



## Air Transport System: A Review on the Advancement, Opportunities and Challenges

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### ABSTRACT

The air transport system has undergone remarkable advancements in recent years, driven by technological innovations, digital transformation, and improved air traffic management. These developments have revolutionized global connectivity, leading to substantial benefits in economic growth and passenger experiences. However, the industry faces significant challenges, particularly concerning its environmental impact. Issues like carbon emissions, noise pollution, and resource consumption demand urgent attention. To mitigate the environmental footprint, the air transport industry must prioritize the adoption of sustainable practices and technologies. This includes embracing alternative fuels and implementing energy-efficient operations. Additionally, infrastructure constraints, such as limited airport capacity and outdated air traffic control systems, pose obstacles to efficiency and performance. Therefore, investments in infrastructure expansion, modernization, and regional cooperation are crucial to meet the growing demand and improve overall efficiency. Amidst these challenges, numerous opportunities exist for the industry to transform itself. By embracing sustainable aviation practices, the industry can significantly reduce its environmental impact and ensure long-term viability. The development and utilization of alternative fuels, along with energy-efficient operations, contribute to a greener and more sustainable air transport system. Moreover, digital transformation plays a vital role in streamlining operations, optimizing maintenance and logistics, and enhancing the passenger experience. Leveraging advanced data analytics and artificial intelligence enables efficiency gains, improved safety and security measures, and data-driven decision-making. Furthermore, emerging markets and increased air connectivity to underserved regions present substantial growth opportunities, economic development, and improved access to air travel. These factors not only benefit the industry but also foster inclusive and sustainable development for the communities it serves. This article explores the advancements, challenges, and opportunities in the air transport system. It emphasizes the need for sustainable practices, technological innovation, infrastructure investment, and regional collaboration to address environmental concerns, enhance efficiency, and ensure future growth in the industry.

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### INTRODUCTION

Air transportation was slow to take off after the Wright Brothers' breakthrough at Kitty Hawk in

1903 (Carroll, 2005). It took over a decade after that for the world's inaugural scheduled flight with a paying passenger to hop across the bay separating

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Tampa and St. Petersburg, Florida on January 1, 1914 (Davies, 2016). During its nascent stage, the airline sector forged a mutually beneficial alliance with military aviation. The advent of World War I, which commenced shortly after the inaugural flight from Tampa, served as a catalyst for the advancement of commercial aviation, as the strategic implementation of air power necessitated the swift introduction of more sophisticated aircraft.

Throughout the 20th century, air travel has endured as a paramount advancement in transportation, evolving significantly over time. It enabled the expedited conveyance of individuals and commodities, fostering a surge in the demand for both short and long-distance journeys. In actuality, aircraft enabled the accessibility of any destination worldwide within a span of 24 hours, thereby fostering the process of globalization. Over the years, the tourist industry's transportation segment has seen tremendous growth in the market share of air travel (Bieger et al., 2006).

Air travel will continue to play a major role in the tourist sector for instance, due to the rise in the number of individuals who use aero planes to travel every day for a variety of reasons. Today, the tourist industry now heavily relies on it. Air travel is seen to have played a significant role in the process of globalization and has significantly contributed to the idea that the globe has become a small community. Air transportation is a critical component of economic development. It is one of the yardsticks for measuring progress. Even in the face of airline catastrophes that damage the sector, the aviation industry all over the world is credited with a substantial influence in terms of progress; a specific example is the recent Malaysia twin aircraft mishap within a five-month period (Delmo & Chaidaroon, 2019). Despite the aviation industry's numerous issues, there are over two thousand (2,000) airlines operating over twenty-three thousand (23,000) aircraft that serve around three thousand seven hundred (3,700) airports worldwide (Alexander et al., 2015).

Developing this industry would help to boost global economic activity. Nigerian air travel has several positive economic effects (Ameer et al., 2021). First, the use of air travel supports the creation of jobs. The Nigerian aviation sector directly or

indirectly employs over 159,000 locals and foreigners in paid positions (Oladejo et al., 2021).

