IMPACT OF AIRPORT STRUCTURE & TECHNOLOGY IN THE GROWTH OF AVIATION INDUSTRY: ANALYTICAL STUDY

Thesis Submitted to

CMJ UNIVERSITY

In Partial Fulfilment for The Award of The Degree Of

DOCTOR OF PHILOSOPHY

IN

AVIATION MANAGEMENT

By

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Under the Research Supervision of

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DECLARATION

I hereby declare that the thesis entitled **"IMPACT OF AIRPORT STRUCTURE & TECHNOLOGY IN THE GROWTH OF AVIATION INDUSTRY: ANALYTICAL STUDY"** is a bonafide and original research carried out by me under the guidance of **Dr. Sumeet Suseelan,** Research Supervisor, Dept. of. Management**,** CMJ University, Jorabat, Meghalaya. The thesis or any part thereof has not formed the basis for the award of any degree/fellowship or similar title to any candidate of any other University.

Place: Jorabat (Meghalaya) **(SHAMASHAD BEGUM)**

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CERTIFICATE

This is to certify that the thesis entitled, **"IMPACT OF AIRPORT STRUCTURE & TECHNOLOGY IN THE GROWTH OF AVIATION INDUSTRY: ANALYTICAL STUDY"** submitted by **SHAMASHAD BEGUM**, is an original piece of research work carried out under my supervision. This work is being submitted for the award of Degree of **Doctor of Philosophy in Aviation Management**, Department of Management, **CMJ University, Jorabat, Meghalaya.**

It is further certified that this work has not been submitted anywhere else for the degree. The candidate has worked with me for the requisite number of days during the period of this research work.

Place: Jorabat (Meghalaya) **(Dr. Sumeet Suseelan)**

Date:

ACKNOWLEDGEMENT

'*Knowledge is power*' goes the old German adage. But *'Wisdom denotes the pursuing of the best ends by the best means'*

Nothing can be achieved in society in isolation and without proper and valuable guidance of skilful persons of the concerned field. *The secret of success in life, is for a man to be ready for his opportunity when it comes*. I am lucky enough to get an opportunity to work under the most valuable guidance. I express my deep sense of gratitude and special thanks to ***Dr. Sumeet Suseelan*** for his inspiring guidance and great timely encouragement during the process of this Thesis completion. He has not only given the golden opportunity of taking up this Thesis but also supported in every phase of the completion of my thesis on – ***"Impact of Airport Structure & Technology in the growth of Aviation Industry: Analytical Study".*** He guided me in a very subtle way throughout the study of this research.

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Place: Jorabat, Meghalaya

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ABBREVIATIONS

AAI	:	Airports Authority of India
AAM	:	Advanced Air Mobility
AAS	:	Advanced Autonomous Systems
ACI	:	Airport Carbon Accreditation
ACI-E	:	Airport Council International Europe
ADS-B	:	Automatic Surveillance-Broadcast
AI	:	Artificial Intelligence
AIRR Act	:	Aviation Innovation, Reform and Reauthorization Act
ANP	:	Aircraft Noise Performance
AOP	:	Airport Operations Plan
AR	:	Augmented Reality
ATC	:	Air Traffic Control
ATL	:	Atlanta Airport
ATM	:	Air Traffic Management
BAA	:	British Airports Authority
BOT	:	Build-Operate-Transfer
CAA	:	Civil Aviation Authority
CAGR	:	Compound Annual Growth Rate
CAN	:	Guangzhou Baiyun Airport
CCTV	:	Closed-Circuit Television
CDG	:	Charles de Gaulle Terminal
CDG	:	Paris Charles de Gaulle Airport
CDM	:	Collaborative Decision Making
CEM	:	Collaborative Environmental Management
CLT	:	Charlotte Douglas Airport
CO2	:	Carbon Dioxide
DBO	:	Design-Build-Operate
DEN	:	Denver Airport
DFW	:	Dallas Fort Worth Terminal
DGCA	:	Directorate General of Civil Aviation
DOH	:	Hamad International Airport
DXB	:	Dubai International Airport
EASA	:	European Aviation Safety Agency
EU	:	European Union
EV	:	Electrical Vehicle
eVTOL	:	Electric Vertical Take-Off & Landing
FAA	:	Federal Aviation Administration
FAAM	:	Airborne Atmospheric Measurements
FDI	:	Foreign Direct Investment
GDP	:	Gross Domestic Product
GPS	:	Global Positioning System
GSE	:	Ground Support Equipment
HD	:	High Definition
HND	:	Tokyo International Airport
IATA	:	International Air Transport Association
ICAO	:	International Civil Aviation Organization
ICN	:	Incheon International Airport
IGBC	:	Indian Green Building Council
IGS	:	Increased Glide Slope
ILS	:	Instrument Landing Systems
IOSA	:	IATA Operational Safety Audit

IoT	:	Internet of Things
IST	:	Istanbul Airport
LAX	:	Los Angeles Airport
LCCs	:	Low Cost Carriers
LCY	:	London City Terminal
LHR	:	Heathrow Airport
LiDAR	:	Light Detection and Ranging
MAD	:	Madrid Barajas Airport
MCI	:	Kansas City Terminal
MCO	:	Orlando Airport
ML	:	Machine Learning
MoCA	:	Ministry of Civil Aviation
mppa	:	Million passengers per annum
MRO	:	Maintenance, Repair & Overhaul
MUC	:	Munich Airport
NAAs	:	National Aviation Authorities
NCAP	:	National Civil Aviation Policy
NERC	:	Natural Environment Research Council
NOx	:	Nitrogen Oxides
NRT	:	Tokyo Narita International Airport
PHL	:	Philadelphia Airport
PHX	:	Phoenix Sky Harbor Airport
PIT	:	Pittsburgh Airport
PKX	:	Beijing Airport
PPPs	:	Public Private Partnerships
RCS	:	Regional Connectivity Scheme
RFID	:	Radio Frequency Identification
SAF	:	Sustainable Aviation Fuel
SIN	:	Changi Airport, Singapore
SJC	:	San José Mineta Terminal
SNA	:	John Wayne Terminal
TAWS	:	Terrain Awareness and Warning Systems
UAM	:	Urban Air Mobility
UAV	:	Unmanned Aerial Vehicles
UDAN	:	Ude Desh ka Aam Nagrik
UHF	:	Ultra-high frequency
USGBC	:	United States Green Building Council
VAT	:	Value Added Tax
VHF	:	Very High frequency
VR	:	Virtual Reality
ZRH	:	Zurich Airport

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ABSTRACT

Airports play a vital role in the growth of the aviation industry by serving as gateways to air travel, facilitating connectivity, supporting economic development, catalyzing tourism, enabling trade and commerce, driving innovation, and responding to market demand. As key components of the global transportation infrastructure, airports are essential drivers of economic prosperity, mobility, and connectivity in the modern world.

Airport operations are greatly influenced and made more efficient by infrastructure and technology. Improvements in airport technology have greatly influenced the safety, efficiency, and overall experience of air travel for passengers.

To improve airport operations and the travel experience for passengers, "smart airport" ideas use technology such as data analytics, artificial intelligence (AI), and the Internet of Things (IoT). Improved efficiency and happiness are the results of smart technologies that allow for proactive resource management, predictive modelling of passenger flows, and individualised services.

Environmental sustainability is also greatly aided by airport infrastructure and technology. Renewable energy sources, waste management systems, and energy-efficient structures all work together to lessen human influence on the environment without sacrificing productivity or affordability.

There are 2 types of Infrastructure. (i) Airport facilities and (ii) Infrastructure located on land.

Different organizations own Airports in different countries. Airports are regulated by the government, regardless of whether they are privately owned or operated. The International Civil Aviation Organisation (ICAO) establishes standards for various aspects of airport operations and infrastructure.

In order to maximise revenue generation, improve passenger experience, and guarantee efficient operations, it is vital to optimise the use of space and resources in terminal architecture and planning.

There are a number of businesses that focus on supplying ATM and ATC systems for the aviation industry. These businesses are leading the way in improving aviation safety, efficiency, and sustainability through creating cutting-edge solutions and technology for air traffic control and management.

Innovations are being created to better every aspect of air travel, and the aviation sector is undergoing a technological revolution. New, state-of-the-art technology is taking off and revolutionising the market. Every part of flying is being fine-tuned to make it safer, more efficient, and more enjoyable for passengers. This includes the runway as well as the cockpit.

The future of the aviation sector is being shaped by developing technologies, which has never been more dynamic.

Some benefits of a smart airport include:

- Utilisation of real-time data led to enhanced operational efficiency.
- The optimisation of processes, raising productivity, and decreasing operational expenses.
- Better demand optimisation as a result of automated entrance procedures and tighter regulation of passenger flows.
- A vastly enhanced traveller experience as a result of enhanced passenger services, flight control, check-in, and so on.
- The use of biometric monitoring systems to increase safety and security, stronger cyber defences, and more dependable facility operations and maintenance.
- Enhanced health monitoring and on-site services (cleaning schedules, amenity availability, etc..,)

An outstanding travel experience for passengers is easily achieved through simplified check-in, efficient luggage processing, and faultless navigation. Optimal and quick check-in at self-service kiosks, tracking and matching of bags through baggage reconciliation, and monitoring of passenger movements and resource allocation through passenger flow management systems are all examples of the state-of-the-art technological solutions that progressive airports invest in.

IMPACT OF AIRPORT STRUCTURE & TECHNOLOGY IN THE GROWTH OF AVIATION INDUSTRY: ANALYTICAL STUDY

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The aviation sector must take environmental factors into account in order to reduce the negative effects of air travel on the environment, safeguard ecosystems and public health, adhere to legal requirements, and maintain corporate responsibility. For the aviation industry to remain viable and gain social approval in the long run, it is imperative that sustainable practices and technology are used.

While flying aircraft account for the majority of aviation's CO2 emissions, ground activities at airports can nevertheless strive towards greater sustainability.

Aviation has expanded faster than rail, road, or shipping in recent decades, and in 2022 it accounted for 2% of global energy-related CO2 emissions. Aviation emissions in 2022 reached about 800 Mt CO2, or 80% of the pre-epidemic level, as demand for international travel picks back up after the Covid-19 pandemic.

The aviation sector functions within a multifaceted regulatory and policy environment encompassing global, regional, and national domains. To guarantee the efficiency, sustainability, safety, and security of air travel, a number of international organisations, governmental authorities, and regulatory bodies have built these frameworks.

Flying is now safer and more effective than ever thanks to new technological developments and industry innovation, which is continuously taking place in the aviation sector. But as the aviation sector innovates, there are dangers and difficulties that must be resolved to make sure that security and safety are not jeopardised. Regulations have been implemented to deal with these hazards and difficulties.

In the last three years, India's civil aviation sector has grown at one of the fastest rates in the nation. It can be broadly divided into three categories: scheduled air transport, which includes mail and cargo flown by air, non-scheduled air transport, which includes charter operators and air taxis, and domestic and international airlines.

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CHAPTER - 1

INTRODUCTION

"Aviation is proof that given the will,
we have the capacity to achieve the impossible"

- *Edward Vernon Richenbacher*

Structure and technology are crucial to the development and expansion of the aviation industry. Examining the significance of both is presented here:

1.1 INTRODUCTION

1.1.1 THE STRUCTURE OF THE AIRPORT

- **Runways and Airports:** The efficient running of aviation operations depends on sufficient airport infrastructure, including well-planned runways and terminals. Congestion and delays are inevitable results of poorly maintained airports, which prevent airlines from operating aircraft efficiently.
- **The ATM System for Managing Air Traffic**: Aircraft safety and orderliness in flight are guaranteed by well-designed air traffic management systems. Communication networks, radar systems, and air traffic control towers are all part of this. Optimising airspace utilisation and reducing accident risk are two goals of an organised ATM framework.
- **Legal Structure:** Adherence to security protocols, safety requirements, and environmental laws is guaranteed by a strong regulatory structure. The FAA in the US and the EASA in Europe are regulatory agencies that keep an eye on the aviation industry and make sure everything is running smoothly and safely.

1.1.2 SCIENCE AND TECHNOLOGY

- **The Design and Manufacturing of Aircraft:** Aircraft designs that are less harmful to the environment and use less fuel have emerged as a result of technological advancements. Reduced operating costs and emissions are two outcomes of modern aircraft's incorporation of lightweight materials, aerodynamic advances, and efficient engines.

- **Navigational Aids:** Inertial navigation systems (INS) and the Global Positioning System (GPS) allow for very accurate monitoring and navigation of aircraft, which increases safety and decreases the need for ground-based navigation aids.
- **Methods of Communication:** Modern communication technologies, like data links and satellite-based communication, improve situational awareness for air traffic controllers and pilots by allowing for real-time information transmission between aircraft and between aircraft and the ground.
- **Security Measures:** By giving pilots up-to-the-minute information and warnings to avoid possible dangers, technological advancements like automated weather monitoring, collision avoidance systems, and terrain awareness and warning systems (TAWS) increase safety.
- **Maintenance and Operations:** Technology reigns supreme in the realm of aircraft repair and operation. Predictive maintenance systems monitor the health of planes through data analytics and sensor technology to spot potential issues before they escalate, hence minimising unplanned downtime and increasing reliability.

The expansion of the aviation sector is, in a nutshell, dependent on the introduction of state-of-the-art technology and the upkeep of existing infrastructure. Aviation safety, efficiency, creativity, and economic growth are all positively impacted by a well-organized system that is backed by cutting-edge technology.

1.2 THE STUDY'S SIGNIFICANCE

a) Airports' significance to the aviation sector is examined in the report;
b) The report emphasises the significance of airport infrastructure and its consistent expansion;
c) The research describes in depth the evolution of airport technology;
d) The study assesses the role of airport architecture and technology in the expansion of the aviation sector, complementing previous reports and case studies in this regard;
e) The study Emphases the significance of Passenger Satisfaction; and
f) An insightful picture of the aviation industry's current and future state is presented in the report.

1.3 OBJECTIVE OF THE STUDY

- To assess and acknowledge the role that airport architecture and technology play in the expansion of the aviation sector; and
- To draw attention to the influence and periodic alteration of the same.

1.4 METHODOLOGY APPLIED

The approach used in this study is a combination of doctrinal and non-doctrinal research, with a focus on the former. This research comprises:

a) Examining or consulting pertinent books, articles, magazines, and journals;
b) Visiting museums and airports;
c) Browsing articles and case studies on internet; and
d) Spoke with prominent figures in the field.

1.5 STUDY DESIGN AND PRESENTATION

Eleven Separate Chapters Make Up the Thesis

- **The First Chapter:** Provides an overview, outlining the rationale and purpose of the research into the architecture and engineering of airports in the aviation industry.
- **The Second Chapter**: We learn about the significance of airports to the aviation industry and how infrastructure and technology influence airport operations and efficiency.
- **The Third Chapter:** Provides a historical overview of the airport, looking at how it has changed over time and how technology and infrastructure have impacted airport operations and efficiency. It also highlights important inventions and milestones in the development of airports.
- **The Fourth Chapter:** Talks about the layout and construction of the airport's terminals and runways, the significance of passenger movement, the air traffic control system, safety improvements, and other related topics are covered.
- T**he Fifth Chapter**: About Technological Innovations, we can observe Digital Transformation, Smart Airport Technologies, Automated Baggage Handling Systems, and Advanced Security Systems.

- **The Six Chapter**: Which focuses on the Passenger Experience and Satisfaction, discusses how the design and technology of the airport made the journey easier and more convenient for passengers.
- **The Seven Chapter:** Emphasises the need to think about environmental factors when planning and executing technological projects, such as strategies for reducing noise and integrating renewable energy sources, as well as attempts to reduce carbon footprints, manage emissions, and so on.
- **The Eighth Chapter:** Importance of compliance with the Aviation Sector's Regulatory and Policy Framework, which encompasses international standards, government policies, public-private partnerships, and the function of financing and overseeing airports, is emphasised.
- **The Ninth Chapter:** Outlines the finest methods for a successful travel, with an emphasis on the lessons learned on the application of technology. Additionally, it outlines the aviation industry's future in 2030.
- **The Tenth Chapter:** Delves into the Indian aviation industry, covering important details, market strategies, challenges, and government activities. Indian Airlines and Airports Ranked First by Customers.
- **The Eleventh Chapter:** Provides a summary of key points, as well as final thoughts and recommendations.

1.6 THE STUDY'S LIMITATIONS

Due to time constraint, this study limits to read and cite pertinent books, articles, magazines, and journals.

I also checked a couple of websites for the latest news because the aviation industry is going through a period of unprecedented expansion and transformation.

The chance to speak with a few of industry heavyweights allowed me to expand my knowledge base.

CHAPTER - 2

INTRODUCTION TO AVIATION INDUSTRY

"Aviation is poetry. It's the finest kind of moving around, you know, just as poetry is the finest way of using words"

- *Jessie Redmon Fauset*

The term "Aviation Industry" is used to describe a wide range of businesses that help make air travel possible. In other words, it encompasses the whole aviation sector, from airlines to manufacturers of aircraft to research institutions to the military aviation sector and beyond.

When people talk about "Aviation," they usually mean mechanical air transportation that takes place on an aeroplane. Although aeroplanes and helicopters are the most common forms of aircraft, the term "Aviation" now often encompasses both human and unmanned aircraft, including drones.

In this light, it is possible to define the aviation industry as the whole set of businesses that support these endeavours.

2.1 THE AVIATION AND AIRLINE INDUSTRIES: HOW THEY DIFFER?

Despite common belief to the contrary, the phrases "Aviation Industry" and "Airline Industry" really refer to distinct sectors of the economy. The airline industry is the umbrella word for all the businesses that provide air transportation services, whether it's for people or cargo.

Nonetheless, there is more importance to the aviation industry than just the airline sector. Aside from airlines, the Aviation Industry encompasses a wide range of entities, such as aircraft manufacturers, researchers, air safety professionals, airports, and organisations that create, manufacture, or utilise drones.

2.2 IS THE AVIATION INDUSTRY NECESSARY? [1]

As a whole, the contemporary aviation industry is crucial. Still, the industry's globalization—which helps to connect different continents, regions, and cultures—is one of the key reasons for its relevance. Therefore, global aviation has played a crucial role in enabling efficient travel to faraway regions, bettering the lives of countless people.

Tourism is a boon to local economies and the aviation industry has helped increase international trade, both of which contribute to global economic development.

Aviation also directly employs millions of people worldwide; this includes not just pilots and flight attendants but also air traffic controllers, aerospace engineers, and cabin personnel. To top it all off, the aviation business has been a major employment creator for the travel and tourism sector as a whole.

2.3 CONCEPT OF AIRPORTS AND AIRLINES

The success of both airports and airlines depends on the other. Airports and airlines both work for the benefit of their customers, the passengers. Nevertheless, they continue to function as independent entities, subject to the treaties and laws that regulate airspace and require equitable business conditions, and, occasionally, working towards distinct objectives.

Airports and airlines work together through partnerships, and anybody who has ever tried to board a flight understands how crucial it is for our carrier to be present at the airport. Customers flock to the airport for airline partnerships, which in turn patronise the airport's businesses and shops as they wait for their flights to take off. Airports play an essential role in the aviation industry because they offer the infrastructure—including a runway, handling areas, and cargo facilities—that airlines need to operate.

Airports are becoming more important as a means of connecting different parts of the world due to the rise of international travel. International expansion typically finds airlines with far weaker, if any, sales and promotion networks than their domestic counterparts. Airports that serve as destinations for international flights can increase

[1] https://www.revfine.com/aviation-industry/

demand for those flights, which is good for the airlines because a local connection makes them seem more credible and ensures that they will keep flying to that airport.

Deregulation, also known as airline liberalisation, was a policy movement in the 1970s that allowed airlines more autonomy in their dealings with airports, moving the relationship away from being governed by the government. Now that customers have more options, airlines may bargain for a better price when they introduce a new service. Once upon a time, airports received a guaranteed fee from airlines. However, with deregulation, that revenue began to come straight from passengers.

2.4 BUSINESS RELATIONSHIP BETWEEN AIRPORTS AND AIRLINES [2]

There are essentially three distinct kinds of partnerships that can develop between airports and airlines:

- Contracts: Compromises are common in these negotiated agreements.
- Remedies Based on Resolve: Consultation is key to the establishment of these, which may include ordinances, regulations, and permissions.
- Mixed: Airports may have revenue sharing in conjunction with rate resolution in some instances.

Country to country, relationships will also differ. An American airport, for instance, serves more as a landlord and service coordinator than an airport in France or the UK, where a mix of public and private entities owns the airport and the airline is seen more as a client. Government regulation, such as rules pertaining to passenger service charges, landing fees, and development, can influence the relationship between airports and airlines, as can the question of whether the airports are publicly or privately owned.

The writers of the article "The Stakeholder Theory Perspective" point out that all parties involved in a relationship have their own unique aims.

[2] https://www.floridatechonline.com/blog/aviation-management/how-airlines-and-airports-work-together/

- **What Do Airlines Desire?**

a) Enhanced profits due to streamlined operations
b) Short processing periods
c) Almost no airport fees
d) Expanded runway space
e) Flexible timetables
f) Reliable travel service
g) Above and beyond for clients
h) Shops and restaurants that people love

- **What Do Airports Desire?**

a) Environmentally friendly business practices
b) Growth
c) That takes into account the requirements of every single carrier
d) Capacity to entice travellers as a worldwide transportation hub
e) A variety of airline partnerships

A. Methods for Airports and Airlines to Cooperate More Efficiently

By remembering these best practices, airports can make it easier to balance their interests with the (often conflicting) interests of other airlines:

1. **Stakeholders Reap the Benefits**: Is there a specific list of those involved? Participants in the connection include the airport and airline, as well as other parties such as passengers, investors, service providers, federal and state governments, suppliers, and general aviation.
2. **Enhance Consumer Spending Through the Utilisation of Unified Sales Platforms:** Buyers on flights may be stymied by the passage of time. Travellers may have to dash past stores in the airport in order to catch their flights, and when in flight, they may be left to their own devices without the ability to buy anything. Strategy & advises of a consulting firm, suggests that airports and airlines work together to make sure that passengers may access their services whenever they want. Some possible integrations include letting customers pick up in-flight purchases at their gate, transferring purchases between planes, or even letting customers buy things ahead of time and pick them up at their gate.

3. **Drive Sales with Collaborative Loyalty Programmes:** Airports are not as likely to have loyalty programmes as airlines. According to Strategy & advises, airports and airlines might pool their resources to offer more comprehensive rewards programmes, such as free parking, retail discounts, or frequent flyer miles. This would not only increase sales, but it would also help reduce expenses.
4. **Enhance the Satisfaction of Customers:** In a keynote speech, IATA CEO Tony Tyler stated that this practice is a primary objective for the organisation. Streamlining the process from arrival to departure, enhancing luggage delivery, implementing self-service kiosks, and e-ticketing are all ways to make the experience better. Furthermore, Tyler brought attention to a crucial strategy for enhancing the customer experience: pushing e-freight as a means to save expenses.
5. **Streamline Hub Operations, Real Estate Development, And Infrastructure:** Involving airline stakeholders in airport development projects guarantees that these projects will benefit airlines, since airport development can affect airlines. The goal of development and infrastructure is to enhance operations so that they are more effective, efficient, and flexible.
6. **Collaborate On Safety Measures:** Everyone involved should make this their number one priority. To improve runway safety and provide a worldwide standard for ground operations, airports and airlines can work together.
7. **Collaborate On Security Measures:** Long security lines are practically a given when taking a flight, but as Tyler pointed out, customers might be using that time to shop instead. He fiercely advocated for a more efficient and safer procedure that does not necessitate the current level of undressing and unpacking.
8. **Collaborate For a Sustainable Future:** Majority objectives have already been set by the aviation sector, such as halving the 2005 net emissions rates by 2050 and increasing fuel economy by 1.5% yearly. There are many other types of organisations that can think outside the box. Airports that employ land to develop sustainable biofuel source crops include Madrid-Barajas, Detroit, and Stockholm-Arlanda, according to Tyler.

9. **Work Collaboratively to Achieve Cost Efficiency:** Airline and airport profit margins are getting thinner and thinner, which might lead to friction. In response to this tension, Tyler proposed a new method for businesses to grow: by working jointly on capital expenditure development, consulting openly, incorporating service level agreements into longer-term contracts, and exploring new ways to share risk.

Close quarters, like any symbiotic connection, might cause some friction, but in the end, it's best for both sides to work together.

CHAPTER - 3

IMPORTANCE OF AIRPORTS IN AVIATION INDUSTRY

"I Think it's inevitable that aviation is a part of the economic growth that surrounds airports"

- Tim Griffin

AIRPORTS are crucial nodes in the aviation industry that enable worldwide connectivity, propel economic growth, and nurture innovation and advancement. For many reasons, airports are vital to the aviation industry:

- **Centre for Transportation:** Connecting different regions, cities, and nations, airports play a crucial role in transportation. They make it possible for people and goods to travel around the world, which in turn opens up opportunities for commerce, tourism, and enterprise.
- **Effect On the Economy:** The areas around airports reap substantial economic benefits. Airport operations provide direct job possibilities, while ancillary businesses like hospitality, transportation, and tourism provide indirect job opportunities.
- **Making Trade and Commerce Easier:** The efficient transportation of commodities and products is a key component of airports, which in turn promote global trade and business. They help global supply chains by providing a fast and effective way to deliver goods with a high monetary value or a tight deadline.
- **Being Able to Access:** If not for airports, it may be quite difficult to reach far away or distant places. They improve connectivity and cut down on travel time, allowing individuals easy access to places all over the globe.
- **Promoting Travel:** Tourists frequently have their initial encounter with a new location at the airport. They are vital to the expansion of the tourist sector because of the impact they have on visitors' perceptions and experiences.
- **Regional Development Catalyst:** By luring investors, companies, and infrastructure developers to the surrounding communities, well-functioning airports can spur regional growth.

