amounts of waste daily. This includes food waste from restaurants, packaging from retail stores, maintenance waste from aircraft services, and traveler-generated trash. Sustainable airports are now adopting integrated waste management systems that focus on reduction, reuse, and recycling to minimize landfill disposal.

Recycling stations are placed throughout terminals to encourage passengers to sort waste properly. Back-end systems further process and separate waste, while partnerships with recycling firms ensure that paper, plastics, metals, and even e-waste are diverted from landfills. Composting is another growing trend food scraps from airport kitchens are turned into fertilizer for landscaping use.

Circular economy practices go beyond waste disposal. Airports are designing systems that reuse materials whenever possible. For instance, construction debris from renovations is reused for paving, and old uniforms are turned into new materials. Retail and food partners may be required to use reusable packaging or compostable materials to align with the airport's sustainability goals.

These efforts not only reduce environmental harm but also help airports comply with stricter waste regulations. In the long term, embracing circular economy principles makes airports more efficient, cost-effective, and environmentally responsible.

E. Climate Change Adaptation and Resilience Measures

Airports are highly vulnerable to the effects of climate change. Rising sea levels can flood runways, extreme heat can damage tarmac and electronics, and stronger typhoons or hurricanes can disrupt operations or even cause structural damage. This makes climate adaptation a critical part of modern airport planning and management. Simply put, if airports don't adapt, they risk becoming unsafe or inoperable in the future.

One major strategy is infrastructure elevation. Coastal airports may build higher runways or terminals to protect against storm surges and sea-level rise. Some facilities are also using storm-resistant materials and building wind-resistant structures to withstand extreme weather. Runway designs may incorporate better drainage to handle heavier rainfall, reducing delays and damage from water pooling.

In addition to physical changes, airports are also investing in climate forecasting and emergency planning. Advanced climate data helps them prepare for long-term shifts in temperature, rainfall, and storm patterns. Emergency plans include backup power, rapid evacuation routes, and secure areas for stranded passengers. Training programs and drills ensure that airport staff can respond quickly and effectively in a crisis.

These resilience measures ensure continuity of service and protect both travelers and infrastructure. As climate impacts grow more unpredictable, airports that plan ahead will remain operational and competitive while also protecting the safety and welfare of their communities.

F. Biodiversity and Land Impact Mitigation

Airport development can have a major impact on local ecosystems. Large-scale construction often disrupts forests, wetlands, and farmland. Wildlife habitats may be destroyed or fragmented, and animal populations can be displaced. This leads to loss of biodiversity, changes in land use, and potential conflict between human activity and natural systems.

To reduce harm, responsible airport planning includes environmental impact assessments (EIA) before construction begins. These studies identify endangered species, fragile ecosystems, and water resources that could be affected. Based on the findings, developers create mitigation strategies such as conservation areas, tree replanting, and protected buffer zones. Some airports even modify construction plans to avoid sensitive habitats entirely.

Airports also face challenges with wildlife strikes when birds or animals collide with aircraft. To address this, wildlife management teams monitor animal activity near the airport and use humane deterrents like noise devices, fencing, or habitat modifications to reduce risks without harming animals. In some cases, vegetation is managed to discourage birds from nesting near runways.

Finally, some airports take a proactive role in protecting biodiversity. They may restore nearby wetlands, support reforestation, or create educational zones for conservation. These initiatives show that airports can coexist with nature when proper planning and stewardship are in place. It transforms the airport from a threat to the environment into a partner in sustainable development.

VI. CHALLENGES AND ISSUES

A. Land Acquisition and Community Displacement

Building or expanding airports often requires acquiring large areas of land, which can lead to forced relocations of homes, farms, or even entire communities.

This creates social tension, particularly when local residents are not properly informed or compensated. Land acquisition without transparent processes can result in legal challenges, protests, and delays in project timelines.

Displacement causes not only the loss of physical homes but also of social networks, livelihoods, and cultural heritage. Indigenous populations and low-income families are often disproportionately affected, further deepening social inequality. When people are relocated without access to housing, jobs, or public services, it leads to long-term hardship.

To prevent these issues, governments and developers must implement inclusive consultation processes, where affected communities are involved in decision-making. Fair compensation, relocation packages, and social support services like job training or livelihood programs should be standard. International organizations such as the World Bank have guidelines to ensure displacement is handled ethically and humanely.