The rest of this paper is structured as follows: section one defines major concepts in air transport, section two highlights the advancements and growth experienced by civil aviation. In section three, the opportunities available in air transportation were briefly highlighted. Section four itemizes the challenges bedeviling global air transportation and section five concludes with recommendations on addressing these challenges.

## FUNDAMENTAL CONCEPTS IN AIR TRANSPORT SYSTEM

In this section, some of the fundamental concepts regarding Air Transportation are discussed.

### *Air Transport System*

As one of the characteristics of every living thing is movement from one point to another, there has always been the need for systems or mechanisms that can aid this process of movement. The transportation system therefore allows for the movement of people and goods from one location to another, thereby bringing people together and exchanging goods. This has made transportation a primary system for the development of civilization. Over the years, the transportation system keeps evolving creating various means of transportation, which includes the road, railways, water and air and for special purposes, pipelines, cables and space transport can be considered.

The air transport system refers to the interconnected network of various components and entities involved in the movement of people, goods, and services by air. It encompasses airlines, airports, air traffic control, aircraft manufacturers, regulatory bodies, supporting industries, and passengers.

### *Airlines*

Commercial airlines are the primary entities in the air transport system (Button, 2017). They operate scheduled flights, carrying passengers and cargo between different destinations. Airlines manage fleet operations, ticketing, customer service, and safety measures.

### Airports

Airports serve as the infrastructure for air travel (Cidell, 2006). They provide facilities and services for aircraft to land, take off, and be serviced. Airports include runways, terminals, control towers, security systems, and ground handling services.

### Air Traffic Control (ATC)

Air traffic control ensures safe and efficient movement of aircraft in the sky and on the ground. ATC manages airspace, provides guidance to pilots, monitors flight routes, and coordinates landings and takeoffs (Alkurdi, 2018). It involves communication between air traffic controllers, pilots, and ground support personnel.

### Aircraft Manufacturers

Companies like Boeing, Airbus, and other aircraft manufacturers design, develop, and produce commercial airplanes. They incorporate advanced technologies, safety features, and fuel efficiency improvements into their aircraft to meet the demands of the air transport system.

### Regulatory Bodies

Regulatory bodies establish and enforce safety, security, and operational regulations for the air transport system (Aliandrina, 2012; Richmond,

2019). These bodies, such as the Federal Aviation Administration (FAA) in the United States and the European Union Aviation Safety Agency (EASA) in Europe, oversee aircraft certifications, pilot licensing, and airworthiness standards.

### Supporting Industries

The air transport system relies on various supporting industries. These include aircraft maintenance, repair, and overhaul (MRO) providers, fuel suppliers, catering services, ground handling companies, cargo handlers, and travel agencies.

### Passengers

Passengers are an integral part of the air transport system. They rely on airlines and airports to travel to their desired destinations. Passengers benefit from the connectivity, speed, and convenience offered by air travel.

The air transport system is a complex and highly regulated industry that plays a vital role in global connectivity, trade, tourism, and economic development (Button & Taylor, 2000; World Tourism Organization, 1997). It requires coordination and cooperation among multiple stakeholders to ensure safe, efficient, and sustainable air travel. Figure 1 gives an insight into the relationship between the air transport system and its environment.