- **Providing Assistance to Airline Operations:** Airports are vital to the smooth operation of airlines because of the infrastructure and services they offer. Runways, terminals, fuelling facilities, air traffic control, maintenance services, and ground handling services are all part of this.
- **Protection And Well-Being:** To keep planes running smoothly and safely, airports put safety and security first. To ensure the safety of passengers, crew, and aircraft, they put strict security measures in place, including as screening people, checking bags, and managing air traffic.
- **Innovation In Technology:** In order to streamline operations, provide a better experience for passengers, and lessen their influence on the environment, airports are always investing in new technology. Automated check-in, biometric identification, renewable energy, and smart airport technologies are all examples of these advancements.

3.1 EVOLUTION OF AIRPORT INFRASTRUCTURE AND TECHNOLOGY

3.1.1 TERMINAL DEVELOPMENT

The primary functions of airports changed throughout time, moving from government and military to commercial and civilian usage. As commercial aviation expanded in the early 20th century, the importance of airports for the transportation of people and goods grew.

Airports have gone through a number of distinct phases that have all been characterised by major improvements in technology, architecture, infrastructure, and operations. A brief history of airports is presented here:

1. **Initial Airfields (1900s - 1920s)**

- Taking off and landing on plain old fields or meadows was the first kind of airport.
- Historic military actions and pioneering aviators used these airfields, which often did not have permanent infrastructure.
- Airfield infrastructure, including hangars, fuelling stations and control towers, started to take shape as aviation technology progressed.

2. Growth and Commercialization (1920s–1940s)

- Airports became more organised places to handle more planes as commercial aviation expanded.
- Paved runways, terminals, and basic passenger amenities started to be incorporated into airports during this period.
- Radio beacons and air traffic control towers, which are navigation aids, have been improved, which has increased efficiency and safety.

3. The Modern Era and the Jet Age (1950s–1970s)

- Airports around the world have been upgraded and expanded since the advent of jet aircraft, which completely changed the way people travel by air.
- Longer runways, bigger terminals, and enhanced ground infrastructure were all necessities as airports grew to handle quicker and bigger jetliners.
- Improvements in operating efficiency and passenger comfort were brought about by innovations such as radar systems, instrument landing systems (ILS), and jet bridges.

4. Model of The Hub and Spoke (1980s–2000s)

- Large international airport hubs sprang up as a result of airlines channelling traffic via their hubs, giving rise to the hub-and-spoke model.
- To accommodate the increasing number of passengers, airports upgraded their security procedures, installed automated baggage handling systems, and built larger terminals.
- Computerised reservation systems and self-service kiosks are examples of how technological improvements have revolutionised passenger handling processes.

5. Efficacy and Environmental Stewardship (2010s – Present)

- Energy efficiency, trash reduction, and emissions reduction are the modern airport's primary sustainability and environmental responsibility priorities.
- More and more, airports are incorporating green building principles, renewable energy sources, and environmentally friendly transit options into their design and operations.

- Airport operations, security, and passenger experience are all being revolutionised by digital technology like data analytics, artificial intelligence, and biometrics.

Airports have transformed from humble airfields into modern transportation centres over the years, mirroring the ever-changing global aviation business, passenger expectations, and technological developments.

3.1.2 THE DEVELOPMENT OF AIRPORT FACILITIES

Airport architecture has changed and developed throughout the years, mirroring the expansion and development of aviation from its infancy to the present day. The following is a timeline:

a) Initial Airfields (Late 1800s–Early 1900s)

When first established, airfields were typically just grassy or open fields with a level surface for take-off and landing. These undeveloped airstrips did not have any permanent buildings or amenities.

b) Buildings Used for Storage and Command in the Early 20th Century

Hangars for storing and maintaining aircraft and control towers for managing air traffic started to pop up at airfields as aviation developed.

c) Buildings for Terminals

Airport terminals were established to accommodate passenger services in response to the growth of commercial aviation. These smaller terminals have simple amenities including ticket booths and waiting spaces.

d) Construction of Runway Taxis (1930s–1940s)

Paved runways have replaced grassy ones, allowing for faster and larger planes to land. Aircraft movement on the ground is made easier with the construction of taxiways, which lead to runways.

e) Expansion during World (War II in the 1940s)

In order to accommodate the military's air operations, airports expanded greatly during World War II. During this time, additional hangars, taxiways, and runways were built to house military planes.

f) Infrastructure of the Jet Age (1950s–1960s)

Airports needed to be upgraded much more when jet aircraft first came out in the 1950s. In order to handle the increased speed and weight of jetliners, the runways were reinforced and lengthened.

g) Contemporary Airport Terminals (1960s–1970s)

There were more concourses, boarding gates, lounges, shops, and restaurants in today's larger and more intricate airport terminals. These state-of-the-art terminals were built to manage the ever-increasing number of passengers and to support the wide variety of air travel options.

h) Centralised System (1980s–1990s)

Large hub airports with many terminals sprang up as a result of the hub-and-spoke model of airline operations. Additional development and investment in terminal infrastructure was spurred by the fact that these hub airports became vital transfer locations for connecting aircraft.

i) Improvements to Security (2000s to the Present)

Airport security systems underwent substantial modifications following the 9/11 terrorist attacks. To make things safer for passengers, measures like strengthened barriers, improved screening procedures, and surveillance systems were put in place.

j) Efforts to Promote Sustainability (2010s–Present)

Airports have made sustainability a priority in recent years, building environmentally friendly structures and using green technology. Water conservation measures, renewable energy sources, and energy-efficient buildings all fall under this category.

k) Concepts for Smart Airports (Present – Future)

In order to streamline operations, provide a better experience for passengers, and increase efficiency, airports are now utilising smart technologies. Internet of Things (IoT) gadgets, data analytics, and automation systems are all part of this effort to make things run more smoothly and with less downtime.

3.1.3 IMPROVEMENTS IN AIRPORT TECHNOLOGY

Improvements in airport technology have greatly influenced the safety, efficiency, and overall experience of air travel for passengers. The following is a synopsis of the most important turning points in airport technology.

a) Radio Transmissions in the Early Twentieth Century

One of the most important technologies for controlling air traffic and coordinating pilots in the early days of aviation was radio communication. It made airspace management more efficient and made pilots safer.

b) Advanced Radar Technology (1930s–1940s)

After its development during World War II, radar technology found rapid use in commercial aviation. Radar systems improved airspace monitoring and collision avoidance by providing air traffic controllers with real-time information regarding the locations of aircraft.

c) Instrument Landing System (ILS) (1940s-1950s)

To help pilots land safely in bad weather, instrument landing systems (ILS) were deployed. ILS enhances landing accuracy and safety by providing precise guidance to planes using radio signals.

d) Technology of Jet Engines (Decades 1950–1966)

Improvements in aircraft speed and fuel efficiency made possible by jet engines ushered in a new era of air travel. The development of jet propulsion technology revolutionised the aviation industry by allowing larger and faster commercial aircraft to enter the market.

e) Reservation Systems Used by Computers (1960s-1970s)

Airlines were able to streamline their booking procedures and better handle customer reservations with the advent of computerised reservation systems in the 1960s. Modern airport and airline information systems can trace their roots back to these systems.

f) Streamlined Checked Baggage Processing (1970s–1980s)

To make the process of handling and tracking bags through airports easier, automated baggage handling systems were implemented. These systems made things easier, faster, and safer for everyone involved by reducing the need for physical labour and increasing efficiency.

g) Technologies for Airport Surveillance (1908s–1990s)

To increase safety and keep an eye on the airport's activities, cutting-edge monitoring equipment such perimeter intrusion detection systems and Closed-Circuit Television (CCTV) cameras were set up.

h) Security Screening and Biometric Identification (2000s–Present)

The utilisation of biometric identification technology, such as facial recognition systems and fingerprint scanners, for the purpose of passenger verification and airport security screening has been on the rise. These innovations speed up the screening of passengers without sacrificing security.

i) Technologies for Smart Airports (2010s–Present)

The idea of "smart airports" has been gaining popularity, with the help of technologies like the IoT, AI, and Big Data analytics. The goals of smart airports are operational optimisation, passenger experience improvement, and security enhancement.

j) Unmanned Aerial Vehicles (UAVs) for Airport Operations (Present-Future)

Drones and other Unmanned Aerial Vehicles (UAVs) are being considered for use in airport perimeter monitoring, runway inspections, and freight delivery, among other tasks. There is hope that unmanned aerial vehicle (UAV) technology can make airport operations safer and more efficient.

3.2 AIRPORT DEVELOPMENT INFLUENCED BY SIGNIFICANT MILESTONES AND INNOVATIONS [3]

Many important events and technological advancements have shaped the evolution of airports. The following, according to my findings, are Key Milestones that have significantly influenced the evolution of airports and contributed to the global improvement of air travel in terms of safety, efficiency, and accessibility.

- **The Wright Brothers Flying for the First Time (1903)**

The Wright brothers' first powered flight was a watershed moment in aviation history, paving the way for airport construction.

- **An International Passenger Flight for the First Time (1919)**

Royal Dutch Airlines' inaugural passenger flight from Amsterdam to London proved the viability of commercial air travel and prompted the construction of international airports.

- **Concerning the Commerce of the Air (The Act of 1926)**

Standardised airport infrastructure and air traffic control systems were outcomes of federal regulation of civil aviation, which was instituted by the United States by the Air Commerce Act of 1926.

- **Instrument Landing Systems (ILS): A Brief Overview (1930s)**

Airports were able to function more consistently and safely with the invention of Instrument Landing Systems (ILS) gave pilots exact direction during landings regardless of the weather.

- **Deuxieme Guerre Mondiale (1939–1945)**

Improvements to airport infrastructure and aviation technology were propelled during World War II. After the war, many airfields that had been used for military purposes were turned into civilian airports, which helped to expand commercial aviation.

- **The Commercialization of Jet Engines in the 1950s**

[3] BUDD, L., 2008. A history of airport technology. Airports of the World, 19 (September/October), pp. 44 – 51.

Airports had to adapt their facilities to accommodate jet-powered aircraft when the commercialization of jet engines in the 1950s made them quicker and more efficient.

- **Beginning with Computerised Reservation Systems in the 1960s**

Airport services saw a surge in demand as computerised reservation systems like Sabre and Apollo transformed the way airlines sold tickets and took reservations, allowing air travel to expand.

- **Model of the Hub and Spoke (1970s–1980s)**

Airport operations were revolutionised when airlines adopted the hub-and-spoke concept. Large airports now function as connecting flight hubs. Airports had to undergo massive expansions as a result of this strategy so they could accommodate the influx of passengers.

- **The Airline Industry's Deregulation in 1978**

More efficient and cost-effective airport infrastructure was in high demand after the United States deregulated the airline sector in 1978, which boosted competition among airlines and gave rise to low-cost carriers.

- **The Information Age (the 1990s present)**

Airport operations and passenger experiences have been transformed by the arrival of digital technology. Biometric security screening, automated luggage handling systems, and self-service kiosks are just a few examples of how technology has simplified and improved processes.

- **The Idea of a Smart Airport (2000s to Now)**

A new idea called "smart airports" has evolved to optimise airport operations, improve passenger experiences, and increase safety and security. These airports integrate technology like the Internet of Things (IoT), artificial intelligence (AI), and data analytics.

- **Sustainable Development Programmes (from the 2000s to the Present)**

Airports have begun implementing sustainability efforts, such as energy-efficient building designs, renewable energy sources, and trash reduction programmes, in response to the increasing public awareness of environmental issues.

3.3 THE IMPACT OF AIRPORT INFRASTRUCTURE ON OPERATIONS AND EFFICIENCY

Airport operations and efficiency are greatly influenced by infrastructure and technology. Airports can improve security, make better use of resources, and provide passengers and stakeholders with pleasant and trouble-free experiences by investing in cutting-edge infrastructure and using technological innovations. Airport operations are greatly influenced and made more efficient by infrastructure and technology. Their contribution is as follows.

- **Terminal and Runway Infrastructure**

Minimising aircraft turnaround times and passenger wait times requires efficient design of the terminal and runway. Congestion is minimised and operating efficiency is increased with well-planned infrastructure, which guarantees that aircraft movements are seamless.

- **A System for Managing Air Traffic and Navigation**

Instrument Landing Systems (ILS) and radar systems are examples of advanced navigation technologies that allow for safe and accurate movements of aircraft, particularly in bad weather. Systems for managing air traffic (ATM) improve aircraft routes, cut down on delays, and maximise airspace use.

- **Automated Systems for Handling Baggage**

Automated baggage handling technologies make it easier to track and handle bags, which means fewer mistakes and happier passengers. These solutions improve productivity by reducing the amount of time it takes to process bags and guarantee that they are delivered to planes on schedule.

- **Passenger Processing Technologies**

There are now shorter lines and less wait periods for passengers thanks to technologies such as electronic boarding passes, biometric authentication, and self-service kiosks. Passenger movement and overall airport efficiency are both improved by this.

- **Digital Communication & Collaboration Platforms**

Airlines, ground handlers, and regulatory agencies are just a few of the airport stakeholders who can benefit from digital communication platforms that allow for real-time information sharing and collaboration. Coordinated decision-making, optimal resource allocation, and enhanced operational efficiency are all made possible by these platforms.

- **Screening Technologies**

Passengers experience less hassle and more effective security with the help of advanced screening technologies including bomb detection systems and full-body scanners. Throughput rates are increased as passengers and bags are screened efficiently with automated screening systems.

- **Managing Assets and Maintenance**

Optimisation of maintenance schedules, tracking of equipment performance, and availability of essential infrastructure can be achieved with the use of digital maintenance and asset management systems, which airports utilise. Improved overall efficiency, less operational disturbances, and less downtime are all results of using predictive maintenance procedures.

- **SMART Airport Ideas**

To improve airport operations and the travel experience for passengers, “smart airport” ideas use technology such as data analytics, artificial intelligence (AI), and the Internet of Things (IoT). Improved efficiency and happiness are the results of smart technologies that allow for proactive resource management, predictive modelling of passenger flows, and individualised services.

- **Environmental Monitoring & Sustainability Initiatives**

Environmental sustainability is also greatly aided by airport infrastructure and technology. Renewable energy sources, waste management systems, and energy-efficient structures all work together to lessen human influence on the environment without sacrificing productivity or affordability.

CHAPTER - 4

AIRPORT INFRASTRUCTURE

"Airport infrastructure is the heartbeat of the aviation industry, pulsating with the rhythm of take-offs, landings, and the movement of millions of passengers and tons of cargo"

- *Walter Raleigh*

4.1 INTRODUCTION

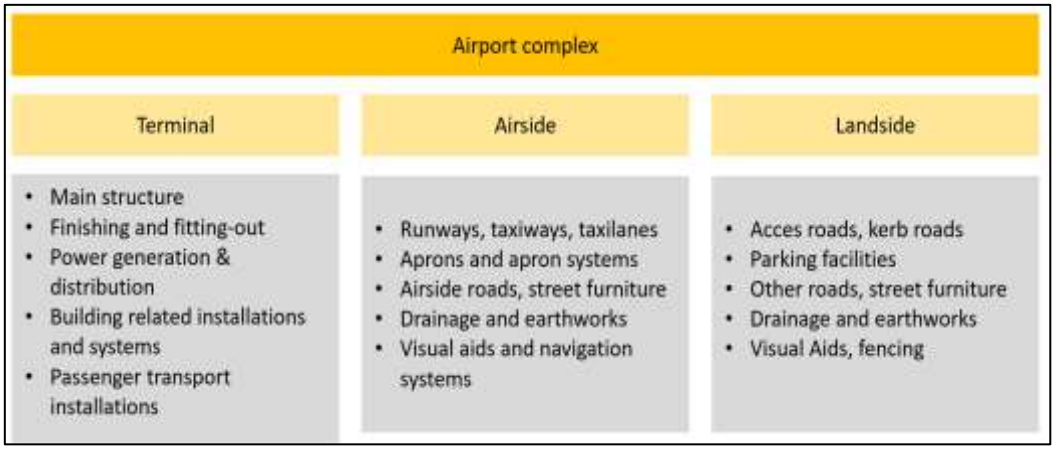
An old adage goes something like, "If you have seen one airport, you have seen ONE airport." The idea is to highlight how different each airport is. When comparing the volume of traffic and the necessary infrastructure at different airports, it is clear that there is a wide range of variation. Although airports may differ substantially in terms of the quantity of infrastructure, they will often share similarities in terms of the type of infrastructure. It doesn't matter how big or complicated an airport is; the signage used to guide pilots and planes around the airfield will be very standard. The same is also true for a wide variety of airport facilities.

In Common Parlance, There Are Two Types of Airport Infrastructure: [4]

(i) Airport facilities and (ii) Infrastructure located on land. Runways, taxiways, airfield lighting and signage, parking aprons, and other visual and navigational aids are all part of the airside infrastructure that allows planes to manoeuvre around the airport.

The landside infrastructure consists of many features that facilitate the passage of vehicles and passengers on the ground. These features include roads leading to the airport, parking lots and garages, businesses associated to aviation and those unrelated, support buildings, and terminal buildings.

[4] David C Poeger and Robert B Champman & David G. Peshkin "Preventive Maintenance at General Aviation Airports", ACRP report 138, Vol – I: Primer, P.7-8.



4.2 AIRPORT INFRASTRUCTURE OWNERS AND ADMINISTRATORS [5]

The vast expanse of an airport's infrastructure includes both physical components and more abstract processes. From the most prominent and outwardly visible passenger terminals—complete with security and food courts—to the less obvious but no less important baggage systems, gate operations, lighting systems, and organisational compositions like finance and management.

When it comes to money, it's no secret that maintaining and improving airport infrastructure is no picnic. Between now and 2030, infrastructure developments will cost between $1.2 and $1.5 trillion, according to IATA. The value of the 159 airport projects that began construction in 2021 reached about $110 billion.

Airport Technology noted that out of all the projects started in that year, with a combined investment of over $87 billion, 59% were related to terminals, either new developments or extensions. The Philippines is home to two of the world's most costly new construction projects, with a combined investment of more than $10 billion. The majority of the projects on the list are located in Asia, although a $2.6 billion terminal project in San Diego did manage to make it.

[5] Justin Hayward and Simple Flying Staff "Airport Infrastructure – Everything You Need to Know", Journal Jan 12, 2023, Pp.8- 12.

The question of who pays for and owns such infrastructure naturally arises when one sees such figures. Worldwide, there is a wide range of public and private ownership structures. Because of their historical origins as military airfields, high cost, and vital role in the economy of their respective regions and countries, it is not unexpected that airports be owned by the government. When it comes to private ownership, the government is still usually rather involved.

4.2.1 OWNERSHIP IN US AND EU

Nearly every major airport in the United States is owned by some level of government, most often by the state or municipal level. For instance, the New York City government owns both JFK and La Guardia airports in the Big Apple. Both Newark and Elizabeth hold a piece of Newark.

Other firms run several US airports, even though the government owns them. The Port Authority of New York and New Jersey, for instance, oversees all three of New York's airports; it is a publicly traded corporation that does not get any funding from the federal government.

In Europe, private ownership is the norm. A small number of airports, such as the ones in Zurich, Rome Fiumicino, and Copenhagen, are privately held with a small percentage held by the government. Frankfurt, Munich, Madrid-Barajas, Paris CDG, Amsterdam Schiphol, and Paris are among the others that are majority-owned by the government with private participation.

The government of the United Kingdom privatised many of its airports in 1987. Later on, Heathrow and six other airports in the United Kingdom were owned by the British Airports Authority (BAA). In an effort to broaden its competitive landscape, BAA has since divested itself of additional airports; now, it owns and manages only London Heathrow under the name Heathrow Airport Holdings.

However, private property ownership is frequently intricate. The real name of the consortium that owns Heathrow Airports Holdings is FGP Topco Limited. The following entities make up this group: the Government of Singapore (11%), the Qatar Investment Authority (20%), the Spanish infrastructure provider Ferro vial (with a 25% stake), the Caisse de dépôt et placement du Québec (12.62%), the Government of

Singapore (11%), and the China Investment Corporation (10%). When they use or transit Heathrow, not many passengers realise that.

4.2.2 AIRPORT REGULATIONS

Airports are regulated by the government, regardless of whether they are privately owned or operated. Given the intricacy of the infrastructure and operations, this will encompass the relevant aviation regulator as well as multiple other government entities. Therefore, the CAA and the UK Government will govern airports in the UK, even though private ownership is complex.

The International Civil Aviation Organisation (ICAO) establishes standards for various aspects of airport operations and infrastructure. Perhaps its most notable function is the establishment of standards for air navigation and safety. The document does, however, lay out detailed requirements for "Aerodrome Design and Operations." Annexe 14 of the ICAO Convention on International Civil Aviation contains these, in case anyone is interested.

These lay out comprehensive guidelines for the planning, construction, and operation of airports. Finally, it is up to specific aviation authorities to adjust and implement these rules as needed, as is typical with most aviation standards.

4.3 THE LAYOUT AND DESIGN OF TERMINAL

Planning, arrangement, and architectural elements of an airport's terminal building are known as the terminal's design and layout. This involves the layout of the terminal's several functional areas, including the check-in desks, security checkpoints, departure gates, baggage claim areas, retail stores, dining options, lounges, and more. A well-designed and efficiently laid-out terminal is essential for a pleasant passenger experience, efficient operations, and a steady stream of passengers. The flow of passengers, portability, zoning, accessibility, natural light, sustainability, and adaptability are important factors to consider while designing and constructing a terminal.

Passenger flow is the rate at which people are able to go from the terminal's main entrance to its departure gates and back again. With the goal of reducing congestion and bottlenecks, the design should make passenger flow easy and natural.

Airline operations, passenger volumes, and technological improvements are subject to change, hence it is necessary that systems be modular and flexible. The modular architecture of terminal facilities makes it easier to expand or modify them as needed.

Separating the terminal into several zones allows for specialised services like retail/dining, security screening, boarding gates, and check-in. Zoning is a useful tool for efficient passenger flow and space organisation in airports.

Passengers with decreased mobility or disabilities can travel easily around the terminal thanks to its accessibility facilities, which include ramps, elevators, accessible restrooms, and specific seating places.

Passengers will have a more pleasant and comfortable experience because of the open layout and abundance of natural light. Passengers are more likely to feel comfortable and relaxed in terminals that are well-lit by natural light.

Terminal design should take sustainability principles into account, such as the use of water conservation techniques, renewable energy sources, ecologically friendly practices, and energy-efficient building materials. Responsible resource management and reduced environmental effect are the goals of sustainable ports.

4.3.1 PRIMARY LAYOUT OPTIONS FOR AIRPORT TERMINALS

Airport designers are constantly striving to provide a positive first impression on passengers because the airport is the first location we see when we arrive in an unfamiliar city. Airport terminals are meticulously planned to ensure maximum efficiency while minimising walking distances. Linear, pier, and satellite layouts are the three most common kinds of airport terminals.

(i) Simple Linear

Planes align up in front of the terminal in a straight line in a linear terminal design. A shorter path from the curb to check-in, security, and the gates results from this layout. Because of its efficiency, this plan is used by many regional and municipal airports. The majority of airports with a linear terminal layout are smaller airports without jet bridges, including London City (LCY). But sometimes you'll see similar layout at bigger airports like John Wayne (SNA) and San José Mineta (SJC). Due to aircraft parking on just one side of the terminal, a linear terminal plan is extremely inefficient

in terms of land consumption at big airports. Also, because it would be too tiring to walk between gates, big airports with a lot of connections don't use this layout.

SNA Airport: (Source: John Wayne Airport, Facebook)

Linear with a Curve

A variant of the linear terminal layout called curved linear makes use of a curved terminal to enhance the quantity of parking spaces directly in front of the terminal. Terminals 2A-2D at Charles de Gaulle (CDG), Dallas Fort Worth (DFW), and Kansas City (MCI) are good examples of this.

MCI Airport (Source: Trygve Restan on Pinterest)

(ii) Pier Layout

In a pier layout, planes park on both sides of a small, narrow terminal building, which is linked to the check-in and security building at one end. In this way, the most planes can be handled while the land is used efficiently. By far, the most popular type of design

for a commercial airport is the pier. Phoenix Sky Harbour (PHX), Charlotte Douglas (CLT), Philadelphia (PHL), Los Angeles (LAX), and Guangzhou Baiyun (CAN) are a few these cities.

LAX Airport (Source: Deborah Silver Music)

The Star Pier

It's a unique way to set up piers where several are grouped in a star shape. Orlando (MCO) and Pittsburgh (PIT) are two examples. A star pier terminal lets you make links quickly, but it's not as efficient as a parallel pier. New mega-airports in hub towns like Beijing (Daxing, PKX) and Istanbul (IST) chose this design because it allows for architectural innovations and is easy to build.

PKX Airport (Source: Peapix)

(iii) A Satellite

A satellite station is separate from the other buildings at the airport so that planes can park all the way around it. It makes sense that satellite stations make the best use of land. But there are also some bad things about it. Because of how they are set up, getting to and from a satellite terminal needs some kind of transportation. For smaller satellite terminals, shuttle buses would work. For bigger satellite terminals, though, monorails or underground metro tracks are more common. For smaller airports, this plan doesn't work because it makes the cost of building the terminal much higher. A lot of airports, like LAX and DFW, have satellite terminals where planes from other cities land.

LDFW's regional satellite terminal (Source: Andy's Travel Blog)

Straight-Line Satellite

Dubai (DXB), Atlanta (ATL), Denver (DEN), and Heathrow (LHR) are all airports that have straight satellite halls.

ATL Airport (Source: www.yakimankagbu.ru)

Circle-Shaped Satellite

The Charles de Gaulle (CDG) terminal 1 is an example of a round satellite airport. It's important to note, though, that in small satellite stations, there may not be a lot of room for shopping or sitting.

CDG Terminal 1 (Source: Sketchfab)

4.3.2 THE SIGNIFICANCE OF TERMINAL LAYOUT AND DESIGN

Improving the Travelling Experience is the Goal of Terminal Design.