Ultimately, land acquisition is a sensitive challenge that requires balancing infrastructure needs with human rights. When done transparently and responsibly, it is possible to expand airports without sacrificing community well-being.

B. Security Threats and Cybersecurity

Security threats in airports are no longer limited to physical dangers like terrorism or smuggling. Today, cybersecurity has become just as important. As airports adopt more digital systems such as automated check-ins, biometric scanners, and smart baggage tracking they become vulnerable to cyberattacks that can disrupt operations or steal sensitive data.

Airports have been targeted by hackers aiming to access passenger information, disrupt flight schedules, or demand ransom by locking down systems. A successful cyberattack can cause flight cancellations, delays, loss of trust, and even safety risks if systems like air traffic control or runway lighting are affected. This makes cybersecurity a core part of airport safety today.

In response, airports are investing in multi-layered security systems, including firewalls, intrusion detection tools, and encrypted networks. Staff are trained to detect phishing scams, and IT departments conduct regular system audits. Collaboration with government agencies, airlines, and cybersecurity firms helps keep threats at bay.

C. Operational Delays and Capacity Constraints

As global air travel increases, many airports struggle with overcrowding and limited capacity. Terminals may become congested, runways overused, and baggage systems overwhelmed. These issues lead to flight delays, passenger frustration, and logistical headaches for airlines and staff alike. Older airports, in particular, were not designed to handle today's traffic levels.

Capacity constraints affect nearly every part of the airport—from long security lines and check-in queues to gate availability and taxiing delays. This reduces

efficiency and makes the airport experience more stressful. In extreme cases, flights may be rerouted to nearby airports or canceled entirely because there's simply no room to handle them.

To combat these problems, airports are expanding terminals, building additional runways, and introducing technological upgrades like automated check-in kiosks and dynamic gate assignments. However, these projects are expensive and take years to complete. In the meantime, smart scheduling and real-time monitoring tools are used to manage crowd flow and reduce bottlenecks.

Operational delays and capacity problems don't just affect passengers—they have financial consequences too. Delayed flights cost airlines money and damage the airport's reputation. As demand continues to grow, investing in infrastructure and modern systems is essential for keeping airports efficient and competitive.

D. Privatization, Governance, and Ownership Conflicts

Many airports worldwide have undergone privatization, where private companies either partially or fully manage the airport operations. This can bring benefits like improved services, faster infrastructure development, and increased efficiency due to private sector investment and management expertise. However, privatization also raises important concerns about accountability, equity, and the public interest.

Conflicts often emerge between profit-driven private operators and government goals. For instance, a private operator may prioritize revenue-generating areas like retail space or parking, while governments may emphasize accessibility, safety, or regional development. Tensions can also arise when it comes to fare increases, contract transparency, or how the benefits of the airport are shared among stakeholders.

Ownership disputes can also complicate airport development. In some countries, national and local governments, airlines, and even foreign investors may all hold a stake in the same airport, leading to conflicting priorities and delays in decision-making. Governance frameworks must clearly define roles, responsibilities, and conflict resolution mechanisms to avoid inefficiencies and political interference.

While privatization can be a tool for modernization, it must be balanced with public oversight and accountability. Strong regulatory bodies, transparent bidding processes, and clearly defined public-private partnerships (PPPs) are key to ensuring that privatized airports still serve the broader needs of society.

E. Environmental and Health Concerns

Airports contribute to various environmental issues, including air pollution, noise pollution, water contamination, and greenhouse gas emissions. Aircraft engines emit nitrogen oxides, particulate matter, and carbon dioxide, which degrade air quality and contribute to climate change. In highly urbanized areas, the proximity of airports to neighborhoods increases residents' exposure to these pollutants.

One major concern is noise pollution, particularly from takeoffs and landings. Constant exposure to loud aircraft noise has been linked to sleep disturbance, hearing loss, and even cardiovascular problems among nearby residents. Noise also impacts wildlife, disrupting animal behavior and breeding patterns in surrounding habitats. Communities often push back against airport expansion due to these health and environmental risks.

Airports also generate substantial waste and wastewater, which, if not properly treated, can pollute nearby rivers, lakes, or groundwater sources. Spills of fuel, de-icing chemicals, or cleaning agents are hazardous, requiring strict environmental controls. Furthermore, climate change-related risks, such as heatwaves and floods, pose health threats to travelers and workers, particularly those with preexisting conditions or working long hours in outdoor environments.