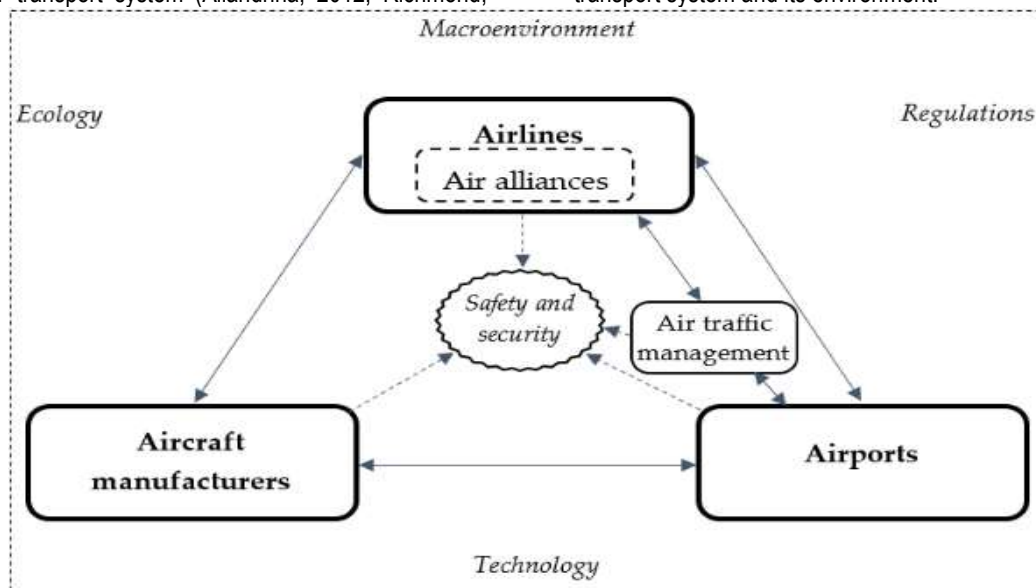


Figure 1: The Air Transport System and Its Environment (Ivanova, 2017)

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An aircraft is a device/vehicle that is used for, or is intended to be used for flight in the air (Boštjan, 2016). Major categories of aircraft are airplane, rotor-craft, glider, unmanned area vehicles (UAV), lighter-than-air vehicles, etc. as illustrated in Figure 2. Aircraft operations are carried out by the military and airlines, which provide air transport as a service.

To ensure the safe, efficient and effective operation of this service, Air Traffic Management (ATM) performed by Air Navigation Services (ANS) has to ensure safe and scheduled aircraft flow around the world (Mohammed et al., 2022).



**Figure 2:** Examples of different categories of aircraft, clockwise from top left: lighter-than-air, glider, rotor-craft, and airplane.

Some of the influential factors affecting aviation operations generally, both civil as well as military operations are mainly society's expectations and developments, politics, represented by authorities which develop and sets the legal and regulatory policies for air transport system, the economy as a key for people's welfare, amongst others.

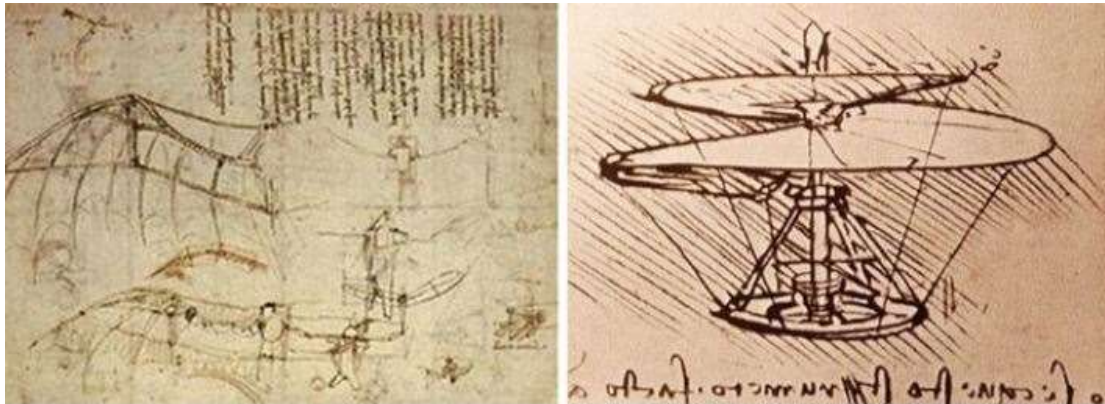
#### **AIR TRANSPORT SYSTEM ADVANCEMENT**

Air Transport has experienced significant growth since its inception. This section briefly discusses the advancements in Air Transportation.