In order to ensure the safety of both airport employees and passengers, the terminal's design must take slips and falls into consideration. Additionally, state-of-the-art security systems like body scanners and baggage X-rays need to be accommodated at the terminal.

It is of the utmost importance that airports are designed and built in a way that helps airlines and airport management simplify processes so that passengers may board aircraft easily. It is easier to find one's way around the airport terminal building thanks to the well-placed signs and graphics and the attractive floor and wall patterns.

The airside area, which is sterile from the liquids, aerosols, and gases security checkpoint to the boarding queue, is where passengers spend the majority of their leisure time. By utilising good airport architecture and spatial organisation, this area may be transformed into a shopping paradise.

Additionally, airport designers should consider adding interactive screens that display up-to-the-minute flight and time information clearly and in real-time. By giving them a realistic idea of how much time they have before they have to get off the plane, this helps alleviate anxiety and makes the trip much better overall.

When planning an airport's operations, terminal architecture and layout should be top priorities to ensure passenger comfort, efficiency, and safety while also promoting long-term sustainability.

- **The Pinnacle of Travel Experiences - From Airports to Aerotropolis** [6]

There's no denying that airports are revolutionising the transportation sector. Although the daily movement of millions of people is their principal objective, airports are becoming into much more than simply a transportation centre. These locations are vital for business, employment, trade, and recreation; thus, they must be up-to-date. A growing number of airports around the world are expanding and diversifying their non-aeronautical offerings to provide travellers with a whole new kind of travel experience, all made possible by digital technologies and big data. Airports are transforming into what are now called aerotropolis, or airport cities, with amenities such as movie theatres, ice skating rinks, Michelin-starred restaurants, delivery-to-gate services, and even chapels for wedding ceremonies.

Accordingly, airports are changing into that special spot in the middle, connecting cities to the rest of the globe. Without sacrificing the airport's technological growth, airport interior design and architecture can consecrate this duty by bolstering and transmitting the idea of a nation's cultural identity.

Without a doubt, the travel experience of the future will be very technological, but it is critical to ensure that it also incorporates cultural elements. It is our responsibility as designers to stay on course.

[6] https://rmjm.com/how-airport-design-affects-your-travel-experience/

4.3.3 HOW MIGHT THE TERMINAL'S DESIGN AND PLANNING MAKE THE MOST EFFICIENT USE OF AVAILABLE SPACE AND RESOURCES? [7]

In order to maximise revenue generation, improve passenger experience, and guarantee efficient operations, it is vital to optimise the use of space and resources in terminal architecture and planning. To that end, here are a few approaches:

(i) Comprehend the Need

Examining the terminal's present and future demand in light of factors including passenger traffic, flight frequency, peak hours, and service level is the initial stage. The ideal terminal capacity, layout, and necessary facilities and equipment can then be ascertained with this information. We can predict the demand and identify any bottlenecks and gaps in the terminal using methods like as simulation models, surveys, and historical data.

(ii) Create a Versatile Design

Designing the terminal to be flexible and adaptable is the second phase. As a result, the terminal needs to be flexible enough to adapt to shifting demand, new technologies, new rules, and evolving consumer tastes. We can accomplish this by incorporating scalable and modular components, like seating that can be adjusted, walls that can be moved, and security and check-in zones that can be reconfigured. To further improve the terminal's operations in terms of efficiency and convenience, we can additionally employ smart technologies like sensors, biometrics, and automation.

(iii) Maximise Efficiency

Improving the terminal's traffic flow for people, bags, and cars is the third objective. Passengers should not have to waste time or energy walking long distances between the curb and the gate, and the terminal should do the same. All it takes to do this is the use of well-placed signs, easy-to-follow directions, and smooth transitions between the various transportation options and areas of the terminal. To alleviate congestion and increase throughput, we can also implement solutions like off-site processing, common-use terminals, and self-service kiosks.

[7] https://www.linkedin.com/advice/1/how-do-you-optimize-use-space-resources-terminal

(iv) Maintain a Balanced Approach

Finding a happy medium between all the various needs of the terminal's users is the fourth step. Airports should be places where everyone's needs are met: passengers, employees, airlines, and the community at large. The terminal should be a safe and welcoming place for all. To achieve this goal and make the terminal unique, we can combine functional and visually beautiful elements like lots of green space, art displays, cultural attractions, and natural light. In order to monitor the terminal's quality and customer satisfaction, we can collect feedback in the form of surveys, complaints, and reviews.

(v) Bring Everyone Involved

Coordinating the various parties with a stake in the terminal's design and development is the fifth stage. Because of this, the terminal should encourage cooperation and dialogue among all stakeholders, including airport officials, airlines, contractors, consultants, regulators, and consumers. Workshops, meetings, and consultations can help us engage and align the stakeholders on the terminal's vision, goals, and requirements in an open and inclusive manner. To further clarify and bind all parties involved, we can make use of instruments like standards, contracts, and agreements.

(vi) Review The Results

Verifying the efficacy of the final strategy and design is the sixth step. To rephrase, the terminal must monitor and assess its impact on the operational, financial, social, and environmental indicators of the airport. To do this, we can assess the terminal's efficiency by looking at indicators and measures including customer happiness, revenue creation, carbon footprint, and passenger throughput. Additional resources for extracting and implementing the terminal's best practices and lessons learned include audits, evaluations, and benchmarking.

4.4 DESIGN OF THE RUNWAY AND THE TAXIWAY: SUFFICIENCY, SECURITY, AND TECHNICAL DEVELOPMENTS [8]

As centres of transportation and development, airports play a crucial role in facilitating worldwide connectivity. Improvements in infrastructure have been necessitated by the development of aviation over the years. With all these new developments, updating airport runways and taxiways has become an important project for many airports throughout the world.

- **Ensuring Operational Efficiency and Catering to Bigger Aircraft**

Improvements that accommodate larger planes and boost operational efficiency are in high demand at airports nowadays. The growing number of larger planes in the sky is driving this increase, which in turn need more infrastructure to support the aviation industry.

- **Paving the Way for Improved Safety and Longevity: Resurfacing**

Many modernization projects for runways and taxiways revolve around resurfacing activities. This method restores damaged surfaces using cutting-edge technology and materials to make them sturdier and safer for use during aeroplane manoeuvres.

- **Exploring New Horizons: Embracing Development and Technological Progress**

Runways and taxiways have had to be extended and widened to handle the wider wingspan and heavier weights of contemporary aircraft. In order to alleviate congestion and guarantee smoother operations, airports are expanding these routes to create a buffer for safe take-offs and landings.

- **Improving Safety While Decreasing Air Traffic**

Airline and passenger operations are both negatively affected by airport congestion. The goal of these modernization projects is to improve safety standards, which in turn

[8] Airport Infrastructure

will reduce congestion, by making the most efficient use of the runways and easing traffic flow.

Improving safety during crucial parts of flight, such as take-offs and landings, is an essential objective. In order to make take-offs and landings safer and more secure, airports are updating their runways and taxiways with new lighting systems, better signs, and higher-grip surfaces.

- **Aviation Infrastructure that is Prepared for The Future**

The capacity of airport infrastructure to adapt to the changing demands of the aviation sector is demonstrated by the continuous renovation of runways and taxiways. In addition to meeting the needs of larger aircraft in the here and now, these projects will set the stage for an aviation industry that is future-proof by putting an emphasis on safety, efficiency, and seamless connection.

Optimising operations, strengthening safety measures, and hardening infrastructure to navigate tomorrow's skies are the unwavering goals of airports undergoing dramatic changes.

Runway and taxiway upgrading is of utmost importance in this dynamic aviation industry. The path towards a more secure, efficient, and flexible aviation infrastructure is now well under way, as airports throughout the globe begin these vital renovations.

4.5 THE FUNCTION OF AIR TRAFFIC CONTROL SYSTEMS IN IMPROVING EFFICIENCY AND SAFETY [9]

The primary focus of air traffic control and management is the regulation of airspace, airports, and terminals. The responsibility for maintaining a safe distance between all aircraft, whether in the air or on the ground, is with the air traffic controllers who operate out of the air traffic control (ATC) towers.

Lead Providers of Air Traffic Control Systems and Companies That Manage Air Traffic

There are a number of businesses that focus on supplying ATM and ATC systems for the aviation industry. These businesses are leading the way in improving aviation

[9] https://www.airport-technology.com/buyers-guide/air-traffic-management-control-systems/

safety, efficiency, and sustainability through creating cutting-edge solutions and technology for air traffic control and management. Here are only a handful of them:

1. The Thales Group

Thales is a world leader in security, defence, and aerospace solutions. They offer many ATM devices and services. They sell air traffic control centres, radar systems, data networks, and automation tools that make it easier to handle air traffic.

2. Leonardo S.p.A., Which Used to be Called Leonardo – Finmeccanica

Leonardo is a global Italian aerospace and defence company that offers full ATM solutions, such as radar systems, surveillance sensors, communication networks, and ATC automation systems.

3. The Saab Group

Saab is a Swedish aerospace and defence company that is known for its advanced ATM solutions, such as surveillance cameras, tools for making decisions together, and air traffic control systems. They offer unified ways to handle air travel in a safe and effective way.

4. Harris Corporation, which is now Called L3Harris Technologies

It makes some of the best ATM and ATC systems. For managing air traffic, they have a lot of different options, such as radar systems, surveillance sensors, communication networks, and automation software.

5. The Indra System

Indra is a Spanish global company that focuses on providing technology-based solutions for many fields, such as managing air traffic. They provide automated air traffic control systems, surveillance cameras, communication networks, and tools for making decisions together that help make the best use of airspace.

6. Raytheon Business

Raytheon is a big defence contractor based in the U.S. that makes ATMs and ATC systems for both military and commercial use. They sell advanced technologies for handling air traffic, automation tools, communication networks, and radar systems.

7. Frequentis

It is an Austrian business that focuses on providing communication and information solutions for ATM and ATC work. Voice communication systems, data sharing networks, automation tools, and software for managing air traffic that is safety-critical are some of the things they sell.

8. Navi Canada

The civil air guidance services in Canada are run by Nav Canada, a non-profit organisation. They offer ATM solutions, ATC systems, navigation services, and more. These services include radar monitoring, communication networks, and processing of flight data.

9. Searidge Technologies

This is a Canadian business that makes smart video solutions for managing air traffic. They provide high-tech tracking systems, automation tools, and analytics software to help people better understand what's going on and make air traffic management more efficient.

10. The Aireon

It offers service around the world for ADS-B (Automatic Dependent Tracking-Broadcast) tracking in space. Their satellite-based system lets them watch planes around the world in real time, which improves safety and surveillance of air traffic.

Air Traffic Control Systems and Technologies

To keep the air traffic flow steady and avoid accidents, air traffic controllers are important. Air traffic management and control typically make use of the following technologies and systems:

- Tracking and monitoring radars for surfaces
- Radar with holographic capability
- Systems for navigation and monitoring
- Systems for controlling voice communication
- Devices for transmitting data at extremely high frequencies (UHF and VHF)
- The apparatus used to show flight data information

- Telephone transceivers and modems
- Systems that prevent collisions
- Systems for tracking noise levels
- Weather monitoring equipment
- Management and oversight of airfield lighting
- Management software for training

➢ **Automated Systems for Monitoring Air Traffic**

The management and control of air traffic is becoming more reliant on automation and digital technologies. Digital towers that do not require human intervention are becoming a reality thanks to advancements in high-definition (HD) cameras, automatic surveillance broadcasting (ADS-B), and remote sensing technologies.

➢ **Creating A System for Controlling Air Traffic**

These innovations allow for centralised air control centres to collect feeds from camera masts and display a full panorama of the airfield, giving controllers a better idea of what's going on. The use of digital tower technology has several benefits, including less maintenance requirements for systems and equipment, more productivity owing to centralization of operations, and improved operational safety and flexibility.

4.6 CASE STUDY - KEMPEGOWDA INTERNATIONAL AIRPORT, TERMINAL – 2 [10]

This Case Study delves into the numerous remarkable ways in which the development project of Kempegowda International Airport's Terminal 2 paid homage to Bengaluru's cultural identity.

➢ Nature is woven throughout travellers' experiences at Kempegowda International Airport Bengaluru (BLR)'s new Terminal 2 (T2) complex through indoor planting, outside gardens, and natural materials. In addition, the terminal and the surrounding architecture are connected by an uninterrupted ring of outdoor, planted areas. This outdoor forest belt spans 24,000 square metres and features indigenous plants, winding pathways with multiple levels, and bamboo pavilions with two stories that

[10] Kempegowda Airport gradual growth

draw inspiration from traditional Indian cane weaving. The Garden City Airport in Bengaluru, India, developed a "terminal in a garden" based on these blueprints.

- It wasn't easy to make this realistic, immersive experience. Skidmore, Owings & Merrill (SOM) was asked by the airport to help bring its green vision to fruition. SOM specialises in architecture, urban planning, and engineering. We aimed to create a unique garden experience at each level of passenger processing - some immersive, some passive, all innovative," says Derek Moore, the company's design principle. The terminal gives the impression of being encircled by gardens from the landside approach all the way to the gate piers. Once constructed, riders on the ground level will soon also have the option to ascend to tree houses for refreshments. These outdoor pavilions, which will be about 40 metres tall, will offer a complete panorama of the airport.
- **Creating Structures from Bamboo:** Terminal 2's interiors highlight BLR's connection to its surroundings by reflecting the natural beauty of the woodland belt. Bells and veils hold a variety of plants, and bamboo lattices filter skylights. To bring the lattice pattern to the floor and create a feeling of light and space in the terminal, each column of the structure is made of a cluster of four steel elements wrapped in bamboo. The terminal exudes a cosy and inviting atmosphere because to its custom furnishings adorned with traditional woven rattan, red brickwork, and ivory-brown granite acquired from the area.

Bangalore International Airport Limited (BIAL) COO Satyaki Raghunath explains, "We aimed to capture the essence of the tropical surroundings and the Deccan Plateau's organic, earthy aesthetic by using locally available brick for external cladding and re-engineered bamboo for internal use. The bamboo was designed in India but mass-

fabricated in China." The pre-engineered bamboo ceilings let in a lot of natural light, which made the station look amazing during the day and makes it feel cosy at night. The abundance of natural light within the terminal not only makes it look better, but it also helps the lush vegetation grow, which in turn increases the biological diversity that makes it special.

Another advantage was held by bamboo. "This was our first time using engineered bamboo," says Peter Lefkovits, principal of design at SOM. To top it all off, the material outshines even real bamboo and wood in every way. Not only is bamboo a sustainable resource, but its excellent strength and durability mean it doesn't need as much reinforcing.

Installations by a variety of Indian artists adorn the terminal, further adding to the local flavour. The Naurasa, or nine human emotions according to Indian aesthetic philosophy, are the central focus of these installations.

Even the terminal's retail and duty-free concept aims to incorporate Indian culture into this global area. International brands like PF Chang's, Giraffe, Tim Horton's, Jamie Oliver's Pizzeria, Carluccio's, and Wolfgang Puck are on display alongside new concepts and restaurants that have never been seen in an Indian airport before. Indian brands like Fabindia and Anand Sweets are also prominently displayed. In order to accommodate the increasing volume of foreign passengers, the terminal's international side now contains a lounge that can sit around 600 people.

- **Centre for Transportation**

Beside T2 is a multimodal transit hub with a construction area of 123,000 square metres. Serving as a hub for the entire airport, this T-shaped, two-story facility features parking, taxi service, and a rideshare zone along the entrance roads, as well as a lower-level metro and bus station. This is why it has a prime location in the airport complex, bordered to the east by Terminal 2, the northwest by Terminal 1, and the southwest by the airport hotel. Passengers will be able to cross the access roads to Terminal 1 and the hotel on elevated bridges, allowing them to walk around the entire airport. Once the line is finished and operational, this station will also serve as the endpoint for the planned metro link from the city.

The transportation hub's goals include connecting the facility to Bengaluru and bringing a new type of airport space to BLR. "As a new civic square for the growing city, we envisioned this space as a destination for local residents," Lefkovits adds, referring to their collaboration with BIAL. Locals and visitors alike can enjoy the outdoor shopping, events, and entertainment options provided by the transit hub, which also makes it easier to use public transportation. In an effort to increase traffic to the new transportation hub, the airport plans to upgrade the area over the next six to twelve months with additional dining and shopping options, larger lounges, and designated areas for customers to have a memorable experience.

A lightweight steel canopy covers the hub, mimicking the form of Terminal 2. A glass and steel skylight atop the metro station entry adds to its architectural flair. The western side of the hub is home to outdoor lagoons that draw inspiration from the waterways of Karnataka. These lagoons serve to both recycle the stormwater runoff from the airport and provide an attractive sight for visitors. Rainwater collected, treated, and reused throughout the terminal means that all of the inside plants and outdoor gardens may thrive with just the water that is harvested on-site.

The interconnectedness of design principles that shaped the terminal's ethos from the start is exemplified by this creative and environmentally friendly usage of local water. For Raghunath, "there were four main pillars around which the design and development of the terminal, which began in 2016," stands as an explanation. The first pillar considered the city's reputation as India's Garden City and envisioned a terminal that mirrored this lush image. The second pillar aimed to bring the terminal in line with Bangalore's status as India's Silicon Valley by incorporating state-of-the-art technology and digital innovations. The terminal achieved LEED Platinum certification thanks to the third pillar's focus on sustainability. The fourth and last pillar was to incorporate the

region's artistic and cultural traditions into the terminal's design in order to highlight Bangalore and Karnataka's rich history and culture. The terminal is an engineering and environmentally remarkable wonder, in my view. To keep the plants alive, for instance, Internet of Things devices are installed in such a way that they regulate the amount of water and how it is distributed throughout the terminal. Also common is digital technology, which is reflected in the region's art and culture through the use of visual displays for messaging and advertising.

- **Creative Reasoning**

The new BLR terminal is a technological marvel, with 90 check-in desks, 54 immigration counters, 36 departure gates, 20 boarding bridges, and dedicated Code F stands for specific operations. It also features self-bag-drop devices throughout the facility and state-of-the-art common-use check-in equipment. In the first stage, the airport's capacity to handle 25 million passengers per year is increased by the 255,000 m^2 terminal and its associated technology. Additional 200,000 m^2 and 20 million m^3 of capacity will be added in a later phase.

It was our main goal to make the passenger experience as easy and digital as possible while simultaneously reducing the need for boarding passes at every stage, Raghunath explains. This is why the Bangalore Airport Innovation Lab came up with the idea and launched the Digi Yatra facial biometric system, which is now used all over the country. With this setup, boarding, security clearance, and check-in can all use facial biometric technologies. With the Digi Yatra technology fully installed for local processing, the terminal is currently awaiting regulatory clearance to expand its operations to overseas markets. This is subject to the biometric processing for customs and immigration being approved by the Indian government.

The terminal also takes use of the city's reputation for technological innovation by deploying new apps. For instance, BLR Pulse, the airport's newly-launched app, provides a number of useful features, such as flight status updates, waiting times, and the ability to order meals for delivery or pickup at certain locations. Because the app is compatible with Digi Yatra, the airport can employ biometrics all the way through a passenger's trip. In the future, the app will have capabilities like cab booking, priority access to lounges, security lanes, and immigration, and it will integrate the Digi Yatra facial biometric technology.

- **Maintaining A Long-Term Viability**

In 2023, BLR got all of its energy from renewable sources since sustainability and technology kept coming together. Solar power accounts for 70% of the airport's energy production, while wind power accounts for 30%. Equally impressive is T2, which, even before opening to the public, had already achieved the distinction of being the biggest terminal ever to have been pre-certified as a LEED Platinum building by the US Green Building Council. Because of its eco-friendly layout and construction, the terminal is also Platinum certified by the Indian Green Building Council.

"Using renewable materials, intelligent building systems, and solar sharing are some of our holistic, sustainable design strategies," Raghunath explains. We started this procedure by putting solar panels on the roofs of different buildings that are located on the airside. A wind and solar power plant three hours away from the airport was also one of our investments. We linked it to the electricity grid, making sure the airport runs on green power only. On top of that, we are currently installing solar panels on T2's rooftop.

- **Advice From Experts**

Airports face a multitude of competing priorities when designing a high-traffic, high-security public space like an airport terminal. These include ways to reduce passenger stress, increase revenue, optimise operations, implement the latest technology, ensure cleanliness, build for the future, and so on. Derek Moore of SOM offers three suggestions for airport terminal design to those airports that are currently grappling with this issue. Developing an appropriately sized plano-spatial framework for the building is the first, and it may sound straightforward, but it is often not accomplished to the degree that it should. Efficient design is required, but not at the expense of

flexibility or responsiveness to changing operating demands. So that areas like immigration, baggage claim and other such areas do not feel cramped and low, it is crucial that the building sections housing bigger passenger spaces have ceiling heights that are proportional to the plan dimensions.

While it may be easier said than done, our second piece of advice is to make things as versatile and adaptable as possible when designing. Reaching this objective will necessitate some structural changes to the structure, which can conflict with other parts of the programme. It also necessitates expanding the site design to incorporate potential extensions.

Finally, and maybe most importantly, think about how to make the airport terminal fit the specifics of the property. Rather than depending on literal graphics, fleeting internet trends, or flimsy interior design, how can one convey the ineffable soul of a city, region, or country? Understanding the local context, conducting thorough study, and devoting significant mental energy are all essential components of this intricate alchemy.

- **Consistent Growth for the Future**

Designers were acutely conscious of the significance of protecting the terminal from future obsolescence in order to justify all this construction and sustainable planning in the end. With a jump from 9 million in 2009 to 27 million in 2018, the airport's passenger volume tripled in less than a decade.

Furthermore, Moore says, "Forecasts show demand at the airport as a whole growing beyond 50 million passengers per annum (mppa) in the new terminal in the coming years." With a capacity of 25 mppa, about 20 mppa of that is for foreign traffic. Additionally, the second step would increase the capacity by 10 mppa. These two main goals guided the design of Terminal 2's structural system: to be environmentally friendly through efficient structure and cost-effective through flexibility. Both goals had to be met without stopping the current processes of the terminal.

The innovative bamboo roof over the check-in and shop halls is one example of how the airport developed T2 with future growth capacity. It comprises long-span steel moment frames supported by steel columns spaced 18m apart. There are four interconnected posts that make up each column. A great deal of leeway to adapt to new circumstances has gone into the column grid design. It also installed skylights

throughout the terminal to let in plenty of natural light, filtered, so that the number of plants inside might grow in the future.

The transit hub and terminal are designed in a rectilinear layout, which allows for versatile aircraft parking, gate uniformity, and modular construction. The ability to adapt to changing circumstances was an integral part of Terminal 2's design, according to Lefkovits. In the dynamic aviation sector, every gate has the ability to "swing," or adapt, to accommodate various wide-body and narrow-body planes. This makes the terminal more adaptable to future changes in aircraft technology and ensures that gates are rarely idle for extended periods of time. To accommodate future innovations in passenger processing and building operations, we made sure the terminal was adaptable in its design.

Looking ahead, Raghunath predicts that airlines and other important players will place a greater emphasis on exchanging data. Also, consumers want more control and a smooth flying experience, therefore biometric technology that doesn't require touching anything is going to be more common. As mobile technology becomes more indispensable, we should expect to see a further transition towards delivering information and services through mobile platforms. So that T2 would last for a long time, we made sure to include these trends into its design. Furthermore, we have set aside room for a future Terminal 3 that is expected to open in the late 2020s or early 2030s. Our goal is to reach a maximum capacity of around 90 to 100 million people per annum by the early 2030s.

CHAPTER - 5

AVIATION SECTOR: TECHNOLOGY AND INNOVATIONS

"Innovation comes from recombining existing technology and different perspectives in innovation ways"

- Charles Kech

The aviation sector has always been at the forefront of innovation and technology, constantly pushing the envelope to improve passenger experience, efficiency, and safety. The aviation business is still advancing due to technology and innovation, which will shape air travel in the future by providing safer, more effective, and environmentally friendly options. The aviation sector has been greatly impacted by innovation and technology in the following important areas:

- **Design and Materials of Aircraft**

More ecologically friendly and fuel-efficient aeroplanes have been developed as a result of developments in materials science, aerodynamics, and manufacturing processes. In order to reduce weight and increase performance, aeroplane building is increasingly using composite materials like carbon fibre.

- **Technology in Cockpits and Avionics**

With the advent of digital flight displays, fly-by-wire systems, and sophisticated navigation and communication systems, cockpit technology has grown dramatically. The efficiency and safety of flying have increased because to cockpit automation, which includes flight management systems and autopilot.

- **Engine Technology**

Fuel consumption and pollutants have decreased as a result of the increased power and efficiency of petrol turbine engines. The development of engine technologies like geared and high-bypass turbofans has made aeroplane operations more ecologically friendly and quieter.

- **Air Traffic Control**

Radar, satellite navigation, and data transmission systems are examples of modern air traffic management technologies that enable more effective aircraft routing, lowering traffic and enhancing safety. Airspace management and capacity are further improved by next-generation technologies like Collaborative Decision Making (CDM) and Automatic Dependent Surveillance-Broadcast (ADS-B).

- **Experience of The Passenger**

With in-flight entertainment systems, onboard Wi-Fi, and networking becoming common equipment on many aeroplanes, technology has completely changed the in-flight experience. Additionally, airlines are spending money on amenities that improve passenger comfort, such mood lighting, ergonomic seating, and quieter interiors.

- **Maintenance Repair and Overhaul (MRO)**

Airlines can now track the health of their aircraft in real time and take pre-emptive measures to fix maintenance issues before they cause disruptions thanks to predictive maintenance systems, which are driven by data analytics and machine learning. In order to improve productivity and cut costs, 3D printing and robotics are also being used for component manufacture and maintenance jobs.