F. Regulatory and Bureaucratic Hurdles

Airports operate under complex layers of local, national, and international regulations, often involving multiple government agencies, industry bodies, and legal frameworks. This can lead to bureaucratic red tape that slows down construction, complicates operations, and discourages innovation. Every decision—whether it's expanding a runway, adding a new airline route, or adopting a new technology—requires navigating these regulatory systems.

One common issue is the lengthy permitting process for airport development. Environmental permits, land use clearances, and aviation safety certifications can take years to secure, particularly in countries with overlapping or outdated laws. Delays not only increase costs but can lead to missed economic opportunities and strained relationships between stakeholders.

International compliance adds another layer of complexity. Airports must align with standards set by the International Civil Aviation Organization (ICAO), including those related to runway safety, security screening, and environmental reporting. Failing to comply can result in sanctions or reduced airline traffic. In addition, global disruptions—such as the COVID-19 pandemic—can trigger new regulatory requirements with little preparation time, putting added pressure on airport authorities.

To improve efficiency, many airports and governments are adopting digital governance systems and regulatory streamlining. Centralized application portals, clear timelines, and inter-agency coordination help reduce confusion and speed up approvals. However, success depends on strong leadership, transparency, and a commitment to cutting unnecessary red tape while still maintaining safety and oversight.

VII. FUTURE TRENDS AND INNOVATIONS

A. Smart Airport Technologies (IoT, AI, Automation)

Modern airports are increasingly adopting smart technologies to improve efficiency, safety, and the overall passenger experience. These include the Internet of Things (IoT) for real-time monitoring, artificial intelligence (AI) for predictive

analytics, and automation to streamline operations. For example, IoT sensors can track passenger movements to manage crowd flow, while AI can predict maintenance needs before equipment fails.

Automation plays a major role in speeding up services like check-in, security screening, and boarding. Self-service kiosks, automated baggage drops, and robotic cleaning systems reduce the need for human staff and help process more passengers quickly. Smart lighting and HVAC systems also respond to real-time usage, saving energy and improving comfort. AI-powered surveillance systems enhance security by detecting unusual behavior in real-time.

These technologies not only improve operational efficiency but also help airports adapt to future challenges. As passenger volumes increase, smart systems can scale easily without expanding physical space. In the long term, fully integrated digital ecosystems will allow airports to operate like intelligent hubs where every component communicates with each other to ensure smooth and seamless operations.

B. Post-Pandemic Design and Health Protocols

The COVID-19 pandemic fundamentally changed how airports are designed and operated. There is now a greater emphasis on health, hygiene, and disease prevention in both architecture and daily procedures. Airports around the world have incorporated contactless technologies such as biometric scanners and touch-free payment systems to reduce physical contact and transmission risks.

Terminal layouts have been redesigned to allow for social distancing, with wider walkways, spaced seating, and one-way passenger flows. Enhanced cleaning protocols have become permanent, with increased use of UV sanitizers, antimicrobial surfaces, and high-efficiency air filtration systems. Thermal scanners and health declaration systems are also part of many entry procedures.

These changes not only address current health concerns but prepare airports for future pandemics. Designing terminals that are flexible and adaptable allows airport authorities to quickly respond to new health crises without halting operations. Health and safety have become central to passenger trust, and post-pandemic design plays a key role in restoring confidence in air travel.

C. Urban Air Mobility and Integration of Vertiports

Urban Air Mobility (UAM) is an innovative concept that introduces short-distance air travel within cities using electric vertical takeoff and landing aircraft, commonly known as eVTOLs. These aircraft are designed to transport people or cargo across urban areas much faster than traditional ground vehicles. The goal is to alleviate traffic congestion, reduce travel times, and introduce a new layer of urban transport that complements existing road and rail systems.

For UAM to work, cities and airports must develop specialized infrastructure known as vertiports. These are compact hubs where eVTOLs can take off, land, recharge, and pick up or drop off passengers. Vertiports can be integrated into rooftops of buildings, near train stations, or within existing airport facilities to allow

smooth intermodal connections. This infrastructure must be carefully planned to ensure safety, accessibility, and minimal disruption to existing urban operations.