##### ***The Beginning of Flight***

According to Leonardo da Vinci, man would be able to depart into the air with the help of machines with large wings, which had to be designed

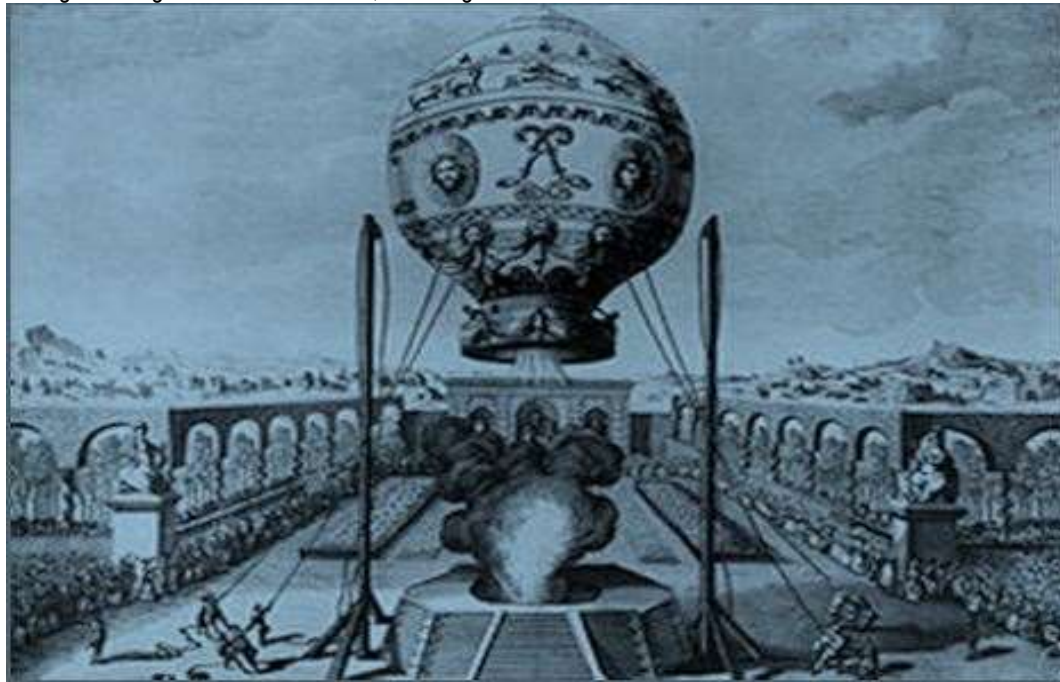
to overcome the air resistance (Schmitt & Gollnick, 2016). He created numerous illustrations depicting various principles of his airborne machines. Certain drawings depicted a person positioned horizontally within the flying apparatus, with hands and feet either fixed or operating cables or bars. Other depictions showcased an individual manipulating a flapping mechanism to maneuver the wings in an upward and downward motion. Additionally, some illustrations portrayed a screw-like contrivance, capable of vertical ascension through rotational motion when sufficiently accelerated (Galluzzi, 1987) as in Figure 3. Also a parachute system can be found in his archive of drawings. So a lot of different flying principles were shown in his drawings and it may seem that he had constructed a lot of models to test his principles.



**Figure 3:** Drawings about flying vehicles from Leonardo da Vinci. (Galluzzi, 1987)

Furthermore, considering the case of the Montgolfier brothers, who fortuitously pioneered the hot air balloon, they successfully uncovered the underlying principle behind such balloons and proceeded to construct one (Schmitt & Gollnick, 2016). The momentous flight of their hot air balloon in front of the King at Versailles in 1783 created a sensation and grand spectacle. Onlookers were captivated as they witnessed the first three passengers being elevated into the air, including a

rooster, a sheep, and a dog as seen in Figure 4. The concept of hot air balloons was swiftly recognized as a promising opportunity for military applications. However, a significant drawback soon became apparent: the lack of controllability. Balloons simply drifted with the wind, devoid of the capability to steer them in a specific direction. As a result, interest in balloons rapidly waned.