- **Sustainable Aviation**

The aviation industry is investing in alternative propulsion technologies like as hydrogen fuel cells, electric and hybrid-electric propulsion systems, and Sustainable Aviation Fuels (SAF) in response to growing environmental concerns. These developments are meant to lessen the industry's environmental impact and cut down on carbon emissions.

- **Urban Air Mobility (UAM)**

New urban transport options are being made possible by the development of autonomous aerial vehicles and electric vertical take-off and landing (eVTOL) planes. UAM offers quick and effective airborne transport for people and goods inside cities, which has the potential to completely transform urban mobility.

5.1 LEADING AVIATION TECHNOLOGIES REVOLUTIONISING THE AVIATION SECTOR [11]

Innovations are being created to better every aspect of air travel, and the aviation sector is undergoing a technological revolution. New, state-of-the-art technology is taking off and revolutionising the market. Every part of flying is being fine-tuned to make it safer, more efficient, and more enjoyable for passengers. This includes the runway as well as the cockpit.

The future of the aviation sector is being shaped by developing technologies, which has never been more dynamic. These innovations are changing the game and opening up a world of possibilities for new ideas. Some of these technologies are leading the pack and will undoubtedly alter the course of history. Most experts predict that the following aviation industry-altering technologies will be around for a long time.

- **Artificial Intelligence (AI)**

AI has a revolutionary effect on aviation because it reduces costs, improves safety, and simplifies operations. Predictive maintenance systems based on artificial intelligence (AI) can identify possible system faults ahead of time, and AI algorithms optimise flight paths to minimise fuel consumption and carbon emissions. AI chatbots also deliver travellers fast updates on weather, flight schedules, and other important information.

- **Blockchain**

Airlines are now able to track aircraft maintenance records, manage supplier chains, and safeguard passenger data from unauthorised access thanks to blockchain, a decentralised and distributed ledger technology that offers an irreversible and secure method of information storage. By using blockchain technology, airlines can easily confirm an aircraft's maintenance history, guaranteeing its dependability and safety. Additionally, it protects private passenger data and aids airlines in adhering to data privacy laws. This innovative technology has transformed aviation data management by offering a seamless and safe solution for data security.

[11] https://gmraviationacademy.org/blog/top-aviation-technologies-transforming

- **Internet of Things**

By enabling airlines to monitor and optimise several systems, including aircraft engines, navigation systems, fuel tanks, and in-flight entertainment systems, Internet of Things technology has completely changed the aviation sector. IoT sensors have the ability to identify any problems with aircraft systems before they get serious, which lowers downtime and improves safety. IoT sensors also collect information on passenger behaviour and preferences, which helps airlines improve customer happiness by tailoring the in-flight experience.

- **3D Printing**

Due to the ability to generate spare parts on demand, 3D printing allows airlines to retain less inventory while enabling more effective fleet maintenance. All things considered, the aviation sector has undergone a revolution thanks to 3D printing technology, which has made it possible to produce lightweight parts and vital components just in time.

- **Augmented Reality**

Airports may improve their customers' experiences by using augmented reality (AR) technology to provide real-time updates on flight status, directions, and important landmarks. AR can also be a useful training and simulation aid, allowing pilots to practice procedures in a virtual setting before putting them into practice in actual situations.

- **Cloud Computing**

The utilisation of cloud computing has the potential to greatly improve airline operations' efficiency by providing instant access to current data and insights. Cloud-based systems allow for the most accurate execution of activities like staff scheduling and flight planning. Moreover, cloud computing's universal access to data can improve decision-making quality and foster collaboration across the airline sector.

The aviation sector leads the way in technical innovation, and the effects of these developments are immense. The leading aviation technologies covered above are already revolutionising the sector, and it's safe to say that they will continue to do so for some time to come. By combining these technologies, safety has been raised,

expenses have decreased, sustainability has been strengthened, and passenger satisfaction has improved.

Although there have been difficulties in implementing new technologies, the aviation sector has proven incredibly resilient and adaptive in adjusting to these developments. The industry's capacity to use innovation and technology to stay ahead of the curve will determine its long-term success and growth.

The aviation sector will surely continue to lead the way in technical innovation in the years to come. New technologies that have the potential to significantly expand the sector, such augmented reality, cloud computing, and driverless aeroplanes, are already in the works. We can only speculate about the possibilities that lie ahead as the aviation industry undergoes its ongoing transition.

5.2 AIRPORT TECHNOLOGY'S TOP SEVEN TRENDS TO WATCH IN [12]

The newest developments in airport technology will surely change air travel like never before. In addition to improving the traveller experience, innovations in AI, metaverse, and sustainable development will propel airport company expansion.

The aviation industry's trailblazers who choose to broaden their scope of innovation can look forward to these seven fascinating technological opportunities.

(i) Robotics and Automation

According to a survey by Mordor Intelligence, by 2025, the airport robot market is expected to grow at a Compound Annual Growth Rate of 15%. Under the general heading of "smart airports," investing in automation and robots will probably result in additional growth in this industry. Since smart robots can offer passengers information and assistance whenever and wherever they need it, they are essential in removing the need for human-manned workstations. They also help to improve airport operations by simplifying floor management, baggage handling, and security screening. People who are disabled can benefit greatly from automated robots. Automated robots can help these travellers navigate airports without the need for extra assistance.

[12] https://mapsted.com/en-in/blog/airport-technology-trends

(ii) ChatGPT to Transform Consumer Experience and Improve Sector Functions

Several people have been using ChatGPT since its inception in late 2021, and they have been finding creative and novel ways to use the language paradigm. The announcement by Air India that it will be implementing GPT4 on its website to enhance the user experience, however, was the real turning point. At the CAPA India Aviation Summit in 2023, CEO Campbell Wilson stated that the language model would not be used in a "gimmicky" way, but rather that it will be applied to actually improve the airline's operations.

A number of major players in the market, like Morgan Stanley and the US payment processing company Stripe, have already declared their intent to deploy GPT4. There's no denying that the language model is the way of the future for numerous industries, including airports, given the large number of corporations investing in this technology. Soon, passengers on flights will be able to design unique itineraries without the anxiety and inconvenience that usually accompany this process. Currently, dealing with data that is not fully current and does not account for geolocation is a weakness for airports. By resolving a significant problem that airports around the world have been trying to solve, ChatGPT has the potential to change everything and completely transform the aviation sector. The industry is excited about the fact that AI chatbot development is far more agile than the internet's progress over the past few decades.

(iii) Sustainable and Unmanned Aviation

Advanced Air Mobility (AAM) gained public awareness in 2021, and results from a McKinsey study showed a considerable degree of interest. AAM firms went public, record-breaking investments were made, and manned AAM aircraft were in high demand. AAM funding will primarily concentrate on unmanned AAM and sustainable aviation as we approach 2023. A new supply chain that prioritises quality control, certifications, and low volume production will emerge to speed up the production of futuristic AAM. Growing interest will be seen in optimising maintenance, training, and infrastructure as Advanced Air Mobility approaches commercial production. This will help to guarantee a smooth transition for AAM clients and the industry at large.

(iv) Autonomous Systems in Airport Management

The best places to test advanced autonomous systems (AAS), the next generation of self-driving car technology, are airports. Modern technologies like computer vision, AI-powered object identification, and Light identification and Ranging (LiDAR) are utilised by these AAS to enable complete driving automation, doing away with the requirement for real-time monitoring or active physical control. AAS can handle a variety of airport use cases well. However, airport managers can find it difficult to understand the legal and regulatory obligations surrounding AAS and to determine whether they are appropriate for complicated use cases in deployments that are both airport-controlled and not. Although these technologies are still in the early stages of development, airport operators can gain a competitive edge by investing in advanced autonomous systems as early adopters.

(v) Advanced Location Intelligence & Data Analytics

Data and technology will play a major role in the decision-making processes of tomorrow's airports. Even with the wealth of data at hand, current approaches to managing the massive volumes of information frequently fail to recognise and address problems, leading to inaccurate estimates that do not account for the costs of delays that affect the entire system. That will all change, though, in 2023 and beyond. Airport delays are a regular occurrence, but they can be easily avoided with the right strategy. Although data can offer insightful information on passenger flow, airline schedules, taxi wait times, airport capacity, operational behaviour, and weather effects, it is not enough to provide a complete picture that enables prompt interventions. Predictive analytics are therefore essential for improved decision-making.

The use of cutting-edge technology can effectively address this specific difficulty. With real-time asset and person analysis, Mapsted's state-of-the-art location technology for transportation hubs improves situational awareness, provides traffic pattern insights, and maximises arrivals and departures. The location analytics platform from Mapsted is made to predict future operating circumstances using cutting-edge insights.

One of Mapsted's many distinctive features is its scalable technology, which enables it to automate data collection and visualisation. Additionally, we provide strong pre-built analytics tools made especially for marketers and administrators of airports. Furthermore, Mapsted offers a comprehensive platform that meets all kinds of analytics requirements.

(vi) Augmented and Virtual Reality

By 2025, the aviation augmented and virtual reality market is predicted to reach a projected value of USD 1,372 million, indicating a substantial growth trajectory. The aviation sector can use AR and VR technology for a variety of purposes, such as maintenance, training, and spotting possible threats. With the immersive and interactive approach that these technologies offer, the aviation ecosystem may be connected to enhance work efficiency and save costs. Improved customer experience, economic effectiveness, and a safer learning and maintenance environment are all possible with the usage of XR and Metaverse in aviation. Airlines are therefore anticipated to quickly use these solutions in order to transform the in-flight and landing experience.

Furthermore, Virtual Reality (VR) and Augmented Reality (AR) are not just catchy buzzwords to boost employee and staff training efficacy; they also have enormous potential to deliver unmatched in-flight entertainment. In the business lounge at Frankfurt Airport, Lufthansa tested Avegant's Glyph video glasses, giving patrons a cinematic experience. At the 2017 CES technology tradeshow, these spectacles were recognised with the Innovation Award Honoree. More airports and airlines will collaborate in the future to entice travellers with cutting-edge technology in order to promote seat upgrades.

(vii) Cloud, 5G and IoT

One of the biggest problems with air travel is the deteriorating infrastructure and the never-ending battle to keep up with the growing number of passengers. Year after year, lines grow longer, planes get overbooked, and airport space fills to capacity, overtaxing airport infrastructure and going above and beyond what is sustainable for travellers and airport stakeholders. The average terminal in the United States is forty years old, and by 2037, 8.2 billion people are predicted to travel by air worldwide. This shows how out of step passenger growth is with infrastructural readiness. Airports and airlines have

worked together to improve their terminals in order to meet future demand in order to address this difficulty. However, passengers will be negatively impacted by this modernization drive since they will have to put up with the disruption brought on by the continuing work.

In the future, new technologies like cloud computing, 5G, AI, and the Internet of Things (IoT) will all work together to support sustainable airport operations, which will boost earnings potential, efficiency, and visitor experience.

Within this framework, Mapsted has already committed to modernising airports through the use of smart location technology that does not require hardware. With its cutting-edge indoor wayfinding and location marketing solutions, the company is transforming airports and opening doors for airport-based businesses while also making it possible for travellers to receive personalised attention more quickly.

The utilisation of sophisticated air mobility, autonomous systems, data analytics, robotics, automation, and location intelligence will all skyrocket in airports by 2023. By expediting security checks, luggage handling, and floor management, smart robotics, sophisticated autonomous systems, and data analytics will improve the traveller experience. The industry intends to refocus its spending from manned aircraft to unmanned aerial mobility and sustainable aviation. Airport decision-making will be heavily influenced by data and technology, with cutting-edge systems leveraging real-time location intelligence to improve situational awareness. Furthermore, by designing customised itineraries for visitors without the stress or difficulty, ChatGPT will completely transform the client experience. We have put up a presentation if you're interested in finding out how a location-based solution might improve the operational capabilities and passenger experience at your airport. This little video could be entertaining too. Speak with Mapsted right away to become the first to use cutting-edge airport positioning technology. To experience the revolutionary powers for yourself, just get in contact and ask for a free demo.

5.3 AIRPORT SECURITY AND AI: BALANCING SECURITY AND PRIVACY [13]

Airports facilitate global travel and trade in today's fast-paced world. Protecting passengers, airline crew, and airport staff is crucial. However, as aviation security issues rise, more efficient and effective security measures are needed. Artificial Intelligence (AI) is changing airport security and generating privacy and civil liberties concerns.

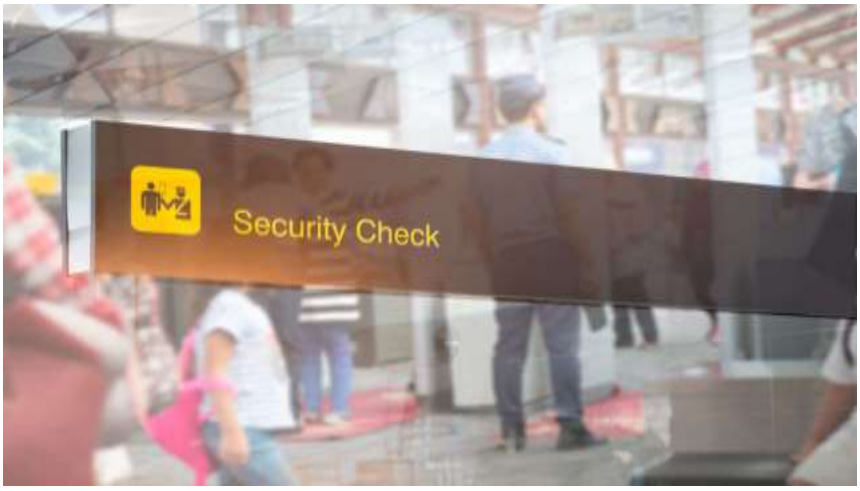
- **The Development of Security at Airports**

Over time, airport security has changed dramatically. New technologies have been added to traditional procedures like metal detectors and manual luggage checks. AI has changed the game in the field of aviation security in recent years. It has many features that improve security protocols and simplify airport operations.

- **How Does AI Improve Security at Airports?**

  - **Enhanced Threat Detection:** Artificial intelligence (AI)-driven security systems are able to instantly examine enormous volumes of data from a variety of sources, such as aircraft schedules, cameras, and passenger profiles. Airports can now swiftly and correctly detect any threats thanks to this. Security staff may receive notifications to investigate suspicious behaviours, such as strange movements or conversations.
  - **Biometric Authentication:** Biometrics have become essential to airport security, much like facial recognition and fingerprint scanning. By comparing a passenger's biometric information with their travel documentation, AI algorithms can verify that the individual boarding the aircraft is, in fact, who they say they are. This lowers the possibility of identity theft and increases the effectiveness of passenger screening.

[13] https://acorel.com/en/the-role-of-ai-in-airport-security-balancing-security-and-privacy/



- **Predictive Analysis:** Using patterns and previous data, AI can forecast possible security risks. Airports can proactively strengthen security measures and direct resources where they are most needed, preventing potential security breaches, by spotting patterns of suspicious behaviour or developing threats.
- **Customised Security Measures:** By using AI, airports can set up distinct security procedures for different types of travellers according to their risk profiles. Regular passengers with comprehensive background checks can be subject to accelerated screening, while suspicious people might be subject to closer examination. For passengers who pose little risk, this "risk-based" strategy reduces discomfort while enhancing security.

➢ **Managing Airport Security while Maintaining Privacy**

Although no one can deny AI's advantages for airport security, but privacy and civil liberties are also raised concern. It's critical to strike the correct balance between personal liberty and security. These are some important things to remember.

- **Data Security:** Large volumes of personal data, such as travel records and biometric data, are needed for AI systems. Protecting the privacy of passengers requires making sure that this data is handled responsibly and stored securely. Airports are required to abide by data protection laws and conduct routine data security audits of their AI systems.

- **Openness & Responsibility:** Airports should be open and honest about their AI-powered security procedures in order to foster public confidence and trust. Passengers need to be well-informed about the usage and storage of personal data, and clear norms and guidelines need to be set. Mechanisms for independent accountability and supervision can aid in ensuring AI is used responsibly.
- **Non-Discrimination:** Thorough testing of AI systems is necessary to avoid prejudice and discrimination. Human rights and civil freedoms may be violated by algorithms that unfairly target particular individuals or groups. To guarantee that AI-driven security measures do not discriminate against any group, audits and changes must be performed on a regular basis.
- **Option to Opt Out:** If a passenger feels uneasy with AI-based security procedures, they should be allowed to opt out, but this will need extra traditional security checks. This preserves general security while honouring personal preference.

5.4 CURRENT AIRPORT ACCESS SOLUTION TRENDS: IMPROVING SECURITY & PASSENGER EXPERIENCE [14]

As the globe becomes more accessible for foreign travel, security precautions need to be strengthened, which has led to a rapid growth in technology. Airports must make sure all security is in place and use top-notch access control systems to prevent unwanted access. In essence, access solutions are ways to manage who has access to facilities, buildings, and restricted locations.

Airports are especially difficult because they have to strike a compromise between optimal passenger experience and security. Airport surroundings are undoubtedly getting more complicated; thus, safety concerns must stay current. Accordingly, airports require cutting-edge access solutions to guarantee that operations function properly and without causing passengers any inconvenience. Even more crucially, airport access control systems need to be strong enough to recognise and resist manipulations that can endanger passenger safety, airport security, or general aviation safety.

[14] https://go.dormakaba.com/articles/latest-access-solutions-trends-in-airports-enhancing-security-and-passenger-experience.

The demand for synchronised processes that are efficient and supported by a comprehensive airport security policy is growing. As a result, numerous novel access solutions have emerged in airports to enhance both passenger experience and security. These consist of data analytics, access control systems, and biometric technology.

- **Increasing Airport Security**

Airports are significant locations because they handle daily cargo and passenger transportation. Airports need to have strong security measures in place to keep everyone safe.

However, it's crucial to make sure that the passenger flow isn't overly impeded by the security procedures. Striking this balance can be difficult. New trends and technologies are being created to assist keep airports secure as security concerns get increasingly complex. Among them are:

(i) Biometric Technology: To increase passenger security and speed, airports are increasingly utilising biometric technology. This method uses unique biological characteristics such as fingerprints, face recognition, or iris scans to confirm an individual's identity.

The primary benefit of biometric systems is their ability to replace conventional forms of identity, such as passports, which are susceptible to theft. Because each person's biometric data is unique, impersonation is not conceivable.

In order to further verify passenger identities, the biometric data can also be connected to other security systems, such as facial recognition systems.

(ii) Improved Radiography Screening: Using security equipment, advanced X-ray scanning looks for potential threats in carry-on luggage and other personal belongings. To identify any object that can endanger passengers or crew, X-rays are used to create photographs of the contents of the baggage.

Millimetre wave technology and backscatter X-rays are the most often employed. Millimetre wave technology creates a three-dimensional image of the contents of the bag using radio waves, whereas backscatter X-rays employ low-dose X-rays to provide a detailed image of the contents of the bag. Both have demonstrated efficacy in detecting firearms, explosives, and other items that are prohibited.

(iii) Integrating Security Systems: An all-encompassing security solution can be achieved by integrating several security systems, such as biometric technology, X-ray scanning, etc. Increased security and better information sharing between various security systems are provided by this.

(iv) Drone Use: These unmanned aerial vehicles are used to monitor vital infrastructure, patrol airport perimeters, and conduct surveillance missions. To detect and track unusual activity, they can be fitted with cutting-edge sensors and cameras, enhancing the security of air travel.

(v) Artificial Intelligence and Machine Learning: The application of machine learning (ML) and artificial intelligence (AI) is becoming more and more common in airport security. These cutting-edge technologies make it easier to automate a number of security processes, such as inspecting cargo and baggage and identifying possible security risks.

Moreover, large-scale datasets, like passenger and flight data, can be examined closely using AI and ML to spot possible security flaws. This improves airports' overall security and increases everyone's safety when travelling.

(vi) Mobile Access Solutions & Smart Locks: These innovations, which enable travellers to access airport amenities using their mobile phones instead of traditional keys, are one of the largest trends in the airport sector. This redesign reduces the likelihood of misplaced or stolen identity cards and keys, improving both the convenience of the traveller experience and security procedures.

5.5 SYSTEM FOR AUTOMATED BAGGAGE HANDLING

Airports and airlines can save money and provide better service to passengers by installing automated baggage handling systems. These systems use technology to improve the efficiency, accuracy, and dependability of processing passenger bags. In today's airports, automated baggage handling systems are vital for increasing productivity, decreasing human error, and bettering the travel experience for passengers. These systems accomplish their aims in the following ways:

- **RFID & Barcode Technology:** RFID (Radio Frequency Identification) tags and barcodes that carry flight information and passenger details are attached to baggage tags. Error rates are decreased since automated systems can swiftly scan and follow these tags during the luggage handling procedure.
- **Automated Sorting Systems:** Using barcode or RFID information, sophisticated conveyor belts and sorting devices automatically direct bags to the right location. By doing away with the necessity for manual sorting, handling times are sped up and errors are greatly decreased.
- **Baggage Screening Technology:** To guarantee that all bags are appropriately scanned for prohibited materials, automated systems combine with security screening equipment. This minimises delays in the baggage processing procedure while enhancing security.
- **Real Time Tracking & Monitoring:** Automated solutions enable airport workers to swiftly detect and address any potential problems, such misplaced or delayed luggage, by giving them real-time visibility into the whereabouts of each bag.
- **Passenger Information System Integration:** For a smooth transmission of luggage information, automated baggage handling systems can be coupled with airline reservation systems. This integration guarantees that luggage are moved between connecting flights correctly and helps prevent misrouting.
- **Baggage Reconciliation System:** To make sure that every bag is present, these systems check the passenger manifest against the luggage that is loaded aboard each flight. Reconciliation procedures that are automated reduce the possibility of misplaced or damaged luggage.

- **Effective Process for Baggage Claim:** By precisely sorting and delivering luggage to the appropriate baggage claim location, automated technologies expedite the baggage claim procedure. Passenger wait times are shortened as a result, and general satisfaction is raised.
- **Predictive Maintenance:** Predictive maintenance methods can be used by automated systems to foresee possible problems with sorting machines, conveyor belts, and other equipment. Airports can reduce downtime and guarantee the ongoing functioning of baggage handling equipment by proactively addressing maintenance needs.
- **Provide Robotic Support:** Robotic devices are being investigated by certain airports to help with duties like moving bags around the terminal or loading and unloading luggage onto conveyor belts. Airport workers can work more efficiently and with less physical strain thanks to these robots.

5.6 SMART AIRPORTS

A SMART airport, also called a Smart Airport or an Intelligent Airport, is one that uses cutting-edge technologies and data-driven solutions to make the airport safer, more efficient, and better for passengers. These airports use a range of digital technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), data analytics, and automation, to make their processes run more smoothly and give passengers and other stakeholders a smooth travel experience.

- **The Rise of Smart Airports:** Smart Airports were created to meet the control and management needs of airports that are having more and more trouble with the large number of people and things that pass through them.

5.6.1 IMPORTANT DOMAINS FOR DIGITAL CHANGE IN SMART AIRPORTS [15]

Modern technology solutions that allow for monitoring, process automation, and 360° control have been implemented in both airport administration and the development of new airports throughout the past several years. The three areas are as follows:

[15] Linkedin Article: Inside Bytes, Weekly News Letter "The Future of Airports: Tech driven SMART Airports", April 26, 2023

(A) Digitalization of Infrastructure

To facilitate effective communication and data sharing, infrastructure digitization entails integrating airport assets and infrastructure. It features data-driven insights for decision-making and smooth connectivity.

Source: Siemens

- **Connectivity:** An essential component of digitalizing infrastructure is connectivity. It makes it possible for various airport assets to easily communicate with one another, including parking structures, security systems, and baggage processing systems. Airport operations can be made safer and more efficient by incorporating these systems. To lower the possibility of misplaced or delayed luggage, baggage handling systems can be integrated with flight schedules to guarantee that bags are put onto the appropriate aircraft.
- **Decision Making:** Decision Making based on data is just another crucial component of digitalizing infrastructure. Airport managers can get insights into their operations, spot bottlenecks, and make data-driven decisions to streamline procedures, distribute resources effectively, and enhance overall performance by gathering and evaluating data from a variety of airport systems.

(B) Digitalization of Commercial Flow

Trade movement Utilising technology to enhance the movement of products and services at airports is known as digitalization. Process automation and the establishment of reliable network systems are part of it.

Source: STAT Times

- **Infrastructure for Networks:** For real-time communication and data sharing between various airport stakeholders, including airlines, ground handlers, and cargo carriers, robust network solutions are necessary. When a strong network infrastructure is in place, stakeholders may collaborate more effectively and efficiently by exchanging real-time information regarding aircraft schedules, cargo deliveries, and other crucial data.
- **Automation of Processes:** Another essential element of digitalizing the commercial flow is process automation. Resource planning, cybersecurity, and shipment tracking are all possible with automation. The danger of loss or damage can be decreased by using automated cargo tracking systems, which can offer real-time information about the location and status of cargo. Airports can manage resources more effectively by using automated resource planning, such as allocating gates and parking spaces for aircraft. By automating threat detection and response, cybersecurity automation can improve security.

(C) Digitalization of Passenger Flow

Source: Infsoft

Digitalization of passenger flow refers to the application of technology to enhance passenger experience and optimise airport operations. Real-time data analysis and the implementation of cutting-edge technologies are part of it.

- **Streamlining Operations:** One of the main components of digitalizing passenger flow is operations streamlining. This entails employing cutting-edge technologies to boost customer pleasure and optimise airport operations, such as sophisticated queue management systems and dynamic signs. Intelligent queue management systems have the potential to decrease wait times at security checkpoints by automatically routing passengers to the shortest queue. Additionally, dynamic signage can furnish up-to-date information regarding aircraft delays and gate changes.
- **Data Analysis:** Another essential element of digitising passenger movement is data analysis. Airports may enhance customer experience and streamline procedures by tracking and evaluating real-time data from various systems, including boarding gates, baggage handling systems, and check-in kiosks. Real-time data analysis, for instance, can help airports discover bottlenecks and deploy resources more effectively, resulting in quicker passenger check-in times and shorter wait times. Furthermore, by utilising passenger data to provide customers customised recommendations and services based on their tastes and behaviour, personalised customer experiences can be produced.