Airports are expected to play a central role in integrating UAM into broader transportation networks. By connecting traditional long-haul flights with local air mobility services, passengers can enjoy end-to-end air travel without relying on congested roads. This concept could dramatically reduce travel times from the airport to the city center or business districts, especially in sprawling urban environments where ground transportation is slow and inefficient.

However, implementing UAM is not without challenges. Governments and aviation authorities must update air traffic regulations to manage low-altitude airspace shared by multiple small aircraft. Noise concerns, visual pollution, and safety risks must also be addressed. Despite these hurdles, continued advancements in electric propulsion and automation are making UAM increasingly viable, and cities that begin planning today will be ahead when this technology becomes mainstream.

D. Sustainable Aviation Fuel (SAF) and Green Runways

Aviation Fuel (SAF) is a game-changing alternative to conventional jet fuel. It is produced from renewable resources such as used cooking oil, plant materials, and agricultural waste, making it much cleaner for the environment. SAF can reduce lifecycle carbon emissions by up to 80% compared to fossil-based jet fuel, depending on the source materials and production methods used. This makes SAF one of the most promising solutions for reducing aviation's environmental footprint.

Airports are increasingly supporting SAF adoption by developing infrastructure and offering incentives to airlines. Some major international airports have created dedicated fueling systems and partnered with SAF producers to ensure a reliable supply. Airlines using SAF can significantly lower their carbon emissions without needing to invest in new aircraft. Despite its current high cost, SAF is expected to become more affordable as production scales up and more countries implement environmental regulations or carbon taxes.

In parallel with fuel innovation, airports are also redesigning their runways and taxiways to align with sustainability goals. Green runways may involve the use of recycled construction materials, better stormwater drainage systems, and energy-efficient lighting such as LED runway lights powered by solar panels. These infrastructure upgrades reduce the airport's overall energy use and environmental impact while maintaining safety and performance standards.

The integration of SAF and green infrastructure reflects a larger shift toward environmentally responsible aviation. It demonstrates how airports can take direct action to meet climate targets, especially as pressure mounts from governments, international bodies, and the flying public. By leading in this space, airports not only protect the environment but also future-proof their operations and improve their public image.

E. Digital Twin and Predictive Maintenance

One of the most innovative trends in airport management is the use of digital twin technology, where a virtual model of the entire airport infrastructure is created in real time. This allows operators to simulate scenarios, monitor conditions, and optimize performance. For example, a digital twin can model how a terminal reacts to sudden spikes in passenger volume or how different security layouts affect wait times.

Digital twins are particularly useful for predictive maintenance, which helps airports fix problems before they cause delays. Sensors installed on critical systems like baggage conveyors, elevators, or air conditioning units collect real-time data on usage, wear and tear, and performance. AI algorithms then analyze this data to predict when a system might fail and recommend proactive repairs.

This proactive approach reduces downtime, lowers maintenance costs, and improves reliability for passengers and airlines. It also enhances safety, as equipment is maintained before it reaches critical failure. As digital twin technologies evolve, they will become essential tools not just for maintenance but also for planning expansions, simulating emergencies, and supporting long-term sustainability goals.

F. Passenger Experience Personalization and Biometric Systems

In today's competitive travel industry, airports are enhancing passenger experience through personalization. By analyzing data from passenger profiles, travel history, and real-time behavior, airports can offer targeted services that improve comfort and convenience. Personalized alerts for gate changes, luggage updates, restaurant offers, or transport connections can now be sent directly to passengers' smartphones, improving satisfaction and reducing confusion in large terminals.

Biometric systems are also revolutionizing the way passengers move through airports. Facial recognition, iris scanning, and fingerprint identification are being used at check-in counters, security gates, immigration, and boarding areas. These systems speed up processes by removing the need for repeated ID checks and physical boarding passes. Travelers can simply walk through checkpoints with facial scans that link directly to their passport and ticket data, reducing wait times and human error.

Airports that implement these technologies benefit from faster passenger processing, increased security, and better crowd management. For passengers, the journey becomes smoother and less stressful, with fewer lines and more time to relax or explore airport amenities. Biometric boarding is already being used successfully in several major airports and is expected to become a global standard in the coming years.

Despite these benefits, privacy and data protection remain important considerations. Passengers must be assured that their personal data is securely stored and used only for legitimate purposes. Transparent policies and consent-based data collection are crucial to building trust. When implemented

responsibly, biometric and personalization technologies can transform air travel into a highly efficient, secure, and user-friendly experience.

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