**Figure 4:** The Montgolfiere hot air balloon. (Schmitt & Gollnick, 2016)

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Several years later, Sir George Cayley (1773-1857) played a crucial role in defining and advancing fundamental principles that would greatly contribute to the future success of flight vehicles. He expounded upon these principles in his paper titled "The Art of Flying, or Aerial Navigation," outlining the following key concepts:

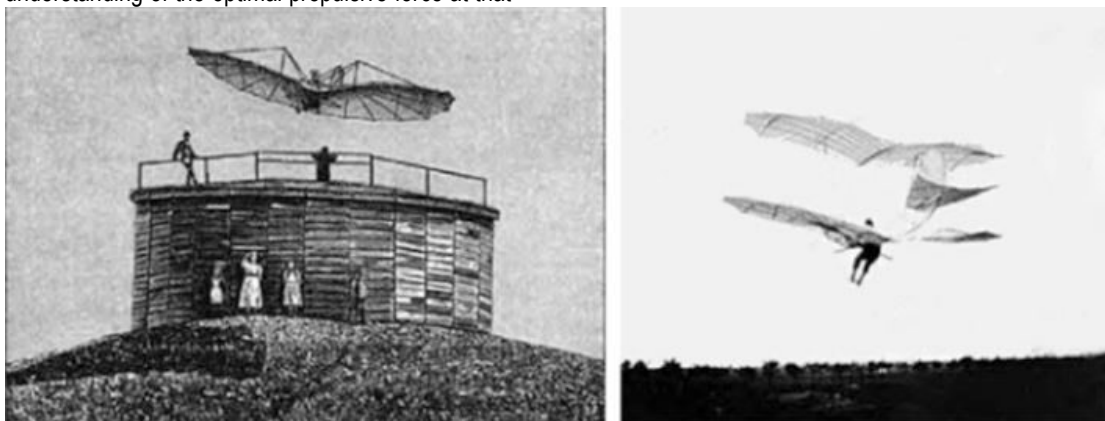
1. Separation of forces acting on the wing: Cayley distinguished between lift (the upward force) and drag (the horizontal resistance force) exerted on the wing.
2. Importance of stability and controllability: Cayley emphasized that stability and the ability to control the aircraft were fundamental principles for any flying vehicle.
3. Lift as compensation for mass: He recognized that generating sufficient lift was crucial to offset the weight of the aircraft, leading to the development of lightweight structures.
4. Independent thrust to counter aerodynamic drag: Cayley advocated for the inclusion of independent sources of thrust to counter the resistance caused by aerodynamic drag.

By constructing numerous models that effectively showcased the principles he postulated, Sir George Cayley garnered recognition as the progenitor of modern aircraft, according to certain historians. However, it is important to highlight that Cayley had not yet achieved a definitive understanding of the optimal propulsive force at that

time. While he diligently constructed models, the conclusive idea regarding the appropriate propulsive force had yet to materialize. (Schmitt & Gollnick, 2016).

A significant breakthrough in aviation was brought about by Otto Lilienthal. While observing storks, both Otto and his brother Gustav were inspired by the generation of lift through movement against the wind, now recognized as dynamic lift. They noticed that young storks, when attempting to take off, always initiated their flight against the wind—a concept that remains relevant to this day. Otto Lilienthal discovered the correlation between forward speed and the wing flapping mechanism of birds, which is crucial for generating lift. To study wing shapes, he developed a circular rotating apparatus called the "Rundlauf," initially testing flat plates and later replicating the wing profiles of storks, incorporating camber and incidence, and eventually complete wings.