5.6.2 INNOVATIVE APPLICATIONS IN SMART AIRPORTS

1. Optimised Airport Operations

- **Self-Service Amenities:** Airport self-service areas are intended to make the check-in procedure quicker and more effective for travellers. Airports increasingly frequently have time-saving biometric identification system-equipped luggage drop stations and check-in kiosks. By utilising fingerprints or facial recognition to confirm a passenger's identity, biometric identification systems can expedite the check-in process and eliminate the need for manual identity checks. Additionally, self-service amenities can ease line-ups at check-in desks, facilitating quick and simple check-in.

Source: Compass Magazine

- **Intelligent Queue Management:** Smart airports also use intelligent line management, which is a new idea. Systems that are run by AI can cut down on wait times at customs, security, and boarding gates. These systems use real-time data to guess how many people will be at each stop and figure out the best way to let them go through. For instance, AI programmes can look at how long the lines are and change how many people are working at each checkpoint based on that information. Smart wait management can help clear up traffic and make the whole airport experience better for people.
- **Predictive Maintenance:** Another new idea used in smart airports is predictive maintenance. AI and IoT-based solutions can be used to maintain aeroplanes, which makes them safer to fly and cuts down on delays. Sensors and data analytics are used in predictive maintenance to find possible problems with planes before they become big ones. For instance, sensors can check the health of the engines, the plane's structure, and other important systems. Then, AI algorithms can be used to look at this data and figure out what problems might happen so that repairs can be planned before they do. Predictive maintenance can help make planes safer and more reliable by lowering the chance of breakdowns that happen out of the blue.

2. Airport Safety Measures Revised

- **Biometric Identification:** The use of biometric identification is essential to improved airport security. Sophisticated facial recognition, fingerprint, and iris scanning technology can be applied to enhance security and facilitate smooth passenger processing. Systems for biometric identification can speed up security checks and lower the possibility of identity theft. Using facial recognition technology, for instance, security staff can be notified if a passenger's face matches a database of known terrorists or criminals. Additionally, biometric identification can lessen the requirement for human identity verification, streamlining and reducing the possibility of error in the process.

Source: Analytics Insight

- **IoT Based Surveillance:** Another cutting-edge use in airport security is IoT-based monitoring. Effective threat identification and effective airport property monitoring can be achieved with the deployment of AI-powered integrated surveillance systems. Security cameras, access control systems, and environmental sensors are just a few of the many types of data that these systems may monitor for irregularities and possible security risks. For instance, artificial intelligence (AI) systems can examine surveillance footage to find people on watch lists or flag questionable activity, such as someone leaving unattended luggage. By lowering the possibility of security breaches, IoT-based surveillance can enhance airport security measures.

- **Cybersecurity:** To further strengthen airport security, cybersecurity is also essential. Smart systems, communications, and sensitive data can be protected from possible cyberattacks with AI-powered cybersecurity solutions. In addition to malware, ransomware, and phishing attempts, cybersecurity solutions may assist defend against a variety of other threats. AI systems can be used to examine network traffic and identify any dangers instantly, enabling security staff to take immediate action and stop possible intrusions. Monitoring employee activities and spotting odd behaviour are two more ways that cybersecurity solutions can assist defend against insider attacks. Upholding airport security and safeguarding private passenger and operational data depend on cybersecurity.

3. Sustainable Airport Management

- **Infrastructure That Uses Less Energy:** Infrastructure that is energy-efficient is essential to sustainable airport management. The airport can lower its energy use and carbon footprint by installing solar panels, LED lighting, water-saving devices, and other green technologies. The airport's reliance on non-renewable energy sources can be decreased, for instance, by using solar panels to produce renewable energy. Lower maintenance expenses and energy usage can be achieved with LED lighting. Water-saving devices can help cut down on how much water is needed for airport operations, such landscaping and bathrooms. Airports can lessen their environmental effect and become more sustainable by implementing energy-efficient infrastructure.
- **Smart Monitoring:** An additional crucial component of sustainable airport management is smart monitoring. Environmental characteristics like temperature, air quality, and energy consumption can be monitored in real-time to provide valuable insights into the most efficient use of resources. Temperature sensors, for instance, can be used to keep an eye on the temperature in various airport areas, enabling more effective usage of the HVAC system. By identifying and resolving indoor air quality problems, air quality monitors can enhance both the staff and customer experience at airports. Airports that use smart monitoring can maximise resource utilisation, cut energy use, and save operating expenses.

Source: Deloitte

- **Waste Management:** Airport waste management is a crucial part of running an airport sustainably. Airports can lessen their environmental effect by implementing recycling, resource recovery, and trash reduction programmes. Recycling programmes for paper, plastic, and aluminium can be established by airports, for instance, to lessen the burden on landfills. By recycling food scraps through composting programmes, the airport can lessen its impact on the environment. It is possible to extract metals from electronic trash and other valuable materials through resource recovery programmes. Improved sustainability and reduced environmental impact can be achieved by airports through better waste management.

5.6.3 THE BENEFITS OF SMART AIRPORTS

Some benefits of a smart airport include:

- Utilisation of real-time data led to enhanced operational efficiency.
- The optimisation of processes, raising productivity, and decreasing operational expenses.
- Better demand optimisation as a result of automated entrance procedures and tighter regulation of passenger flows.
- A vastly enhanced traveller experience as a result of enhanced passenger services, flight control, check-in, and so on.
- The use of biometric monitoring systems to increase safety and security, stronger cyber defences, and more dependable facility operations and maintenance.
- Enhanced health monitoring and on-site services (cleaning schedules, amenity availability, etc.,)

5.6.4 IMPLEMENTATION

Ease of Implementation 	Connected technologies supporting Smart Airport operations need to meet the local requirements, standards and KPIs. Each technology must be fully reliable, and safety should be enhanced rather than compromised. Hence, various use cases should be tested and validated to deliver the relevant accreditations for the use of technologies in airports. Given the high safety and security risks associated with airports, the implementation of such technologies is not easy and is more likely to be staggered.
Cost 	Investments in Smart Airports are lower for new-build airports and the investment costs can typically be repaid from operational revenues. For existing airports, looking at upgrading their operations, the migration cost of the technologies might be higher and require more development, testing and integration. However, as for newer Smart Airports, they will provide benefits over the mid- to long-term.
Country Readiness 	Smart Airports require staff to be trained to use new technologies and be able to provide training to their peers. This upskilling of staff could be more straight-forward in more advanced markets.
Technological Maturity 	While current technologies in place in airports are mature and have been implemented in airports around the world, the technology is still improving to meet future demand and safety/security requirements. Implementation trials need to be performed before a technology is integrated in the Smart Airport operation, to make sure it is reliable, and the requirements are met.

5.6.5 RISK AND MITIGATION [16]

➢ **Implementation of Risk**

- **Risk:** Testing and installing new technologies could make it harder for the airport to run smoothly and make the experience of passengers worse. It could also make the airport less safe.
- **Effects Reduction:** To keep operations running smoothly and keep passengers happy, airport officials and operators should come up with management plans to add new technologies to existing airports and deal with all available risks. Prior to opening, all standards should be met by new airports.

[16] chrome extension://efaidnbmnnnibpcajpcglclefindmkaj/https://cdn.gihub.org/umbraco/media/ 3599/45 -smart-airports.pdf.

- **Social Risk**

  - **Risk:** Some technologies, like face recognition or advanced screening, can be seen as intrusive, which could make it hard for people to accept them. People may also not want to communicate with machines and robots. It might also be hard for staff to figure out how to use these new tools for tasks related to implementing technologies, so they will need to be trained.
  - **Mitigation:** It is important to talk to all of the airport staff who will be affected by the new technologies and include them in the process of designing the solutions. The staff needs to be trained so that they can help travellers as needed.

- **Safety and Cyber Security Risk**

  - **Risk:** Smart airports use sensitive traffic operations data about where planes are going and personal information about passengers that is tied to facial recognition. This means that privacy and safety are at risk if the data being sent and gathered is stolen or not reliable.
  - **Mitigation:** To get rid of hacking risks, airports should make sure their systems are strong and work better with law enforcement to find safety and crime risks. In addition, states should make laws to keep private information safe.

- **Environmental Risk**

  - **Risk:** Smart airports make flying easier, but they could also make more people want to use air services. This might cause more carbon emissions, which is bad for the earth.
  - **Mitigation:** Carbon goals should be set by governments so that airport operators, authorities, and air traffic control can work together to make a plan that spells out the technology needs.

5.6.6 SMART AIRPORTS: SOME EXAMPLES

Example	Implementation	Cost	Timeframe
London Heathrow Airport	British Airways is trialling autonomous robots to guide passengers around Terminal 5. They have also trailed self-driving luggage vehicles and installed automated bag drop machines and self-boarding technology across the airport. They have undertaken extensive staff training programs to enable staff to utilize a suite of specialised apps to solve customer issues.	Part of British Airways' GBP 6.5 billion investment for customers.	British Airways has been experimenting with automation for several years. The autonomous robots are being trialled in 2020.
Hamad International Airport	The airport launched next-generation self-service check-in kiosks and self-service bag drops with biometric technology capability. Additionally, a mobile Automated Visa Document Check has been introduced which enables ground service operators to check passenger visa documentation before they board.	The self-service kiosks are faster than the traditional methods, allowing passengers to process one bag in less than 50 seconds. As per the reports, the new launch is estimated to speed up the processing by 40%.	The self-service kiosks and bag drop facilities have been available to passengers since 15th October 2018. The service will be extended to foreign airline passengers in the near future.
Singapore Changi Airport	The airport is integrated with technologies including sensors, data analytics, and artificial intelligence to enhance the customer experience while improving productivity. They developed a blockchain based digital wallet that enables passengers to use frequent flyer rewards at airport retailers.	The airport extension, a project named 'Jewel Changi', cost SGD 1.7 billion.	The blockchain digital wallet was launched in 2018. The 'Jewel Changi' airport extension opened in 2019.
New Delhi International Airport	The integrated terminal includes several advanced technologies: Self Baggage Drop (SBD) kiosks, Facial Recognition, Automated Tray Retrieval System (ATRS), and Common Usage Self Service (CUSS) to reduce queues and ease the flow of passengers.	The whole renovation and expansion programme is expected to cost USD 2 billion.	The contract was awarded in January 2006 with a master plan having been developed for the development of the airport over the next 30 years.
Dubai International Airport	Dubai Airport's Smart Tunnel uses facial recognition and artificial intelligence to allow passengers to go through passport control procedures in just 15 seconds without human intervention.	High investment cost but significant operations cost savings through passenger efficiency clearing customs and reduction in human involvement in the process.	It took four years to develop the Smart Tunnel which was launched in October 2018.

CHAPTER - 6

PASSENGER EXPERIENCE & SATISFACTION

"One Customer well taken care of could be more valuable than $10,000 worth of advertising"

- *Jim Rohn*

Modern airports serve as entry points to every corner of the globe. Travelling through them is like embarking on a journey. Airports are increasingly concentrating on passenger happiness and making their experiences unforgettable as the aviation industry undergoes continuous transformation.

An outstanding travel experience for passengers is easily achieved through simplified check-in, efficient luggage processing, and faultless navigation. Optimal and quick check-in at self-service kiosks, tracking and matching of bags through baggage reconciliation, and monitoring of passenger movements and resource allocation through passenger flow management systems are all examples of the state-of-the-art technological solutions that progressive airports invest in. Travellers may relax thanks to these technical developments, which improve cleanliness and safety. These days, passengers may expect a more refined, efficient, and pleasurable trip thanks in large part to technological advancements that improve the whole passenger experience.

- **Cultural Enrichment and Exceptional Hospitality**

Hospitality and friendliness are hallmarks of airports that put their customers first. Travellers can transform a possibly negative experience into a positive one when they interact with friendly staff. There are airports that go above and above by providing amenities like lounges, free drinks, and fast Wi-Fi. In order to elevate the airport experience, some even offer spa facilities, relaxation zones, and cultural exhibitions. Travellers can be delighted by regional and international cuisines showcased at airports through culinary events that highlight local culture. Waiting for a flight becomes more pleasurable and memorable with all of these.

- **Green Initiatives & Seamless Connectivity**

A growing number of airports are making efforts to lessen their impact on the environment. Sustainable building materials, solar electricity, and waste reduction are just a few examples of eco-friendly measures that can be used to both attract eco-conscious travellers and help keep the earth clean.

Last but not least, airports need to be conveniently located and linked to the rest of the city and its suburbs. Taxis, buses, and trains all work together to make sure people don't have to worry about getting where they're going.

Airports are increasingly committed to providing passengers with first-rate experiences that exceed their expectations in areas such as accessibility, culture, comfort, technology, sustainability, and service. In today's competitive airport industry, airports are vying for recognition for their outstanding performance. Skytrax's rankings are highly regarded as a measure of airport commitment to providing travellers with unforgettable journeys via the improvement of every aspect of the passenger experience.

6.1 SKYTRAX'S RANKING OF THE WORLD'S TOP 10 AIRPORTS [17]

Skytrax, the go-to site for airport rankings, polls millions of travellers every year to get their honest opinions. These surveys are a great way to get a feel for how well an airport is doing in terms of accessibility, facilities and amenities, customer service, efficiency, and sustainability (through things like green energy and waste reduction, among other things).

The SkyTrax World Airport Awards have announced their 2023 winners, and among them are the following ten airports:

- **Singapore Changi Airport (SIN):** Reputation for efficiency, first-rate facilities, beautiful design, and innovative art displays.
- **Directorate of Health (DOH) Airport in Hamad:** Presents state-of-the-art technologies, art collections, and opulent lounges.
- **Tokyo International Airport (HND)**: Highlights cutting-edge terminals, a variety of eating options, and a firm dedication to passenger safety.
- **Incheon International Airport (ICN):** Renown for its easily accessible terminals, shops, and restaurants.
- **The airport in Paris, known as (CDG):** Provides a variety of services while being efficient and connected.
- **Airport in Istanbul (IST):** Remarkably large, with excellent service and a wide variety of shops and restaurants to choose from.
- **Airport Munich (MUC):** Prominent features include cutting-edge architecture, eco-friendliness, and first-rate amenities.
- **The Zurich Airport (ZRH):** Travellers are known to have a pleasant experience at Switzerland's busiest airport.
- **Airport Narita International in Tokyo (NRT):** Renown for its punctuality and ability to accommodate passengers with ease.
- **Barajas Airport in Madrid (MAD):** The primary airport in Madrid that links Latin America and Europe, guaranteeing a trouble-free journey.

[17] Airport Industry New: Article by TAV Technologies, “What makes an Airport provide the Best Passenger Experience?”, 6 October, 2023.

6.2 PASSENGER'S EXPERIENCE

How airlines and passengers interact at airports is called the airport passenger experience (PAX). This encompasses the full customer journey at the airport, beginning with ticket purchase and ending with baggage claim at the destination.

Due to a number of problems, including flight delays, overbooking, security check, wait times, and more, airports have unfortunately earned a terrible reputation among customers.

➢ Importance of Passengers' Experience [18]

Airports may question the value of investing time, energy, and resources into improving passengers' experiences now that the subject is trending.

Airport passenger experience can be improved and made more valuable in the following ways:

- Increased non-aeronautical revenue and happier customers are the results of superior customer service.
- The groundwork for a customer-centric strategy is laid when the client feels their voice has been heard.
- We can learn about the traveller's habits and anticipate their needs with its help.
- A smooth transition from one part of the airport customer journey to another is established by the passenger experience. For instance, the customer experience at the airport connects the check-in and security processes.
- Positively impacts people's views of their brand and attitudes towards it.

➢ What Elements Impact the Level of Satisfaction Felt by Airport Customers?

Airports, like every other industry, rely heavily on happy customers. But there are a lot of things that might happen at the airport that can affect how happy a passenger is. Here we'll go over some of the factors that make airports great places to visit, such as how easy it is to find your way about, how quickly you can go through security and check-in, what facilities are available, and how good the customer service is. If airport officials

[18] https://tatvaminsights.com/improve-passenger-experience-at-airports/

and employees are aware of these elements, they will be better able to enhance passengers' experiences.

1. User-Friendly Navigation

- **Unobstructed Signs:** Overhead signs and floor markings should be clear and easy to understand so that passengers may navigate the airport more easily.
- **Online Maps**: To make it easier for passengers to find what they're looking for, airport apps or screens should have interactive maps.
- **Helpful Links:** To better serve passengers with directions and questions, set up information counters or help desks at strategic locations.
- **Easily Accessible Data:** Make navigation easier for all passengers by displaying information in several languages and formats.

2. Speed of Check-in & Security Process:

- Automated check-in and luggage drop-off kiosks would greatly improve efficiency.
- A more efficient use of modern technologies, such biometric scanning, for security checks might significantly cut down on wait times.
- Staff training and the simplification of security procedures will guarantee fast and efficient processing.
- Make things go more quickly by providing special lanes for people who fly frequently or have disabilities.

Recommended Actions: Travellers will be much happy and more satisfied with the service they receive if the security checkpoints and passport control procedures are automated.

3. Access to Amenities

- To accommodate a wide range of dietary restrictions, provide a number of alternative eating options.
- Put in cosy seating spaces with places to charge phones and other electronics.
- Make sure the amenities, including restrooms, are clean and well-maintained.
- Provide guests with areas to relax and have fun, including lounges, spas, and gaming areas.

- Be sure to incorporate shopping centres and convenience stores so that people can quickly obtain the things they need.

4. Service Excellence for Customers

- Unwavering Reaction: Make sure that everyone on staff is giving passengers the correct information at all times.
- Individualised Support: Provide passengers with unique requirements with individualised assistance.
- Effective Expression: Make sure there are well-defined avenues for customers to voice their concerns and ask questions.

Advisory Note: Assuming they are pleased with the service they receive, 90% of passengers will return to the airport.

➢ **How Can Airports Make Customers Happier?**

Airports can make customers happier by focusing on a few key areas that have a direct effect on how passengers feel. There are a few methods they can use.

Quick and Easy Check-In: Self-service kiosks, online check-in, and designated lines for people to drop off their bags will speed up the check-in process. This cuts down on wait times and makes the whole experience better.

Smooth Security Screening: Set up efficient security screening procedures with the help of new screening technologies, lanes just for people with TSA Pre Check or similar programmes, and clear signs to help people get through the process quickly.

Comfortable Waiting Areas: Make the waiting experience better for travellers by giving them comfortable seats, lots of places to charge their phones and other electronics, Wi-Fi, and extras like shops, restaurants, and lounges.

Clear Signs and Directions: Make sure there are clear signs and directions all over the airport to make it easy for people to get to and from stations, gates, baggage claim areas, and other facilities.

Efficient Baggage Handling: Invest in automated baggage handling systems to cut down on lost luggage and delays, give people real-time information on where their bags are, and make it easy for them to claim their bags.

Staff That is Friendly and Willing to Help: Teach airport workers how to give great customer service, help people with their questions and requests, and deal with any problems or issues quickly and properly.

Accessibility and Welcoming Everyone: Make sure that people with disabilities or special needs can use the airport's facilities, such as the bathrooms, seating areas, and transportation choices.

Cleanliness and Maintenance: Keep the airport clean and well-kept, including the bathrooms, seating areas, walkways, and food courts, to make a good impact on people who are travelling.

Efficient Boarding Process: Set up efficient ways to board, like boarding by zone or group, to keep the gate from getting too crowded and speed up the process for travellers.

Real Time Communication: Through digital displays, announcements, and mobile apps, give customers real-time updates and information about flight status, changes to gates, delays, and other important information.

Shopping at the Airport: having a range of duty-free shops

Food and Drinks: offering cheap stores for food and drinks

Services After the Flight: As a way to make sure passengers have an easy time when they get off the plane, offer services like transportation choices, rental car services, hotel accommodations and help with bag claim.

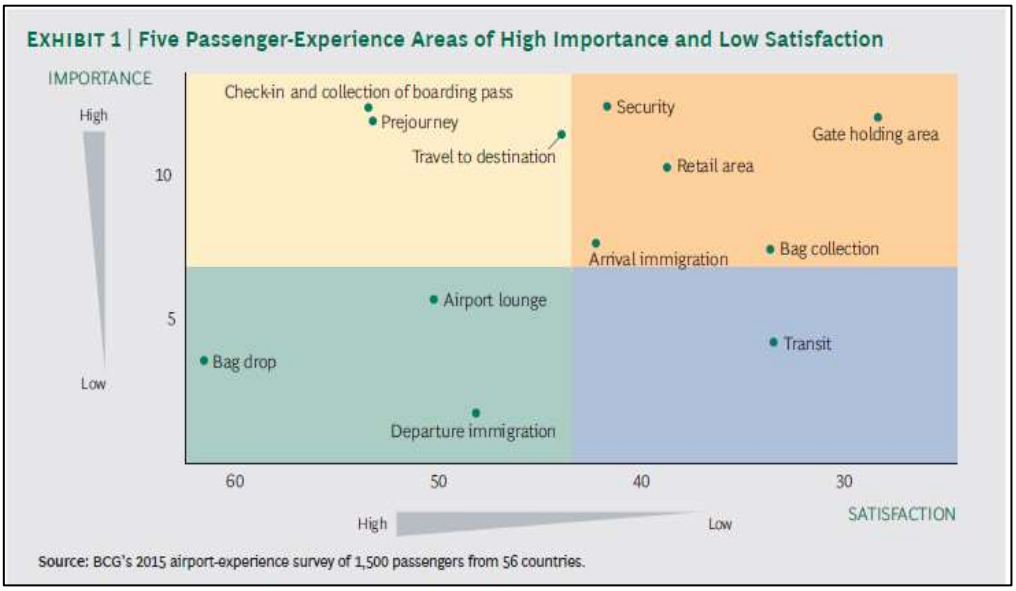


EXHIBIT 2 | Proven and Potential Digital Solutions to Improve the Passenger Experience

	TRAVEL STAGE	MAJOR PAIN POINTS	PROVEN SOLUTIONS	POTENTIAL SOLUTIONS
1	Gate holding area	• Long wait time • Poor Wi-Fi connection • Insufficient boarding-time update	• Digital-content kiosks	• Digital platform for food ordering • Self-service boarding scanner
2	Security	• Long wait time • Insufficient wait-time update	• Smart queuing system to notify on wait time	• Walk-through security scanner • Precheck programs for frequent fliers
3	Retail area	• Poor Wi-Fi connection • Insufficient information updates • Difficulties in "way finding" • Time constraints	• Airport mobile app • Wearable-device-equipped airport staff	• Location-based promotions • Virtual or robotic assistants • Virtual shopping
4	Bag collection	• Long wait time • Lack of collection time updates	• Bag-tracking application	• Real-time bag tracking and estimation of collection time
5	Arrival immigration	• Long wait time • Lack of fast and simple process	• Automated border gate with biometric identification	• Robotic immigration officer

Sources: Expert interviews; BCG analysis.

CHAPTER - 7

ENVIRONMENTAL CONSIDERATIONS

"We learned that Economic Growth & Environmental Protection can and should GO, Hand-in-Hand."

- *Christopher Dodd*

The aviation sector must take environmental factors into account in order to reduce the negative effects of air travel on the environment, safeguard ecosystems and public health, adhere to legal requirements, and maintain corporate responsibility. For the aviation industry to remain viable and gain social approval in the long run, it is imperative that sustainable practices and technology are used.

The aviation business needs to take environmental factors into account for a number of reasons, a few of which I will list below:

- **Carbon Emissions:** Globally, aviation has a major impact on greenhouse gas emissions and adds to carbon emissions. In addition to other pollutants like nitrogen oxides (NOx), particulate matter, and water vapour, commercial aircraft also release carbon dioxide (CO_2). These emissions are a factor in air pollution and climate change, both of which can be harmful to the environment and human health.
- **Climate Change:** The concentration of greenhouse gases in the atmosphere rises as a result of the carbon emissions from the aviation sector, contributing to climate change. Numerous negative effects on the environment can result from climate change, such as increased global temperatures, altered weather patterns, ice caps and glaciers melting, an increase in sea level, and damage to ecosystems and biodiversity.
- **Air Quality:** Air quality in the vicinity of airports and in the communities surrounding them may be negatively impacted by aircraft emissions, especially nitrogen oxides and particulate matter. Particularly for those who live close to airports, poor air quality can make respiratory conditions, cardiovascular disorders, and other health problems worse.

- **Noise Pollution:** In addition to being annoying and disrupting sleep, aircraft noise can have serious negative effects on the environment and public health. It can also impair cognitive function. The mitigation of noise pollution by technical improvements, operational practices, and land use planning surrounding airports are among the environmental factors in aviation.
- **Impact on the Environment:** Airports and runways, examples of aviation infrastructure, can disrupt, fragment, and destroy natural ecosystems. These effects can be both direct and indirect. Land clearance is a common component of airport construction projects, which may lead to the loss of biodiversity and wildlife habitats. Furthermore, aeroplane operations may disrupt local fauna.
- **Resource and Water Management:** Water and other resources are needed in large quantities for aviation operations in order to perform tasks like passenger services, firefighting, and aircraft maintenance. The aviation industry takes environmental factors into account by making an attempt to use less water, produce less waste, and manage resources sustainably.
- **Regulatory Compliance:** Global regulatory bodies are progressively putting policies in place to deal with environmental issues in the aviation sector. Environmental impact assessments for airport development projects, noise limits, fuel efficiency criteria, and emissions standards are a few examples of these rules. To operate legally and sustainably, airports, airlines, and other aviation stakeholders must adhere to environmental rules.
- **Public View and Corporate Accountability:** From the standpoint of business responsibility and public relations, environmental factors are also crucial. Customers that are concerned about the environment may favour airlines and airports that show a dedication to sustainability. Adopting environmental stewardship can improve an organization's standing with stakeholders, draw in business, and cultivate goodwill.

7.1 AVIATION AND ENVIRONMENT [19]

The interaction of aviation with the environment is one of the main issues that industrialised civilizations must deal with. The amount of air travel is increasing every 15 years, and aviation was identified as one of the five industries with the greatest

[19] https://www.cranfield.ac.uk/themes/aerospace/aviation-and-the-environment

challenges to decarbonise in a report released in January 2019 by the industry-led Energy Transitions Commission.

The environmental effects of aviation extend from its role in aggravating climate change to more localised problems like air and noise pollution near airports. In order to reach the environmental targets, set by the European Union and the reductions desired in the Paris Agreement, significant reductions in carbon emissions are necessary.

The recent declaration by the Government that the UK aims to eliminate its net impact to climate change by 2050 is a very positive start. For the next thirty years, emissions would need to be reduced by 3% year (of current levels), which is a reasonable and attainable goal.

Reducing reliance on fossil fuels is essential for success, and significant technological advancements are needed in a number of sectors, such as hydrogen, biofuels, synthetic fuels, and electrification.

In addition to developing approaches that can evaluate the whole system impact, taking into account economic and environmental aspects, as well as how rapidly such technologies may be adopted, will be crucial to this initiative's focus on technology development. Because of the intricate relationships that exist between society and aviation, a systems approach is necessary to guarantee a financially and environmentally responsible transition to sustainable growth in the aviation industry.

Leading the way in the development of integrated strategies for aircraft electrification, digital aviation, and environmental monitoring and mitigation are Cranfield's worldwide research airport and our Urban Observatory. Cranfield is striving to meet environmental targets and provide a sustainable future for aviation; from the environmental work we are doing around atmospheric monitoring and noise pollution with specialist sensors on our runway to researching business models for airlines of the future or looking at how airports can be powered in a sustainable way with our on-site solar farm.

Cranfield is also home to the Natural Environment Research Council's (NERC) Facility for Airborne Atmospheric Measurements (FAAM), the largest aircraft of its kind in Europe and a specifically modified research aircraft devoted to the progress of atmospheric science.

➢ Worldwide Environmental Impact of the Aviation Industry: A Statistical Analysis [20]

Millions of people now use aeroplanes as their primary mode of transportation to get across nations and cover large distances quickly. The global aviation sector has grown rapidly due to a number of factors, including the rise of transcontinental trade relations and people's desire to travel. Over the past 15 years, there has been a nearly two-thirds rise in worldwide aviation traffic, with around 39 million flights being conducted in 2019. However, the environment pays a heavy price for flying due to carbon dioxide (CO_2) emissions and other pollutants. Over 900 million metric tonnes of CO_2 were emitted by commercial aviation companies in 2019, an increase from 627 million metric tonnes in 2004. The global coronavirus (COVID-19) epidemic in 2020 caused most passenger airline operations to be cancelled. As a result, CO_2 emissions from the aviation sector decreased by over 60% in 2020 compared to 2019.

- **Which Airlines Fly Green?**

  Individuals and international regulatory authorities are driving climate action, which incentivizes airline groups to respond and modify their long-term strategy for sustainable development. Studies and advancements have previously demonstrated cause for hope regarding aviation groups' emissions. Using sustainable aviation fuel on its Boeing 777F freight aeroplane, Lufthansa freight made the first environmentally friendly trip in history in December 2020 between Frankfurt, Germany, and Shanghai, China. Airlines can reduce the intensity of their emissions by utilising technology advancements in their fleet of aircraft. With 57 grammes of CO_2 per revenue passenger kilometre (RPK) in 2020, Wizz Air had the lowest carbon dioxide emission intensity of any airline worldwide in Europe. However, within the same time frame, Lufthansa released about 92 grammes of carbon dioxide every revenue passenger kilometre. Airline groups continue to emit CO_2 at below-optimal levels when compared to the worldwide targets set by the 2015 Paris Conference.

[20] https://www.statista.com/topics/7346/environmental-impact-of-the-aviation-industry-worldwide/#topicOverview.

- **Public Views**

  Millions of people are merely unwilling to take on the burden of abatement because this environmental cost is hidden in ticket pricing. Growing public awareness of aviation's carbon footprint and the ongoing global climate change negotiations prompt a multifaceted strategy to reduce the environmental harm caused by the aviation sector. To make flying more environmentally friendly and to provide alternatives to aviation for travel, including domestic travel, both individual airline firms and nations are participating in this respect. Roughly 39% of respondents to a 2020 study stated that they have only lately begun to focus more on the sustainability of air travel. Furthermore, according to 27% of respondents, their goal is to fly less in the future in order to reduce their carbon footprint. According to a country distribution poll, almost one-third of respondents in the UK said they were worried about how flying will affect the environment.

- **Prospect**

  One of the main reasons airline companies are unable to come to a legally-binding agreement on how to mitigate potential environmental catastrophes is that environmental conservation is a public goods problem, with each airline corporation having an incentive to stray from global obligations. The level of CO_2 emissions from international aviation climbed 2.5 times between 1990 and 2019, showing an alarmingly high growth rate, despite global efforts for climate action. International aviation is predicted to emit 1.5 billion tonnes of CO_2 by 2050 if airline groups do not make significant environmental protection efforts, based on a forecast with two post-coronavirus (COVID-19) scenarios. Only in China are carbon dioxide emissions predicted to quadruple between 2019 and 2050, reaching 371.6 million metric tonnes of CO_2 emissions by that time. Global projections suggest a less optimistic picture, but the future is an unpredictable trip, and historical patterns may not always portend future developments. In light of recent rapid technical developments, aviation may eventually turn into a CO_2-neutral sector of the economy.

7.2 SUSTAINABLE AIRPORT [21]

Various industries within our economy face distinct problems as a result of the need for climate change action.

In the field of aviation, there are two distinct priorities: (i) the necessity of developing sustainable airports; and (ii) the ongoing transition to sustainable aviation fuels. Airports have long contributed significantly to the national economy and the local communities through wealth, employment, and cultural exchange, but as sustainable development continues to change the perceptions of policymakers, investors, and travellers, that role is likely to come under increased scrutiny. What, then, qualifies as "sustainable" for an airport in this new economic environment?

An airport that is sustainable isn't just one that is shielded from environmental threats like harsh weather and sea level rise. We think that in order for airports to become fully sustainable, they will need to address these five issues at the very least.

1. How Can an Airport Reach Net Zero Emissions?

While flying aircraft account for the majority of aviation's CO_2 emissions, ground activities at airports can nevertheless strive towards greater sustainability.

To cut carbon emissions, airports must fully transition to renewable energy and make investments in energy storage and efficiency. We have recently thoroughly examined this process for San Francisco Airport. An essential initial step is to map and model the energy use across the complex estates of airports, including improving airfield architecture.

Additionally, there are opportunities to create on-site energy generation from solar, wind, biomass, and hydrogen sources given the typical physical footprint of airports and the ongoing cost reductions in renewable technology. By putting a sizable solar array on the airport's buildings and surrounding area, Cochin International Airport in India asserts that it generates all of its electricity from renewable sources. This is a concept that other airports can adopt.

Airport surface access contributes significantly to emissions. Making public transport a priority helps cut down on emissions caused by surface access. We created first-of-

[21] https://www.arup.com/perspectives/what-makes-a-sustainable-airport

its-kind research using airport data to find methods to enhance the efficiency, dependability, and sustainability of transport to and from the airport. In 2018, surface access accounted for 33% of Heathrow Airport's emissions.

ACI's Airport Carbon Accreditation scheme and new government regulations (such as the UK government's new decarbonisation plan and the European Union's recent Green Deal proposals) are starting to set strict targets for reductions in waste and embodied carbon, as well as levels of procurement of renewable energy, in an effort to shape rapid change. To help operators understand how to attain net zero on both new and existing facilities, governments can also set up a lifetime cost evaluation for airport projects. Achieving net zero requires an integrated strategy from several operational perspectives, but it is doable.

2. Can Airports be Built in a Way that Makes them More Physically Sustainable?

Airports may adopt a 360-degree lifecycle approach for the planning, building, and management of both new and pre-existing physical assets, similar to other infrastructure projects requiring substantial resources. This would allow them to adopt materials passports and other policies that facilitate the reuse of materials when facilities reach the end of their useful lives, thereby reducing lifetime emissions and maintaining the value of building products and assemblies. This would allow them to embody a circular economy approach to their built assets. Our evaluations allowed us to find 8,500m^2 of existing concrete pavement at one of the top airports that may be saved and utilised again after renovations. It just requires a shift in perspective and the expectation of reuse whenever it makes sense.

Essentially, an airport comprises an intricate network of settings, amenities, automobiles, and auxiliary systems that use various forms of energy and resources. Optimising involves adopting a system-wide strategy that includes cutting waste, enhancing recycling, utilising anaerobic digestion and on-site waste-to-energy systems to boost efficiency, and making a commitment to zero waste to landfill.

3. How Can Airports Expand Without Endangering Biodiversity and The Environment?

Airports are probably going to be expected to commit to "green managed growth," which is the idea of limiting environmental effects while fostering economic growth. It

would entail coming to mutually agreeable monitoring and enforcement strategies for matters like air quality, noise, carbon emissions, surface access impacts, and so forth. On the plus side, it would encourage innovation.

There are numerous excellent instances of airports addressing the consequences on biodiversity by implementing measures that are consistent with aviation safety, such as expanding vegetation within their grounds and installing green roofs. These are sensible yet efficient methods of promoting surrounding nature in their immediate surroundings. Other national objectives could also be met via local environmental off-setting. Airports should replace domestic boilers with heat pumps in the neighbourhood rather than just off-setting by planting forests in other locations or regions. This would hasten the decarbonisation of home heating and enhance their standing as socially conscious companies.

4. What Steps can Airports Take to Improve Employee, Community and User Health?

Airports have more they can do to mitigate the negative effects they have on people's health and well-being, from noise levels and local air quality to the standard of the passenger experience. Local air quality objectives can be supported by policies that promote the use of electric vehicles on their property and provide ground power to aeroplanes in order to reduce air pollution. An airport's sustainability credentials would also be strengthened by reducing light pollution, implementing indoor air quality monitoring, restricting the use of hazardous materials, introducing biophilic design, and taking steps to lessen the likelihood of heat island formation.

Developing a radically human-centred design approach for aviation environments, operations, and infrastructure is necessary to make aviation more sustainable in terms of health and wellbeing. We are pushing the industry to build for the needs of everyone who interacts with it in partnership with the EU Aviation Wellbeing Committee.

5. How Can Airports Play a Bigger Role in The Local Community?

Although Airports employ a lot of people, sustainable airports can provide more to the community than just creating jobs. Focusing on a variety of technical, engineering, and service skills, they can serve as a central point for local talents, connecting with underserved groups and providing apprenticeships.

This more proactive stance would present an opportunity to show leadership on a number of related urban concerns. Airports are commonly found on the outskirts of cities, offering a potentially strong network of links in regions with a population that is frequently less affluent. Luton Airport, situated to the north of London, is concentrating on research and development related to green aviation technology, with the aim of serving as a bridge between local engineering enterprises and universities. Other airports might benefit greatly from the development of low-emission agriculture on the land surrounding them, which would assist the food sector cut down on "food miles" and further its own sustainability goals. There are many, different, and local options.

- **Sustainability: An Operational Licence?**

Though it will take time, the development of sustainable aviation fuels, such as biofuels, hydrogen, and electric-powered aircraft, is well under progress. We can accomplish the sustainable airport now. Airports possess a remarkable prospect to spearhead the sustainability movement, introduce forward-thinking economic policies and procedures, and guarantee that the sector is perceived as a proactive contributor to the transition towards a net-zero economy. In the end, airports around the world will have a stronger social licence to operate once they become more outspoken about their sustainability pledges and advancements towards net zero. Not only will this benefit the business, but it will also improve the cities and communities it serves.

7.3 METHODS FOR MITIGATION OF NOISE

Living near an airport might make aircraft noise bothersome for nearby residents. The industry has been attempting to reduce noise for decades, and in the last ten years, noise levels have significantly decreased. Every new generation of aircraft is thought to have a noise footprint that is at least 15% less than that of earlier generations.

- **Noise Regulatory Measures** [22]

The influence of aeroplane noise near airports is mostly managed by two types of European regulations.

[22] Report by EASA (European Union Aviation Safety Agency), 'European Aviation Environmental Report', 2022.

First, in addition to local and national efforts, the Environmental Noise Directive encourages efficient monitoring and management of noise consequences. The other is the Balanced Approach Regulation, which lays forth guidelines for airport noise control, including how to introduce operating limits relating to noise.

EASA supports the aforementioned regulatory actions in two distinct ways. The first step involves validating and disseminating aircraft noise and performance data, which is utilised by models to determine airport noise contours and evaluate the noise impact in the vicinity. This dataset guarantees consistent and reliable airport noise modelling across Europe. The second responsibility is to gather noise certificate paperwork from aeroplanes operating at airports in Europe that have a maximum take-off mass of more than 34,000 kg, or more than 19 passenger seats.

In order to carry out these responsibilities, the Agency has established the Environmental Portal and the Aircraft Noise and Performance (ANP) database, which allow relevant parties to contribute and exchange data.

Airport aircraft noise management, in compliance with the Environmental Noise Directive, entails situational monitoring and assessment, as well as the establishment of baselines, goals, and corresponding noise action plans. This action plan heavily relies on the Balanced Approach, which is made up of the following essential components:

1. Noise reduction at the source, which includes research projects that use technology and design to lessen aeroplane noise.
2. Policies for land-use planning and management to prevent development that is incompatible, such as homes in quiet neighbourhoods.
3. Operational methods for noise abatement allow for the reduction or redistribution of noise surrounding the airport while maximising the usage of contemporary aircraft and air navigation capabilities.
4. Noise quotas and flight limits are examples of operating restrictions on aeroplanes that restrict access to an airport or lower its operational capacity.

Depending on the airport's noise abatement goals and the cost of mitigating solutions, different parts of the Balanced Approach may be prioritised. Airport Council International Europe (ACI-E) found that 79% of European airports use operational restrictions (such as limits on louder aircraft, night flights, runways, noise budgets, and

movement caps), even though these measures should only be implemented after all other aspects of the Balanced Approach have been considered. Airports and aeroplane noise certification determine the extent to which operating limitations apply. Aircraft that do not comply with Chapter 3 of ICAO Annex 16 Volume I should not be completely barred from the airport in question; rather, the limits imposed by Chapters 4 and 14 should be limited in nature.

According to a recent study conducted for the benefit of the European Commission, certain Member States possess the same competent authority for both the Balanced Approach Regulation and the Environmental Noise Directive, while others possess separate authorities. The study found that while the Regulation does contain accountability systems to engage and consult stakeholders, it would be helpful to have best practice guidelines to follow when choosing and implementing noise reduction measures to define objectives and procedures.

- **Collaborative Environmental Management**

In order to find the best ways to lessen the negative effects on the environment around airports while still meeting any requirements put in place by the system, it is essential that all relevant parties (such as airports, airlines, air navigation service providers, local governments, and communities) work together. To help with these kinds of conversations, EUROCONTROL created the "Collaborative Environmental Management" (CEM) specification in 2014. It can be modified to fit local requirements.

In 2021, the CEM specification was revised to address the increasing sustainability concerns in the aviation industry. Included in this upgrade were:

- Facilitating the launch of potential new initiatives in reaction to the EU Green Deal (such as SAF utilisation and provider inclusion);
- Promoting airport-regional council-sponsored initiatives to increase community involvement and cooperation with local government;
- Mentions of recently enacted laws and self-regulatory industry programmes (such Airport Carbon Accreditation),
- Representing the expanding significance of emerging markets (such as drones and urban air mobility); and

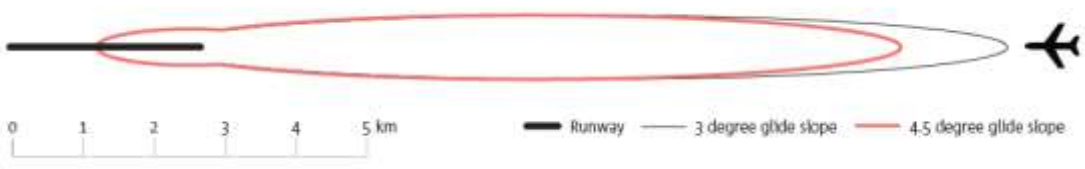
- Research highlighting successful strategies for reducing operational noise and engaging stakeholders.

In order to strengthen the exchange of environmental technical information and broaden collaboration on good practices, ACI-E has accepted the CEM specification as an industry recommended practice. Better coordination with the Airports Regions Council is anticipated.

The SESAR Total Airport Management project is expanding on CEM's work to improve airport management collaboration. It aims to do this by creating tools for active, real-time environmental performance management at airports, which will integrate with the Network Manager and include key parameters into the Airport Operations Plan (AOP). For the purpose of evaluating trade-offs, performance dashboards integrate information for fuel consumption and carbon dioxide emissions with indications for air quality and noise levels. They can help with things like managing runway configurations, optimising gate or taxi route allocation, allocating arrival and departure routes, and making sure certain monitoring stations adhere to agreed-upon noise and air quality norms.

➢ **Superior Adaptability on the Vertical Flight Path**

A proposal for using a Second (alternative) Runway Aiming Point (SRAP) in lieu of the runway threshold during approach has been established and verified by SESAR. Based on their wake turbulence category and the need for more or less runway length, aircraft are cleared to land using this second aiming point, allowing the arriving aircraft to reduce noise footprint and potentially shorten runway occupancy and/or taxi-in times, depending on the layout of the local airport. Furthermore, the Increased Glide Slope (IGS) idea, created by SESAR, allows for a steeper approach to the airport runway threshold (4.5 degrees instead of the customary 3 degrees), which contributes to noise reduction.



Single landing 60 dB L_{night} noise contours for aircraft flying a baseline 3-degree glide slope and an increased 4.5-degree glide slope.

These novel techniques are already in the pre-industrialization stage and can be combined to further boost benefits. The SESAR large-scale demonstration DREAMS carried out a live trial campaign in Germany, Italy, and the Netherlands in 2021 and 2022 after conducting extensive simulations.

➢ **The Reduction of Noise** [23]

Aircraft noise can be a source of annoyance for people who live in close proximity to airports. The noise levels have been cut in half over the course of the last ten years, demonstrating the enormous improvement that has been made by the sector over the course of several decades. Each new generation of aircraft is expected to have a noise footprint that is at least fifteen percent less than the noise footprint of the ones that came earlier.

- **Mandated Reductions**

  The United Nations' international agency on aviation, the International Civil Aviation Organisation (ICAO), unveiled Chapter 14, a new standard for noise reduction, in 2013. According to the former Chapter 4 guideline, new aircraft models must be at least seven decibels quieter than existing ones. This guarantees that aeroplanes of the future will employ the quietest technology.

  Among the various steps taken to lessen engine noise was the certification. In reality, according to ICAO figures, there was a 35% decrease in the global population exposed to aircraft noise between 1998 and 2004.
  The ICAO promotes a methodical strategy for reducing noise. This incorporates operational enhancements, flying limitations, land-use planning and management, and noise reduction at the source. The goal is to minimise expenses and enhance the environmental benefit.

- **Technology**

  Numerous elements, including the volume of air passing through the engines, the size of the fan blades inside the engines, the engine's location on the aircraft

[23] https://aviationbenefits.org/environmental-efficiency/reducing-noise/

fuselage, and even the quantity and size of flaps that help control the form of the wings, have been the subject of substantial research into noise reduction.

The Airbus A380 and Boeing 787, two of the newest large aircraft, have relatively minimal acoustic "footprints." New Pratt & Whitney "geared" turbofan engines, which further reduce noise and pollution, are used in the Bombardier CSeries.

By 2020, the aviation sector hopes to reduce aeroplane noise levels by an additional 50%. There is strong motivation to keep addressing this problem because noise pollution issues can and do impact the economics of airport expansion plans.

- **Air Traffic Management**

  Noise pollution can be significantly reduced by regulating the flight path of aircraft during take-off and landing. Runways must be positioned and used properly. For instance, planes can go across countries or across lakes at night to lessen their noise pollution.

  Flight paths are charted by air traffic control to avoid the densestly populated areas. Thanks to recent improvements in navigation performance, aeroplanes may now fly along precisely marked routes. This can result in fewer residents being subjected to more flyovers, but it also avoids track spreading and the "spaghetti" radar flight track maps that follow. Thus, community organisations must be closely consulted while managing air traffic. It is necessary to take into account matters like the relative advantages of track concentration against track dispersion.

- **Land-Use Planning**

  Land-use planning is essential for limiting the amount of people exposed to aeroplane noise in addition to aircraft noise reduction. In order to enforce zoning regulations in impacted areas, airports must collaborate with local authorities. Good land-use planning can promote development that is not sensitive to aircraft noise, such as light industry or storage spaces, and discourage or prohibit undesirable new residential, health, or educational developments. In

certain regions, new or existing residences must have ventilation and sound insulation to lower indoor noise levels.

Airport operators can only urge local authorities to take airport noise into account when approving plans for residential and other noise-sensitive land use, as they often have no authority over land-use planning off the airport site. The sector urges governments to prepare for land use near airports in a proactive, long-term manner to guarantee that excessive aeroplane noise won't have a negative effect on any future growth.

- **A Balancing act**

Making certain concessions is necessary while addressing environmental challenges. For instance, since the quickest route into an airport occasionally passes over towns, the aircraft industry and governments must decide between shorter routes to save fuel consumption and lowering noise. This requires careful balancing.

7.4 CARBON FOOTPRINT REDUCTION

Aviation has expanded faster than rail, road, or shipping in recent decades, and in 2022 it accounted for 2% of global energy-related CO_2 emissions. Aviation emissions in 2022 reached about 800 Mt CO_2, or 80% of the pre-epidemic level, as demand for international travel picks back up after the Covid-19 pandemic.

In order to mitigate the environmental impact of aviation and combat climate change, airports must reduce their carbon footprint. Various techniques can be implemented by airport operators, airlines, and other stakeholders to enhance sustainability and minimise carbon emissions. The following are some steps airports can take to lessen their carbon footprint:

- **Energy Efficiency Improvements:** The amount of carbon emissions related to airport operations can be greatly decreased by implementing energy-efficient technologies and procedures. This entails switching to LED lighting fixtures, installing HVAC systems that use less energy, improving controls for heating and cooling, and putting energy management systems in place to track and lower energy usage.
- **Renewable Energy Resources:** Airports can lessen their dependency on fossil fuels and their carbon emissions by switching to renewable energy sources including solar, wind, and geothermal power. Airports can create renewable energy on-site or through the purchase of solar panels, which can be installed on parking buildings, rooftops, and vacant ground.
- **Alternative Fuels & Vehicles:** Airports may cut emissions from vehicles like buses, shuttles and ground support equipment (GSE) by promoting the use of alternative fuels and electric vehicles (EVs) for ground transportation operations. This entails switching to electric cars, hydrogen fuel cells, and biofuels in order to reduce carbon emissions and enhance air quality inside airport boundaries.
- **Programmes for Offsetting Carbon:** By investing in initiatives that lower or eliminate greenhouse gas emissions elsewhere, airports can offset the carbon emissions produced by their activities. Passengers, airlines, and other stakeholders may choose to purchase voluntary carbon offset programmes from airports in order to offset the emissions associated with their travels.
- **Green Building Design & Constructions:** By considering sustainability during the design and construction phases of airport facilities, carbon emissions related to building materials, construction methods, and energy usage can be reduced. This involves implementing passive heating and cooling techniques, sustainable materials, energy-efficient design, and water-saving techniques into new construction and remodelling projects.

- **Reducing Waste and Recycling:** Airports may limit the quantity of garbage delivered to landfills and lower the carbon emissions related to waste disposal by implementing recycling and waste reduction programmes. Airports have the ability to establish recycling programmes for commodities like paper, plastic, glass, and metal in addition to composting programmes for organic waste produced on the premises.
- **Partnership & Collaboration:** Reducing carbon emissions throughout the airport ecosystem requires cooperation with airlines, tenants, suppliers, and other stakeholders. Airports and airlines can collaborate to enhance flight operations, minimise aircraft fuel consumption, and investigate prospects for sustainable aviation fuels (SAF). Collaborations between academic institutions, environmental organisations, and municipal governments can help promote knowledge exchange and group action on sustainability-related projects.
- **Monitoring & Reporting:** Airports can measure their progress over time, set reduction targets, and track their carbon emissions by putting in place reliable monitoring and reporting systems. This entails doing routine inventories of greenhouse gases, examining data to pinpoint emission hotspots, and informing stakeholders and the general public about accomplishments in reducing carbon footprints.

  Airports may reduce their environmental effect, show environmental leadership, and support international efforts to address climate change by putting these carbon footprint reduction strategies into practice. Furthermore, cutting carbon emissions can save money, improve operational effectiveness, and improve airports' standing as environmentally conscious and sustainable stewards of the environment.