In 1891, Otto Lilienthal commenced practical gliding tests with his first "gliding vehicle," featuring cambered wings. He conducted these tests from a hill in the vicinity of Berlin. Notably, Lilienthal published a book titled "Der Vogelflug als Grundlage der Fliegekunst" (Bird Flight as the Basis of Aviation) in 1899, which documented his research on wing profiles. This publication was a groundbreaking endeavor as it openly shared an inventor's knowledge and was privately financed. Its contribution proved significant in assisting other inventors in the pursuit of achieving successful flight as illustrated in Figure 5.



**Figure 5:** Lilienthal's "Sturmhügel" Flying base 1894 and a gliding flight. (Schmitt & Gollnick, 2016)

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Orville (1871–1948) and Wilbur (1867–1912) Wright, a pair of American inventors, are credited with inventing and constructing the world's first functional airplane. Their groundbreaking achievement took place on December 17, 1903, when they accomplished the first controlled, powered, and sustained human flight with a heavier-than-air aircraft. Over the subsequent two years, the Wright brothers further refined their flying machine, ultimately transforming it into the first practical fixed-wing aircraft as seen in Figure 6. The Wright brothers' pivotal breakthrough lay in their advancement of

three-axis control, which allowed pilots to effectively steer the aircraft and maintain its stability. Their initial U.S. patent, numbered 821,393, did not assert the invention of a flying machine itself, but rather the invention of an aerodynamic control system that manipulated the surfaces of a flying machine. This development generated great motivation among enthusiasts worldwide upon learning that the Wright brothers had successfully showcased the first independent flight with a heavier-than-air machine. (Schmitt & Gollnick, 2016).

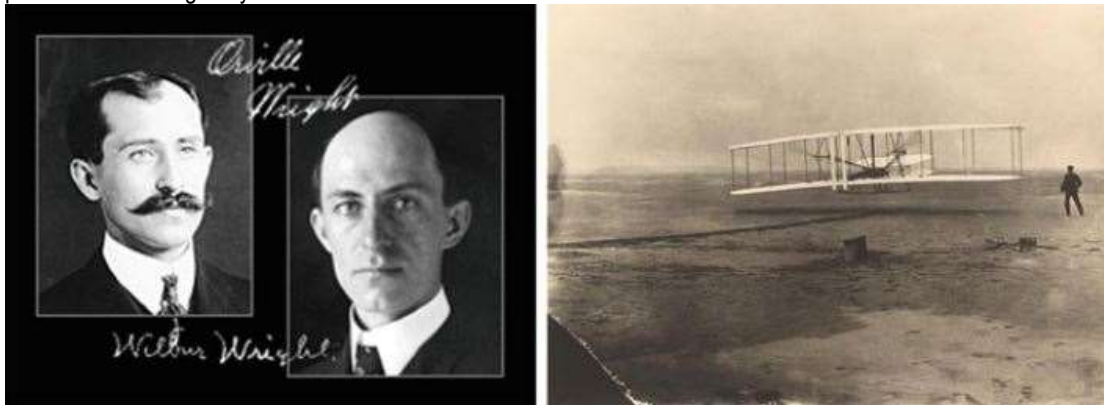


Figure 6: The Wright brothers—Orville and Wilbur and their Kitty Hawk. (Schmitt & Gollnick, 2016)

### **The Birth of Civil Aviation**

During the 1920s and 1930s, the field of civil aviation experienced notable advancements and substantial growth. This era witnessed the rise of renowned aircraft manufacturers like Boeing, Douglas, and Lockheed, who developed dependable and efficient aircraft suitable for commercial purposes. Governments worldwide recognized the significance of regulating and promoting civil aviation, resulting in the establishment of national aviation authorities and the formulation of safety standards.

An important milestone in the history of civil aviation was the Air Mail Act of 1925 in the United States. This legislation incentivized private airlines to transport mail by offering financial incentives. Consequently, commercial passenger services emerged alongside mail transportation. This act played a vital role in the expansion of the airline industry, as airlines gradually shifted their focus from primarily carrying mail to catering to passengers. In

1927, Charles Lindbergh's solo non-stop flight across the Atlantic Ocean in the Spirit of St. Louis captured global attention and showcased the potential of long-distance air travel. Lindbergh's remarkable feat sparked widespread interest in aviation, motivating governments and private companies to invest in the development of intercontinental air routes.

The 1930s marked the introduction of luxurious passenger airliners such as the Boeing 247 and the Douglas DC-3. These aircraft offered enhanced comfort, speed, and reliability, contributing to the growth of commercial aviation. Additionally, the establishment of national and international air routes facilitated the expansion of global air travel networks (Bilstein, 2005).

The beginning of civil aviation marks an important milestone in the history of human flight. It was a period of remarkable advancements in aircraft design, technological innovation, and the establishment of systems and regulations that shaped the aviation industry as we know it today.

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## OPPORTUNITIES IN AIR TRANSPORT

The air transport industry has been a key driver of global connectivity and economic growth, facilitating international trade, tourism, and the movement of people across continents. In recent years, numerous opportunities have emerged within the air transport sector, driven by technological advancements, changing consumer demands, and evolving industry dynamics.

### *Growing Air Passenger Traffic*

The global demand for air travel continues to rise, fueled by increasing disposable incomes, urbanization, and the expansion of low-cost carriers. The International Air Transport Association (IATA) predicts that global passenger numbers will double by 2037, creating significant opportunities for airlines, airports, and associated service providers (Bruce et al., 2020; Keselova et al., 2019). The growth in air passenger traffic presents opportunities for airlines to expand their routes, improve connectivity, and enhance customer experiences. Additionally, airports can leverage this growth to increase revenue from passenger services, retail, and concessions.

### *Emerging Markets and Regional Connectivity*

Rapid economic growth in emerging markets, particularly in Asia-Pacific, Africa, and Latin America, presents substantial opportunities for air transport. Governments in these regions are investing heavily in airport infrastructure, opening new routes, and liberalizing air transport policies, fostering improved regional connectivity (Bowen, 2016). This trend enables airlines to tap into previously underserved markets and expand their customer base. It also provides opportunities for airports to attract new airlines, increase flight frequencies, and develop air cargo capabilities.

## TECHNOLOGICAL ADVANCEMENTS

Advancements in technology are revolutionizing the air transport industry. Several opportunities arise from innovations such as:

### **a. Sustainable Aviation**

The aviation sector is under increasing pressure to reduce its environmental impact. Opportunities lie in the development of alternative

fuels, electric aircraft, and sustainable aviation technologies. Investments in research and development in these areas are driving progress towards more environmentally friendly aviation (Gopalakrishnan et al., 2012). The transition to sustainable aviation presents opportunities for airlines to adopt eco-friendly practices, reduce fuel costs, and enhance their environmental credentials. It also creates opportunities for manufacturers and suppliers of sustainable aviation technologies.

### **b. Digital Transformation**

The integration of digital technologies offers vast opportunities for efficiency gains, enhanced passenger experiences, and cost reductions. Examples include biometric passenger identification, self-service kiosks, blockchain for supply chain management, and artificial intelligence applications for predictive maintenance and operational optimization (Molchanova, 2020; Tan & Masood, 2021). Digital transformation enables airlines and airports to streamline operations, personalize customer interactions, and optimize resource utilization. It also opens avenues for partnerships and collaborations with technology providers.

### **Cargo and E-commerce Growth**

The rapid expansion of e-commerce is driving increased demand for air cargo services. The ability of air transport to offer fast and reliable global shipping solutions positions the industry to capitalize on this growth. Furthermore, the rise of cross-border e-commerce opens opportunities for integrated logistics solutions and partnerships between e-commerce platforms, airlines, and logistics providers (Giuffrida et al., 2017). The growth in e-commerce presents opportunities for airlines to expand their cargo operations, develop specialized services, and explore new business models. Airports can leverage the demand for air cargo to expand their cargo handling capabilities and attract cargo-focused airlines.