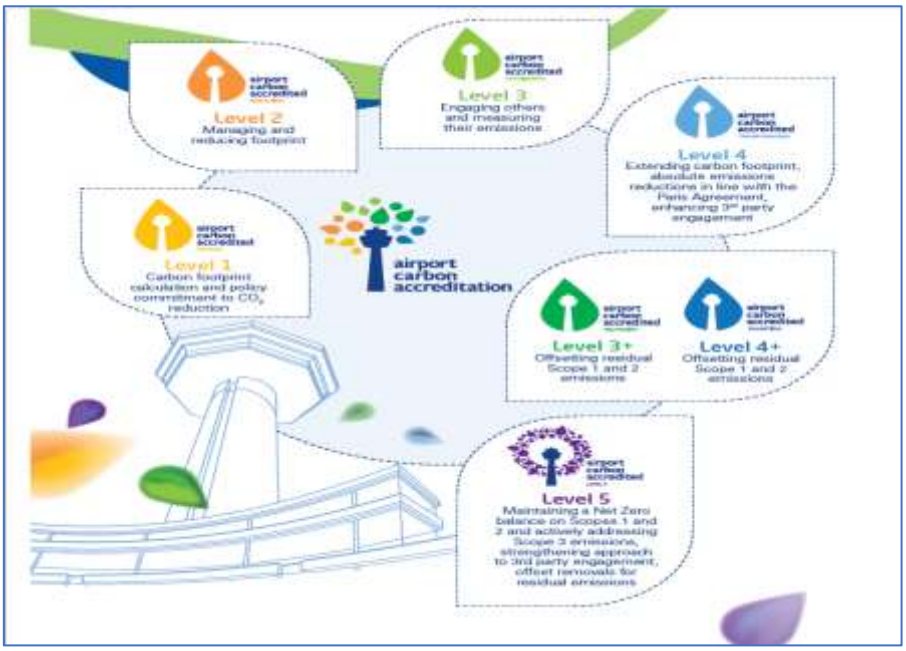
➢ The Role of Airport Carbon Accreditation [24]

The only worldwide carbon management certification scheme for airports that has institutional endorsement is called Airport Carbon Accreditation. Through seven certification levels - "Mapping," "Reduction," "Optimisation," "Neutrality,"

[24] https://www.airportcarbonaccreditation.org/about/7-levels-of-accreditation/

"Transformation," "Transition," and "Level 5" - it objectively evaluates and acknowledges airports' efforts to manage and lower their carbon emissions.

The scheme offers a distinct, standardised framework and instrument for proactive carbon control at airports that yields quantifiable outcomes. It includes the operational operations that have the biggest impact on emissions of carbon. Because it supports and guides airports through a process of ongoing improvement and collaboration with stakeholders, it is site-specific and applicable to any airport as part of its long-term strategy and daily environmental management activities.



CHAPTER - 8

REGULATORY & POLICY FRAMEWORKS

"Obey the Law, or they will be obeyed in a way you won't like."

- Benjamin Franklin

The aviation sector functions within a multifaceted regulatory and policy environment encompassing global, regional, and national domains. To guarantee the efficiency, sustainability, safety, and security of air travel, a number of international organisations, governmental authorities, and regulatory bodies have built these frameworks.

These international legislative and policy frameworks offer a thorough framework for overseeing the aviation sector and advancing safe, secure, and environmentally friendly air travel worldwide. To handle new issues, harmonise laws, and encourage the ongoing development of international aviation standards and practices, cooperation between governments, regulatory bodies, international organisations, and industry stakeholders is crucial.

- **International Civil Aviation Organisation:** ICAO is the aviation specialised agency of the United Nations, and as such, it establishes international rules and guidelines for aviation security, safety, air navigation, and environmental protection. Aircraft operations, airworthiness, personnel licencing, air traffic management, and aviation security are only a few of the topics covered by the International Civil Aviation Organization's (ICAO) standards and recommended practices (SARPs), which are detailed in the Chicago Convention's annexes.
- **Chicago Convention:** The legal framework for international civil aviation and the basis for worldwide aviation regulation were established by the Chicago Convention, which was signed in 1944. In areas like airspace sovereignty, aircraft registration, air navigation, and air traffic rights, it describes the guiding principles and regulations that determine the rights and obligations of states.

- **International Air Transport Association (IATA):** In order to create industry standards, regulations, and best practices, IATA, a trade organisation that represents airlines globally, collaborates closely with governmental and regulatory bodies. In addition to advocating on behalf of the airline industry, IATA also offers services including operational standards and safety audits. It also facilitates international air travel with programmes like the IATA Operational Safety Audit (IOSA) and the IATA Travel Pass.
- **Bilateral Multilateral Air Service Agreements:** International aviation services, including routes, frequency, capacity, and prices, are governed by bilateral and multilateral agreements between nations. These accords create the legal foundation for interstate air travel and encourage collaboration, rivalry, and industry liberalisation. Important instances are the Open Skies accords, which seek to liberalise the air transportation markets and eliminate barriers to airline operations between member nations.
- **European Union Aviation Safety Agency (EASA):** The European Union (EU) agency in charge of regulating and supervising aviation safety within its member states is called EASA. EASA creates uniform safety guidelines, procedures for certification, and standards for aircraft, operators, maintenance companies, and aviation workers throughout the European Union. In order to unify aviation safety standards worldwide, it also works with international partners, such as the ICAO.
- **Environmental Regulations:** The environmental effects of aviation, such as aircraft emissions, noise, and air quality, are covered by environmental rules and policies. In order to reduce the carbon footprint of the sector, regulations may be implemented pertaining to emissions from aircraft engines, noise limits for airport operations, and market-based tools like carbon offsetting and emissions trading systems.
- **Aviation Security Regulations:** Aviation security measures are put in place to guard against illegal interference, such as sabotage, hijacking, and terrorism. Regulations may include standards for cargo security, access control procedures for airport buildings, security screening procedures for travellers and their belongings, and security certification and training requirements for aviation workers.

- **National Aviation Authorities (NAAs):** To supervise and control civil aviation operations within their borders, national governments appoint NAAs. In addition to awarding licences and certificates, carrying out safety supervision inspections, and looking into accidents and incidents, NAAs are in charge of upholding federal aviation laws. They cooperate with regional aviation organisations and international organisations like the ICAO to guarantee adherence to international aviation standards and best practices.

8.1 INNOVATION AND REGULATORY REQUIREMENTS IN THE AVIATION INDUSTRY [25]

Flying is now safer and more effective than ever thanks to new technological developments and industry innovation, which is continuously taking place in the aviation sector. But as the aviation sector innovates, there are dangers and difficulties that must be resolved to make sure that security and safety are not jeopardised. Regulations have been implemented to deal with these hazards and difficulties.

I will discuss how laws can encourage the growth of innovation and the effect that regulations have on innovation in the aviation sector.

- **Firstly**, it's critical to comprehend how legal restrictions affect innovation in the aviation sector. From the engine to the cockpit controls, every part of an aircraft requires approval and certification from aviation authorities including the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). These legal mandates are in place to guarantee the security and safety of every aircraft. They could, however, also erect obstacles to innovation. If manufacturers are uncertain about the response from regulators, they frequently hesitate to use new technology or design strategies.
- **Secondly**, this uncertainty may significantly affect how quickly innovations are made. Even if they think a different approach will produce a superior process or product, manufacturers and designers could be reluctant to stray from the norm. Innovation may be halted as a result, losing the competitive advantage. But innovation in the aviation sector is essential to its growth. Improved aeroplane

[25] Qoco.aero, Blog, Andy Graham, "Regulatory Requirements and innovations in the Aviation Industry, can they co-exist"? July 27,2023.

performance, less operating costs, and less emissions are all possible with new materials, technology, and design. Therefore, a company may exit the market if it loses its competitive edge.

- **Thirdly**, by giving regulators and developers a framework for cooperation, laws can foster innovation. An illustration of this is the Aviation Innovation, Reform and Reauthorization Act (AIRR Act). In order to assess and create regulatory standards for emerging aviation technologies, it instructs the FAA to form an aviation rulemaking committee. By working together, regulatory agencies and entrepreneurs may better communicate, fostering an atmosphere that fosters innovation while upholding security and safety. Therefore, while maintaining safety measures, the law promotes innovation.
- **Fourthly**, another strategy that governments are employing to promote innovation and the advancement of new technologies is the creation of regulatory sandboxes. With the help of these sandboxes, developers can test new technologies in a safe setting with regulatory oversight. To mention a few, the UK, France, and Singapore have all used regulatory sandboxes. These conditions foster innovation in the aviation sector without compromising the security of both workers and passengers. By avoiding some of the regulatory obstacles, this strategy can promote innovation more quickly.

Taking everything into consideration, I can conclude that, although regulations are important to protect aviation security and safety, they can also stifle innovation within the sector. Nonetheless, it is crucial to employ legislation in a way that promotes creativity while maintaining the necessary safety measures. New technologies that are efficient, safe, and secure can be developed through cooperation between innovators and regulatory bodies. Another beneficial strategy for fostering innovation in the aviation sector is the implementation of regulatory sandboxes. The aviation sector is essential, and it needs to keep innovating to stay relevant. Therefore, for the sector to thrive, innovation and regulatory needs must coexist.

8.2 ISO/TC 20/SC 17 - AIRPORT INFRASTRUCTURE [26]

Airside airport infrastructure should be standardised, including the grooving of landing and take-off lanes, asphaltic-ecologic paving, painted vertical signage, and electric-electronic boards (light- and paint-filled signage).

The scope does not include spaceports, which are under ISO/TC 20/SC 14, nor ground handling equipment, which is under ISO/TC 20/SC 9. This includes fixed equipment like passenger boarding bridges and docking guidance systems. The work covered by IEC/TC 97 (Electrical Installations for Lighting and Beaconing of Aerodromes) and the infrastructure supporting air traffic facilities are also not included in this scope.

The goal of SC 17 is to encompass all infrastructure that is specific to the airport environment; however, it will not include any infrastructure that is covered by other ISO and IEC committees or that is not specific to the airport environment.

- **Policies & Investment Incentives from The Government for The Development of Airports**

In order to accommodate the rising demand for air travel and promote economic growth, airport development and modernization are greatly aided by government regulations and investment incentives. Governments may assist in the sustainable development of airports, improve aviation infrastructure, and promote economic growth and connectivity in airport-served communities by putting these policies and investment incentives into place.

1. **Investment in Infrastructure:** Airport infrastructure projects, such as runway extensions, terminal renovations, air traffic control systems, and ground transit facilities, may be supported financially by governments through grants or other financial incentives. Airports can benefit from this investment by increasing capacity, increasing productivity, and improving the traveller experience.
2. **Public-Private Partnerships (PPPs):** Through PPPs, which entail cooperation between public entities (such as government agencies or airport authority) and private sector businesses, governments can support the development of airports. PPPs facilitate the implementation of airport projects using creative financing

[26] https://www.iso.org/committee/5396202.html

methods like design-build-operate (DBO) or build-operate-transfer (BOT) contracts. These mechanisms allow for the sharing of investment costs, risks, and expertise.

3. **Tax Incentives:** To entice private investment in airport construction projects, governments may provide tax incentives. Airport operators, airlines, and investors in airport infrastructure projects may be eligible for tax credits, exemptions, or reductions on corporate income tax, property tax, or value-added tax (VAT).
4. **Regulatory Frameworks:** Governments set up regulatory frameworks to control competition laws, safety requirements, environmental restrictions, and airport operations. For investors and operators, clear and open regulatory frameworks offer stability and certainty, which promotes trust in the long-term sustainability of airport development projects.
5. **Land Use Planning & Zoning Regulations**: By enforcing land use planning and zoning laws that identify appropriate locations for airport growth and safeguard the airspace surrounding airports from conflicting land uses, governments can encourage the development of airports. This aids in preventing the encroachment of commercial, industrial, or residential developments that can impede airport operations or result in noise complaints.
6. **Getting Financed:** Governments can help airport development projects get funding by offering low-interest loans through development banks or other financial institutions, loan guarantees, or subsidies. This lowers finance costs and encourages private funding for infrastructure upgrades at airports.
7. **Streamlined Permitting & Approval Process:** To speed project delivery and lessen administrative constraints for investors and developers, governments can streamline the regulatory and approval processes for airport development projects. This involves setting up one-stop shops or unique regulatory organisations to manage permissions and approvals from various government departments and agencies.
8. **Programmes & Sustainable Development:** Governments might implement incentive schemes, like energy-saving technologies, renewable energy installations, trash minimization plans, and carbon offsetting projects, to push airports to embrace sustainable development practices. Grants, subsidies, or

special treatment throughout the procurement process for eco-friendly products and procedures are examples of incentives.

9. **Promoting Tourism and Fostering Economic Growth:** Airports are important gateways for tourist and economic development, and governments understand this. By raising demand for air travel and igniting the economy in the areas that airports serve, policies that encourage trade, tourism, and investment can indirectly aid in the development of airports.
10. **Participation of Stakeholders and Public Consultation:** Governments interact with stakeholders to get their views on plans and policies for airport development, including members of the industry, environmental organisations, and local communities. Public consultation procedures guarantee airport projects' accountability, openness, and social acceptability, which lessens opposition and possible delays.

CHAPTER - 9

BEST PRACTICES

"Implementing best practice is copying yesterday,
invention is inventing tomorrow"

- *Paul Sloane*

The term "Best Practices" in the aviation industry refers to a broad category of approaches and ideas that are used to guarantee customer satisfaction, efficiency, sustainability, and safety.

Aviation industry stakeholders can maintain high standards of safety, efficiency, and sustainability while providing outstanding passenger experiences and making a positive impact on the industry's overall growth and success by following these best practices.

9.1 KEY BEST PRACTICES FOR THE AVIATION INDUSTRY

- **Prioritising Safety:** The aviation sector places a high priority on safety. Strict safety regulations and standards are followed by airlines, airports, and regulatory bodies to reduce risks and guarantee the security of travellers, employees, and cargo. This entails stringent maintenance protocols, thorough employee training, and compliance with global safety standards.
- **Risk Management:** For all facets of aviation operations to be identified, evaluated, and mitigated, effective risk management techniques are necessary. This involves putting emergency plans into action and doing risk assessments for airport infrastructure, maintenance tasks, and aviation operations.
- **Compliance with Regulations:** In order to preserve operational integrity and guarantee the safety and security of aviation operations, compliance with aviation legislation and standards is essential. Organisations like the Federal Aviation Administration (FAA) and the International Civil Aviation Organisation (ICAO) establish national and international regulations that airlines, airports, and aviation service providers must follow.

- **Effective Operations:** The prosperity of airports and airlines depends on efficiency. The optimisation of flight schedules, route planning, fuel usage, and ground operations is emphasised by best practices in aviation in order to minimise expenses, decrease delays, and enhance overall operational performance.
- **Client Experience:** In order to foster client loyalty and draw in repeat business, it is imperative to deliver an outstanding customer experience. From booking and check-in to boarding and baggage claim, airlines and airports prioritise features like comfort, convenience, and tailored services to improve the passenger experience at every touchpoint.
- **Environmental Sustainability:** As a result of mounting worries about climate change and its effects on the environment, the aviation sector is placing a greater emphasis on sustainability programmes. Purchasing fuel-efficient aircraft, establishing environmentally friendly ground operations, cutting carbon emissions, and investigating alternate fuels and technologies are a few examples of best practices.
- **Training & Development:** Ensuring the ability and proficiency of aviation workers, such as pilots, cabin crew, maintenance specialists, and air traffic controllers, requires ongoing training and development programmes. Sustaining industry-wide safety, efficiency, and professionalism standards is made possible by ongoing education and skill development.
- **Collaboration & Partnership:** For the aviation industry to handle shared difficulties and spur innovation, cooperation between airlines, airports, government agencies, industry groups, and other stakeholders is essential. Partnerships can help with cooperative projects to raise industry standards and practices as well as information and resource exchange.
- **Investment in Technology:** Using technology to its full potential is essential to modernising aviation operations and improving productivity and security. Adopting cutting-edge aircraft technology, putting digital flight planning and operations management solutions into place, and combining automation and artificial intelligence to expedite procedures are examples of best practices.

- **Continuous Improvement:** The aviation sector upholds a culture of continuous improvement, in which businesses periodically assess and evaluate performance indicators, solicit input from relevant parties, and introduce innovations and corrective measures to gradually increase customer satisfaction, efficiency, and safety.

9.2 LEARNINGS FROM NEW TECHNOLOGY AND INNOVATIVE AIRPORT STRUCTURE

Learning from new airport infrastructure and technology implementations is essential to improve future aviation projects and efforts. By using the lessons learned from new airport technology and infrastructure, people involved in the aviation industry can make future projects more successful and have a bigger effect, leading to better safety, efficiency, sustainability, and the passenger experience.

- **Technology Integration:** The incorporation of state-of-the-art technology is a key component of successful airport projects as it improves passenger experience, operational efficiency, and safety and security. The necessity of carefully choosing and implementing technology solutions that seamlessly interact with current infrastructure and workflows is highlighted by lessons learnt.
- **User-Centred Design:** The design of amenities and services for passengers and stakeholders is the main goal of innovative airport projects. The necessity of carrying out in-depth research and user testing to comprehend user behaviour and preferences is emphasised in the lessons gained. These insights can be used to build intuitive and user-friendly airport facilities and technology.
- **Collaboration & Partnership:** Innovative airport projects require cooperation between airlines, airports, technology providers, government agencies, and other stakeholders. The importance of forming alliances and encouraging cooperation is highlighted by lessons learnt. These strategies can be used to maximise knowledge, funds, and resources while also guaranteeing compliance with laws and industry norms.

- **Agile Project Management:** Navigating the intricacies of airport infrastructure and technology projects, which can involve numerous stakeholders, shifting requirements, and unanticipated problems, requires flexibility and agility. The necessity of using agile project management techniques that support rapid decision-making, iterative development, and efficient risk management is highlighted by lessons learnt.
- **Sustainability & Resilience:** In order to address environmental issues, reduce risks, and ensure that infrastructure is future-proof, innovative airport projects are placing an increased emphasis on sustainability and resilience. The necessity of applying strategies to improve resilience against natural catastrophes and disruptive events, as well as incorporating sustainable design concepts like energy efficiency, waste reduction, and the utilisation of renewable resources, is emphasised by the lessons gained.
- **Making Decisions Based on Data:** In order to maximise airport operations and influence decision-making, data analytics and predictive models are essential. Lessons learned emphasise how crucial it is to gather and examine data from a variety of sources, including passenger flows, aircraft movements, and weather patterns, in order to spot trends, predict demand, and allocate resources as efficiently as possible.
- **Investing In Human Capital:** The human element is still crucial for maintaining efficient operations and providing high-quality services, even if technology plays a major role in enabling innovation in airport infrastructure. Lessons learnt stress the value of investing in human resources via talent acquisition, training and development initiatives, and encouraging an innovative and continuous improvement culture among airport staff.
- **Regulations and Involvement of Stakeholders**: For innovative airport projects to succeed, regulatory compliance and good stakeholder involvement are essential. The lessons learnt emphasise how crucial it is to actively communicate with local communities, regulatory bodies, and other stakeholders at every stage of the project to address issues, secure required permits, and foster confidence and support for the endeavour.

9.3 FUTURE OF THE AVIATION INDUSTRY [27]

Although air travel took a major impact during the COVID-19 pandemic, it is now recovering, according to news from the aviation sector. Several estimates put the total amount of air travel, including foreign flights, at about 94% of what it was before the pandemic. Additionally, this summer, domestic air travel was higher than pre-pandemic levels.

This renaissance highlights the significance of Dallas's STEM schools, which are training future aviation experts. What, therefore, lies ahead for the aviation industry? What follows is a more in-depth analysis of the industry's projected developments over the next ten years.

- **The Current Pilot Shortage is Expected to Persist**

  The COVID-19 epidemic had a major effect on airline travel. Many airlines were forced to reduce staff in order to stay in business as a result of new limitations on air travel and passengers' fear of flying because they might be exposed to COVID-19. This involved terminating not only airport staff but even pilots.

  A number of pilots with a long career path made the decision to retire. Others just quit the aviation business as soon as air travel started to pick up again following the pandemic. The best course of action is to promote and provide training for more people to pursue careers as pilots.

  Aviation high schools encourage young students to take to the skies, while commercial firms like United Airlines have established their own flight training academies. However, receiving proper training is a process, therefore the end of the pilot shortage will not occur suddenly.

- **Single-Pilot Flights Are NOT Expected to Become More Common**

  Modern business flights have two pilots: a captain and a co-pilot. If there is a shortage of pilots and it's likely to get worse, wouldn't it make sense to run with only one pilot to make up for the lack of staff?

[27] Blog by Rising Aviation, "What does the future of Aviation Industry Look Like Over the Next Decade?", Sep 8, 2023.

That is a good question, and it has been asked and thought about in the past few years. There are too many risks to replace one driver with high-tech equipment, even though it might be tempting to do so. Some things to think about are the current pilot's inability to do his or her job, problems with technology, and the higher risk of terrorist action caused by fewer airline employees. Right now, the risks are greater than the benefits, so don't expect business flights with only one pilot any time soon.

- **Advanced Technology Will Keep Being Made and Used**

  Although the COVID-19 outbreak caused a lot of problems with air travel and other parts of daily life, it also had some good results. In the aviation business, it sped up many tasks, like boarding, by promoting the fast development of technology.

  People can now print their own bag tags at the airport, check in online and even download electronic boarding passes. Even more self-service technology will be developed in the future of the aviation business. These will make things run more smoothly and quickly, but they will still let the right flight staff keep track of every step.

- **Electric Aircraft Might be Used in Business Flights**

  Hybrid and electric cars have become more popular in recent years as a way to encourage more eco-friendly travel. However, will electric planes be a part of the future of the aviation business any time soon?

  Many people who work in the flight business say that electric planes will be flying within the next ten years. Because work on these kinds of planes has already been going on for a while. Some electric prototypes have already taken their first flights, and electric planes could be used as soon as 2028.

- **Business & Leisure Air Travel Will Be Combined More Frequently**

  Additionally, the COVID-19 epidemic caused fewer business travellers. That's because a lot of businesses allowed employees to work from home. Going to meetings that used to require flying is now possible online. Numerous

companies have never gone back to the way things were done before the pandemic because this saved them time and money.

For some businesses, though, air travel is still necessary for occasional or regular work trips. When looking at the future of the aviation industry, however, it seems that more work trips will be combined with vacation trips. This type of travel, which is often called "bleisure travel," can be good for both employers and workers because it offers more vacation time and lower costs.

- **The Future of Aviation: A Review by GMR Aero Academy** [28]

It seems like the sky is the only thing that can stop the progress in flying in the future. The aviation business is growing very quickly. By 2041, there will be an amazing 19.3 billion passengers, and airports will handle nearly 200 million tonnes of air cargo and 153.8 million aircraft movements. The International Civil Aviation Organisation (ICAO) says that demand for air travel will grow by an average of 4.3% per year over the next 20 years. This will add an amazing $1.5 trillion to the world economy and create 15.5 million direct jobs by 2036. These numbers show how important aviation is for getting people to each other and moving the economy forward. The business will continue to grow in the years to come. There are a lot of new ideas and technological advances that could change the future of flight and make things possible that we didn't think were possible before.

As the number of people who want to fly grows and technology improves, the aviation business has a lot of job opportunities for people who have the skills and credentials to take it to new heights. The aviation industry has a lot of interesting job opportunities, such as designing cutting-edge planes and overseeing air traffic, or working as a flight attendant, pilot, or cyber expert. The pay is good, and there is a lot of room for growth. Being able to meet the needs of this fast-paced and changing business requires a workforce that is both highly skilled and diverse.

The Ministry of Civil Aviation (MoCA) of the Government of India says that India is now ready to become a world hub, and they are very excited about it. India is the world's third-largest flight market right now, following China and the US. Indian flying is getting a boost from both private and public sectors, with programmes like UDAN (Ude

[28] https://gmraviationacademy.org/blog/future-of-aviation

Desh ka Aam Nagrik) helping to do this. India is ready to fly because of these steps. Aviation's future looks like it will be full of exciting adventures, with a lot of new options just waiting to be discovered. To get the most out of this fast-paced sector, the industry needs to be open to change, encourage teamwork, and stay ahead of the curve. But with growth that has never been seen before, the aviation business faces both problems and chances.

Some problems that will need to be solved in the future are the following:

- How to Meet the Safety and Security Challenges of Aviation: Protecting Passengers and Property.
- Skilled Workforce: Meeting the Staffing Needs of the Aviation Industry.
- Managing the Skies: Dealing with the Rules and Logistics of the Aviation Industry.

9.4 AIRPORT INDUSTRY IN THE FUTURE 2030 [29]

A study called "Future of Airport Industry to 2030" by Market sand Markets says the following: This means that investments in airports around the world will grow at a rate of 14.4% per year, from USD 200 billion in 2021 to USD 2,404 billion in 2040. The airport industry's big investments in the area are part of a larger trend around the world to build and improve airport infrastructure. This is happening because more people are expected to travel, these areas are important as foreign transportation hubs, and airport infrastructure is seen as an important part of bigger plans for economic growth and tourism.

A big chunk of the money goes to expanding and improving the airport to make it better for passengers and their experience. Developing the runway is necessary to make it bigger so that it can handle more traffic and bigger planes. Automation, self-service kiosks, biometric identification, and smart baggage systems are some of the technologies that are being used to improve speed and the passenger experience. Also, sustainability projects that use renewable energy, better trash management, and buildings that use less energy are picking up speed. Creating a smooth and enjoyable airport trip by combining design, technology, and services is at the heart of these

[29] https://www.prnewswire.com/news/marketsandmarkets/

investments. They show a comprehensive approach to meeting future aviation needs and environmental obligations.

- **China Is Expected to Pass the US In the Next Few Years, Making India the Third Biggest Aviation Market**

India and China play important roles in the world of aviation, and their fast growth is paving the way for big changes in the business. India has become the third-largest flight market, which is a huge accomplishment thanks to its growing middle class, booming economy, and lower cost of flying. China, on the other hand, is almost ready to pass the United States as the world's biggest aviation market. This will happen in the next few years. India and China's rise as aviation powerhouses shows how their economies are growing and how important they are for connecting travel lines around the world. Their rise shows how the aviation business is shifting its attention to Asia, which is expected to drive most of the growth in air travel in the coming years.

- **Smart Airport Operations Depend on Investments in 5G Network Infrastructure**

When 5G networks are put in airports, they will change how the airports work and how people connect with their surroundings. Thanks to its fast connections, low latency, and ability to handle a huge number of devices at the same time, 5G makes a lot of different uses possible. Some of these are better real-time data sharing, better airport security through advanced monitoring technologies, and better services for passengers, like using augmented reality (AR) for navigation and personalised information sharing.

- **Personas Of Passengers Should Be More Socially, Culturally, And Racially Diverse**

Airport passenger identities are changing a lot, which is a reflection of larger changes in society and travellers' changing tastes. As business travel slowly recovers from the effects of the COVID-19 pandemic, the rise in leisure and tourist travel is changing how the airline industry responds to how passengers feel. In response to this change, micro-personas like solo travellers, music and event fans, and social media influencers have appeared, each with their own set of needs and expectations.

As passengers become more diverse, airport services and perks need to be more tailored to meet their needs. Now it's up to airports and airlines to make travel easier and more enjoyable by giving each micro-persona a personalised experience that fits their unique interests and tastes. These include using technology to communicate more effectively, providing specific amenities, and making airport places that cater to the interests of these different groups.

CHAPTER - 10

INDIAN AVIATION INDUSTRY

The Indian Civil Aviation sector has grown to become the third largest in the world in terms of domestic traffic

10.1 INTRODUCTION

In the last three years, India's civil aviation sector has grown at one of the fastest rates in the nation. It can be broadly divided into three categories: scheduled air transport, which includes mail and cargo flown by air, non-scheduled air transport, which includes charter operators and air taxis, and domestic and international airlines. By 2023, India's airport capacity is estimated to handle 1 billion trips annually, accounting for around 69% of all airline traffic in South Asia. The air traffic flow, which was 327.28 million in FY23 compared to 188.89 million in FY22, shows that the Indian aviation industry has fully recovered from the shock of the COVID-19 epidemic.

The biggest airline in India with the biggest market share is Indigo. By 2023, India will have surpassed the UK to become the world's third-largest air passenger market, having risen to the position of third in domestic aviation.

10.2 OVERVIEW OF THE INDIAN AVIATION SECTOR

The Indian airline industry, which includes scheduled, non-scheduled, and air freight services, is expanding quickly. India makes up over 69% of all flights in South Asia, with domestic flights dominating the market.

The sector is demonstrating evidence of resilience in spite of the disruptions brought about by the COVID-19 epidemic. Having the most market share, Indigo is a significant participant in the industry. By 2023, India is expected to surpass the UK to become the third-largest air passenger market globally.

Growing household incomes, the entry of low-cost airlines, a rise in FDI inflows, and an expanding GDP are some of the major factors contributing to this expansion. Both the public and commercial sectors are making large investments in infrastructure development to support this expansion.

The GDP and employment generation in India are greatly boosted by the aviation industry. It's well-positioned for future growth with good initiatives in place.

10.3 IMPORTANT ASPECTS OF INDIA'S AVIATION INDUSTRY

- **Revenue**

Even though the COVID-19 epidemic severely damaged the Indian aviation industry and caused large financial losses, the industry has shown resiliency and recovery. Forecasts indicate that India would grow to be the third-largest aviation market in the next years, indicating a promising future.

The aviation sector may boost the Indian economy by up to $1 trillion a year by 2043, according to even more bullish long-term forecasts. Strong economic growth, a sizable population, growing incomes, and significant expenditures in infrastructure and technology all support this expansion.

- **Investigation and Progression**

Airlines have lately placed record-breaking orders for aircraft, signalling significant changes in the Indian aviation market. As industry confidence grew, Air India and IndiGo placed unprecedented orders for 470 and 500 aircraft, respectively, in the early months of 2023. Jet Airways and Akasa Air also intend to significantly grow their fleets.

In the upcoming years, 1,300 more orders from Indian airlines are expected, according to consulting firm CAPA India, indicating a robust rebound following COVID-19. Rising demand, low-cost airlines, and government initiatives are expected to propel the Indian aviation market's expansion, with predictions of exceeding 1,200 narrowbody aircraft orders.

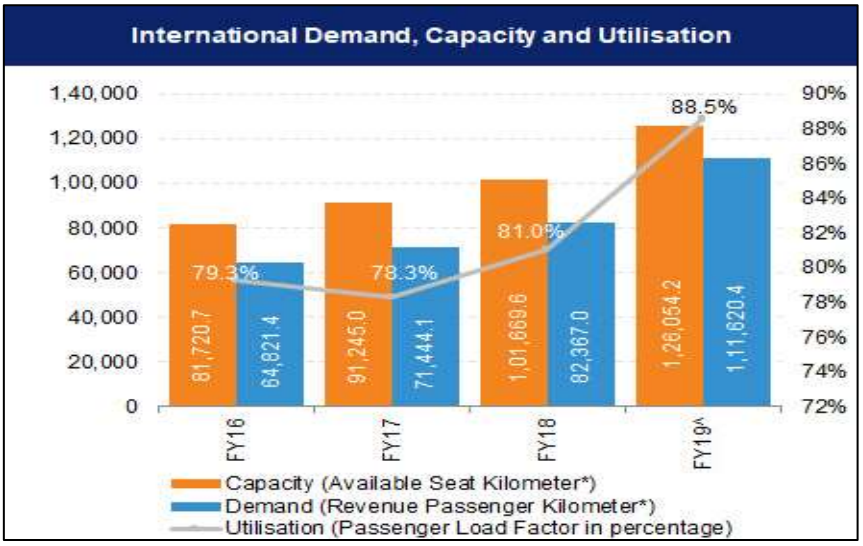
- **Brand-New Orders**

Recent record-setting aeroplane orders from airlines have brought about big changes in the Indian aviation sector. Early in 2023, Air India and IndiGo placed historic orders for 470 and 500 planes, respectively. This shows that people are becoming more confident in the business. Both Aksa Air and Jet Airways are also looking to add a lot more planes to their fleets.

Consultancy CAPA India thinks that Indian planes will place 1,300 more orders in the next few years, which is a strong sign of recovery after COVID-19. More than 1,200 narrow-body planes are expected to be ordered, which will help the Indian aviation market grow even more. This is because of rising demand, low-cost carriers, and government programmes.

10.4 SIZES OF MARKETS

According to the International flying Transport Association (IATA), India will pass China and the US to become the third-largest flying passenger market in the world before 2030. An increasing number of planes are also working in this field because demand is growing. It is planned that there will be 1,100 planes by 2027.



In the same time period last year, between April and October 2023, the number of domestic passengers reached 175.42 million, up 19.4%, and the number of foreign passengers reached 38.55 million, up 26.2%.

Domestic passenger traffic was expected to reach 270.34 million in FY23, up 62.1% year-over-year, and foreign passenger traffic was expected to reach 56.9 million, up 157% year-over-year.

FREIGHT TRAFFIC grew at a CAGR of 2.20 % from 2.70 MMT to 3.15 MMT from FY16 to FY23. In FY23, 3.15 million metric tonnes of goods were moved. The amount of freight that goes through Indian airports could hit 17 MT by FY40. There were a total of 2.5 million aircraft moves in FY23, up from 1.75 million in FY22. The Indian government has been trying to build more airports to handle the growing number of

flights. India has 148 airports that are open and running as of 2023. India wants to build 220 airports so that they can all be used by 2025.

10.5 THE ROAD AHEAD [30]

Many people in India still can't afford to fly, which means that the airline industry has a lot of untapped growth potential. This is especially true for the middle class, which makes up about 40% of the population. The government has played a big role in making laws that have helped the aviation industry. The government has started the UDAN-RCS scheme to make it easier for people to travel by air by making travel on regional routes more cheap, viable, and profitable.

Policymakers and people who have a stake in the industry should work together to make decisions that are efficient and make sense. This will help India's civil aviation business. India wants to become the third-largest aviation market by 2020. To get there, it needs to make sure it has the right policies and keep an eye on quality, cost, and customer interest. By 2021, Indian tourists will have spent a total of 136 billion rupees, or 9.5 lakh crore. India's travel and tourism industry supported the country's income with Rs. 15.7 trillion (US$190 billion) in 2022. The World Travel & Tourism Council (WTTC) says it will be worth Rs. 16.5 trillion (US$ 200 billion) by the end of this year. It's worth a huge almost Rs. 37 trillion (US$ 450 billion) to look ahead ten years.

[30] https://www.ibef.org/industry/indian-aviation

10.6 THE BIGGEST AIRPORTS AND AIRLINES IN INDIA [31]

A. The Biggest Airline

IndiGo is the biggest airline in the country in terms of both scheduled passenger flow and fleet size. It moved 12.50 million people in 2021. It has a fleet of 280 planes right now. The biggest airlines in India that carry civilians are:

IATA	Name	Callsign	Fleet size	Destinations
6E	IndiGo	Ifly	280	96
AI	Air India	Airindia	127	102
SG	SpiceJet	Spicejet	118	53
G8	Go First	Go First	57	38
UK	Vistara	Vistara	54	43
I5	AirAsia India	Red Knight	28	18
IX	Air India Express	Express India	24	33
9I	Air India Regional	Allied	21	75
9W	Jet Airways	Jet Airways	12	69

B. Largest Airports

Largest Airports of India			
S. No.	Airports	Location	Opened
1.	Indira Gandhi International Airport, Delhi	Delhi	1962
2.	Chhatrapati Shivaji International Airport, Mumbai	Mumbai	1942
3.	Kempegowda International Airport, Bangalore	Devanahalli, Bangalore	2008
4.	Rajiv Gandhi International Airport, Hyderabad	Shamshabad, Hyderabad	2008
5.	Chennai International Airport, Chennai	Chennai	2016
6.	Netaji Subhash Chandra Bose International Airport, Kolkata	Kolkata	1924
7.	Sardar Vallabhai Patel International Airport, Ahmedabad	Ahmedabad	1937
8.	Cochin International Airport, Kochi	Kochi	1999
9.	Dabolim Airport, Goa	Goa	1995
10.	Pune Airport	Pune	1939

[31] https://www.worlddata.info/asia/india/airports.php

10.7 THE INDIAN AVIATION INDUSTRY'S MOST IMPORTANT NUMBERS AND FACTS [32]

1. The World Airline Market in India is the third biggest in the world, after the US and China. In 2019, Indian carriers took more than 140 million people within India.
2. In the last ten years, the Indian aircraft business has grown very quickly. In 2010, about 61 million Indians flew on Indian airlines. By 2019, that number will have risen to over 140 million, an increase of over 130%.
3. The Indian aviation business is expected to be the biggest in the world by 2030, when 572 million people will have flown in India.
4. It is mostly low-cost carriers (LCCs) like IndiGo, SpiceJet, and GoAir that run the Indian aviation business. They have about 70% of the domestic market share.
5. The Indira Gandhi International Airport in Delhi is India's largest airport. In 2019, it served over 69 million people. Over 48 million people used the Mumbai Chhatrapati Shivaji Maharaj International Airport in 2019, making it the second busiest.
6. Safety is very important in the Indian aviation business. The Directorate General of Civil Aviation (DGCA) is in charge of making sure safety standards are met. In 2020, the International Civil Aviation Organisation (ICAO) gave the DGCA an award for its programme to oversee safety.
7. For example, the Indian government has made the Regional Connectivity Scheme (RCS) to make it easier for people to get to remote and regional parts of the country by flying. The RCS gives airlines financial incentives to fly to places that are hard to reach or don't have enough flights.
8. In the past few years, the Indian aviation industry has had to deal with a number of problems, such as high running costs, problems with regulations, and tough competition between airlines. The COVID-19 pandemic has also had a big effect on the business, causing a big drop in air traffic and profits.

[32] https://ensureias.com/blog/airport-infrastructure-in-india

9. In the past few years, the Indian government has eased rules on foreign direct investment (FDI), which means that up to 100% FDI can now go into the aviation business. This has made foreign investors want to get into the Indian market, which has made it more competitive and helped the business grow.

10.8 HOW TO DEAL WITH PROBLEMS

1. **Deal With the Limitations of The Infrastructure**: To help the Indian aviation industry deal with its lack of infrastructure, the government could put money into building new airports, expanding current ones, and updating air traffic control systems. This could help ease traffic, make operations more efficient, and improve the experience of passengers.
2. **Increase The Speed of Regulation:** The government could make it easier for airlines to follow the rules by streamlining the regulatory system. This might mean making rules easier to understand, cutting down on red tape, and switching to a risk-based governing approach. This could help the airline industry cut costs and make it easier to do business.
3. **To Encourage Investment and New Ideas:** To get people to invest in the aviation industry, the government could offer tax breaks, make low-cost loans available, and support public-private relationships. This might encourage new ideas and make it possible for airlines to buy new tools and grow their businesses.
4. **Fix The Lack of Skilled Workers:** To help the flight industry get more skilled workers, the government could create training programmes, offer rewards for training employees, and ask businesses to put money into training facilities. This could help make services better and help the industry keep up with the rising demand for air travel.
5. **Encourage Competition and Safeguard Customer Rights:** To make the airline industry more competitive, the government could support fair pricing, encourage the formation of new companies, and put in place rules to safeguard the rights of consumers. This could help make services better and allow customers to save money while getting better services.

10.9 ACTIONS MADE BY THE GOVERNMENT

The Indian government has implemented many measures aimed at bolstering and advocating for the aviation industry inside the nation. These are a some of the major actions the government has taken:

1. **The Regional Connectivity Scheme (RCS):** In order to provide air connectivity to rural and remote regions of the nation, the RCS, also known as UDAN (Ude Desh Ka Aam Nagrik), was introduced in 2016. By regulating rates at INR 2,500 ($34) per hour of flight on RCS routes, the programme seeks to make air travel accessible to the general public.
2. **Relaxation of FDI Regulations:** In the aviation industry, the government has loosened regulations for foreign direct investment (FDI), permitting up to 100% FDI through the automatic route. Due to this, international investors have been more inclined to enter the Indian market, which has boosted industry growth and competition.
3. **The National Civil Aviation Policy (NCAP):** In order to offer a path for the expansion and advancement of the aviation industry in India, the NCAP was introduced in 2016. The policy seeks to increase regional connectivity, lower the cost, increase passenger convenience, and improve the sector's overall competitiveness.
4. **Made in India:** The government's "Made in India" campaign seeks to boost indigenous manufacturing and the expansion of the aviation sector. The government has pushed international aerospace businesses to establish production facilities in India as part of this effort, which will strengthen the country's aviation sector and generate employment.
5. **Modernization of the Airports Authority of India (AAI):** India's airport development and management are under the purview of the AAI. To upgrade technology, modernise airport infrastructure, and improve passenger services, the government has started an AAI modernization programme.
6. **Relief from GST:** By lowering the Goods and Services Tax (GST) on air travel from 18% to 5% for economy class tickets and from 28% to 5% for business and first-class tickets, the government has helped the aviation sector.

10.10 DIGITAL PROJECTS

The Portal For E-Sahaj - The Ministry of Civil Aviation established the e-sahaj online platform, where security clearances related to the Ministry are made. 24 sorts of security clearances are granted via the platform.

The DigiYatra Programme - The pilot programme for the DigiYatra initiative's deployment has begun at the airports in Bangalore and Hyderabad. The programme aims to improve passenger experience and decrease waiting times in lines by implementing biometric technology for seamless and hassle-free travel. Additionally, advanced security solutions will allow travellers to bypass queues and stroll through gates. It will improve resource usage and eliminate duplication at checkpoints.

CHAPTER - 11

CONCLUSION AND SUGGESTIONS

"Aviation records don't fall until someone is willing to mortgage the present for future"

- *Amelia Earhart*

11.1 IMPORTANCE OF AVIATION INDUSTRY TO THE WORLD ECONOMY [33]

The aviation industry contributes significantly to the global economy by offering connectivity via the sole quick global transportation network. By doing this, approximately 22 million jobs and US$1.4 trillion in GDP are directly and indirectly impacted, having a significant worldwide influence on employment and GDP. Additionally, by promoting and assisting other businesses' expansion, the aviation sector benefits other industries. Since a large number of foreign visitors rely on air travel, the aviation sector supports 34.5 million jobs in the tourism sector worldwide and adds approximately US$762 billion to the global GDP annually.21 The advantages of aircraft extend beyond its financial impact. In the long run, the benefits of increased global connectedness brought about by air travel boost economic growth and overall productivity. Oxford Economics calculates that the advantage of air travel to global connectedness over the past few decades should be valued at more than $200 billion to the world's gross domestic product.

A nation's economy is influenced by the aviation sector in many different ways. It stimulates employment, trade, tourism, business connectivity, regional development, innovation, and foreign exchange profits. Governments and policymakers frequently adopt policies and investment plans to support the sustainable development of the aviation sector and optimise its economic advantages because they recognise the strategic relevance of aviation. A nation's economy benefits greatly from the aviation sector in a number of ways.

[33] Julie Perovic, "The Economic Benefits of Aviation Performance in the Travel & Tourism Competitiveness Index", Chapter 1.4.

1. **Immediate Economic Effect:** By generating income, investing in infrastructure, and creating jobs, the aviation sector directly supports economic expansion. Millions of individuals work in a variety of capacities for airports, airlines, aircraft manufacturers, and other companies worldwide, such as pilots, cabin crew, maintenance technicians, airport employees, and aviation professionals. A significant amount of money is also needed for the development and upkeep of airports and aviation facilities, which boosts the economy and creates jobs in the engineering, construction, and associated industries.
2. **Enabling Trade and Commerce:** Through its ability to move people and things across borders quickly, reliably, and efficiently, aviation promotes global trade and commerce. In order to sustain global supply chains and international trade, air cargo operations are essential for the timely and high-value transportation of commodities such as electronics, pharmaceuticals, perishables, and e-commerce shipments.
3. **Travel and Hospitality:** The tourist and hospitality industries rely heavily on the aviation sector, which stimulates employment and economic growth in the locations served by air travel. Travellers' access to business centres, tourist locations, cultural attractions, and leisure pursuits via air travel increases demand for lodging, food, entertainment, transportation, and other tourism-related businesses. Air travel plays a major role in attracting tourists, generating income, and creating jobs in tourism-related industries in economies that depend on tourism.
4. **Connectivity in Business:** By facilitating in-person meetings, conferences, and business travel—all crucial for building relationships, negotiating, and closing deals—aviation promotes corporate connectivity. Business travellers frequently purchase expensive tickets, which boosts the earnings and profitability of airlines. The availability of effective air transport networks bolsters a nation's appeal as a commercial destination, drawing in foreign capital and promoting economic growth.

5. **Development in the Region:** Airports stimulate economic activity and investment in their surrounding areas, acting as catalysts for regional growth. Connected airports draw companies, sectors, and logistical centres, generating jobs and stimulating development in surrounding areas. Airport development initiatives boost building, infrastructure spending, and urban growth, which raises property values and boosts the local economy in airport-served areas.
6. **Technology & Innovation:** Innovation and technical breakthroughs in aircraft design, propulsion systems, air traffic control, safety systems, and airport operations are driven by the aviation sector. Research and development expenditures increase aircraft performance, noise reduction, fuel economy, and environmental sustainability. Innovation in aviation technology has a knock-on effect on other sectors of the economy, increasing productivity and competitiveness.
7. **Earnings in Foreign Exchange:** Through international tourism, the export of air transportation services, and foreign investment in aviation-related enterprises, aviation helps nations make foreign exchange. Foreign carriers' landing fees, international passenger traffic, and cargo shipments provide income for airports and airlines, which goes towards the nation's foreign exchange reserves and balance of payments.

11.2 ROLE OF AIRPORTS IN THE GROWTH OF AVIATION INDUSTRY

Airport development and related infrastructure development are required due to the expansion of the aviation industry. Consequently, the development of airports, runways, terminals, and other aviation-related infrastructure leads to an expansion of employment prospects and a boost to the construction industry.

In order to facilitate air travel, stimulate economic growth, foster connection, and aid in regional development, airports are vital infrastructural hubs in the aviation industry. Sustaining the expansion and prosperity of the aviation sector and fulfilling the increasing demand for air travel need ongoing investments in airport infrastructure, technology, and services.

Being essential infrastructure hubs that support air travel for people, goods, and aircraft operations, airports are essential to the aviation industry. Important roles:

1. **Hub for Connectivity:** Airports act as hubs for connection, linking travellers and goods to locations across the globe via a network of flights run by different airlines. They offer all the necessary infrastructure and services, like as runways, aprons, terminals, and ground transit choices, to ensure smooth travel.
2. **Gateway to Business & Tourism:** Airports provide as entry points to both business and tourism destinations, connecting passengers to trade shows, conventions, and well-known tourist sites. When it comes to drawing in passengers, investors, and tourists, well-connected airports are essential for fostering economic expansion and development in the areas they serve.
3. **Trade and Cargo Logistics:** Airports enable the flow of products and cargo via air freight operations, promoting international trade, business, and supply chain management. When it comes to moving expensive, urgent, and perishable commodities, cargo airports and logistics hubs are essential for boosting trade competitiveness and promoting economic growth.
4. **Economics Engine:** By providing both direct and indirect economic advantages to the local communities and areas they serve, airports stimulate economic growth and development. In addition to drawing investment and economic activity, they generate jobs in a number of industries, including retail, transportation, hotel, and aviation.
5. **Hub for Innovation and Technology:** By making investments in cutting-edge infrastructure, air traffic management systems, security technologies, and environmental sustainability programmes, airports propel technological innovation and breakthroughs in the aviation industry. They act as centres of innovation, where cutting-edge techniques and new technology are applied to improve passenger experience, efficiency and safety.
6. **Regional Development Catalyst:** By drawing in investment, boosting the local economy, and encouraging urbanisation and infrastructure development, airports serve as catalysts for regional development. Airport development initiatives boost the economy of the areas that surround the airport by providing chances for building, real estate development, infrastructural investment, and employment creation.

11.3 TOP AIRPORTS OF THE WORLD IN 2023 [34]

By 2023, the following airports could be among the best in the world, recognised for their excellent design and cutting-edge technology:

1. Changi Airport in Singapore (SIN)

- Changi Airport is always rated as one of the best airports in the world because of its great facilities and cutting-edge technology.
- Jewel Changi Airport, a beautiful mixed-use building with a waterfall, indoor gardens, and entertainment areas, shows how much the airport cares about its passengers. Changi Airport is always rated as one of the best airports in the world because of its great facilities and cutting-edge technology.
- Automated check-in machines, biometric immigration systems, and efficient baggage handling systems are all examples of cutting-edge technology.

2. South Korean Airport, Incheon International (ICN)

- Extolled for its cutting-edge architecture and advanced technology, Incheon Airport
- Slumber lounges, spas, and cultural exhibitions are just a few of the cutting-edge amenities and services available at its terminals.
- The airport enhances its operating efficiency by utilising smart technologies for luggage handling, security screening, and passenger flow management.

3. Japan's Tokyo Haneda Airport (HND)

- Haneda Airport is renowned for its cutting-edge facilities and passenger-focused architecture.
- Enhancing the passenger experience and maximising operating efficiency have been the main goals of renovations and extensions.
- Its sophisticated check-in systems, self-service kiosks, and effective security procedures have earned it a reputation as one of the best airports in the world.

[34] https://bimageconsulting.com/navigating-the-future-top-10-high-tech-airports-worldwide-with-vdc-and-bim-innovations/

4. Germany's Munich Airport (MUC)

- Munich Airport is well known for its creative architecture and environmentally friendly operations.
- Modern amenities like as self-service check-in kiosks and automated baggage handling systems may be found in Terminal 2 of the airport.
- It has made investments in eco-friendly projects and renewable energy sources in line with its dedication to environmental stewardship.

5. Airport International in Hong Kong (HKG)

- The unique architecture and state-of-the-art facilities of Hong Kong International Airport have gained recognition.
- The airport uses technology, like biometric verification and self-check-in kiosks, to expedite passenger procedures.
- Its status as a top worldwide hub is a result of its automated baggage handling system and effective air traffic control.

6. Airport in Dubai, United Arab Emirates (DXB)

- Dubai Airport is well-known for its cutting-edge architecture and heavy reliance on technology.
- It offers top-notch facilities like shopping centres, entertainment venues, and opulent lounges.
- Innovative passenger tracking methods, smart gates, and biometric immigration systems are examples of technological developments.

7. Finland's Helsinki Airport (HEL)

- Helsinki Airport is renowned for its smooth passenger experience and effective design.
- It has integrated cutting-edge technologies to control passenger flow, handle baggage, and conduct security screening.
- The airport's energy-efficient infrastructure and eco-friendly programmes demonstrate its dedication to sustainability.

These airports are leaders in the worldwide aviation business because they are prime examples of integrating state-of-the-art technology with creative design to improve the passenger experience and maximise operational efficiency.

11.4 SUGGESTIONS

1. This study makes it clear that airport structure and technology are important to the aviation industry; so, the top airports are those with excellent infrastructure and high levels of technology.
2. The government and other airport authorities should consider developing airports, given that the expansion of the aviation sector is a major contributor to the economies of all nations.
3. More funding ought to be made available for airport infrastructure and technological adoption.
4. Regulations should be carefully crafted by regulatory bodies to support the expansion of airports and, consequently, the aviation sector.

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D. AIRPORTS VISITED

I visited the following Airports for detail study of infrastructure, facilities & technology:

- **BLR -** Kempe Gowda International Airport – Terminal II, Bangalore
- **DEL** - Indira Gandhi International Airport, Delhi
- **JAI -** Jaipur International Airport
- **DBX –** Dubai International Airport, UAE
- **LKO -** Chaudhary Charan Singh International Airport, Lucknow

- **CDG –** Charles de Gaulle International Airport, Paris
- **JFK –** John F Kennedy International Airport, New York
- **ORD –** O'Hare International Airport, Chicago
- **YYZ –** Pearson International Airport, Toronto

E. MUSEUMS VISITED

I visited the following Museums to have detail knowledge of Aviation Industry, history Aircrafts & Airports and impact:

- ***National Airforce Museum Canada* –** Astra, Ontario
- ***Airforce Museum*** – Palam, New Delhi
- ***HAL Heritage Centre & Aerospace Museum*** - Bangalore

F. INTERVIEWS

1. ***Mubin Bajighar*:** Technology Consultant – Numatech Solutions LLC, New Jersey, US; Ex-CTO Terminal Holdings, Abu Dhabi.