### **MRO (MAINTENANCE, REPAIR, AND OVERHAUL) SERVICES.**

As the global aircraft fleet continues to expand, there is a growing demand for MRO

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services. Opportunities exist in providing efficient maintenance solutions, leveraging advanced analytics, automation, and predictive maintenance technologies. The increasing complexity of modern aircraft systems also drives demand for specialized maintenance expertise. The demand for MRO services presents opportunities for companies to offer innovative maintenance solutions, develop digital tools for predictive maintenance, and establish partnerships with airlines and aircraft manufacturers. The air transport industry is ripe with opportunities across various dimensions. The projected growth in passenger traffic, expansion into emerging markets, technological advancements, e-commerce-driven cargo growth, and the increasing demand for MRO services all offer potential avenues for stakeholders to capitalize on. Embracing these opportunities will require a strategic focus on innovation, sustainability, and customer-centric approaches.

#### AIR TRANSPORT CHALLENGES

Air transport plays a crucial role in global connectivity, facilitating trade, tourism, and economic growth. However, the industry faces numerous challenges that require careful attention and strategic planning.

##### Fuel Costs and Environmental Impact

The rising cost of aviation fuel and its impact on operating expenses pose significant challenges for the industry. Additionally, growing concerns about environmental sustainability and climate change necessitate the development and adoption of more fuel-efficient and eco-friendly technologies and practices

##### Infrastructure Constraints

Airports and air traffic control systems are often strained due to capacity limitations, resulting in delays, congestion, and reduced efficiency. The need for infrastructure development, expansion, and modernization is critical to meet the increasing demand for air travel.

##### Safety and Security

Maintaining high levels of safety and security is a constant challenge for the air transport industry. This includes addressing emerging threats

such as cyber-attacks and terrorism, as well as ensuring robust safety protocols and systems to prevent accidents and incidents.

##### Regulatory Framework

The air transport sector operates within a complex web of international and national regulations, which can create challenges for airlines, airports, and other industry stakeholders. Compliance with evolving regulations and standards requires continuous adaptation and coordination.

##### Workforce and Skills Gap

The aviation industry faces challenges related to attracting, training, and retaining a skilled workforce. The demand for qualified aviation professionals, including pilots, engineers, air traffic controllers, and maintenance personnel, continues to outpace the available supply.

The air transport industry faces numerous challenges that require proactive measures and collaboration among stakeholders. Addressing fuel costs, environmental impact, infrastructure constraints, safety and security, regulatory frameworks, and the workforce skills gap are key areas that demand attention to ensure the industry's sustainable growth and development (Momoh et al., 2023).

#### RECOMMENDATIONS

Based on the challenges highlighted, the following are recommended:

##### Fuel Efficiency and Environmental Impact:

- Encourage the development and adoption of sustainable aviation fuels (SAF) to reduce carbon emissions.
- Invest in research and development of innovative technologies, such as electric or hybrid aircraft, to enhance fuel efficiency.
- Implement carbon offset programs and incentivize airlines to reduce their environmental footprint.

##### Infrastructure Development:

- Collaborate with governments and industry stakeholders to invest in airport infrastructure

- expansion, including runways, terminals, and air traffic control systems.
- b. Implement smart airport technologies and digital solutions to optimize capacity utilization and enhance operational efficiency.
- c. Promote regional cooperation to develop and upgrade regional airports, reducing congestion at major hubs.

#### **Safety and Security:**

- a. Enhance collaboration between airlines, airports, and security agencies to share information and adopt proactive security measures.
- b. Invest in advanced screening technologies and cybersecurity systems to mitigate emerging threats.
- c. Conduct regular safety audits and training programs to ensure adherence to international safety standards.
- d. Airport security screening methods for non-metals involve the use of advanced technologies such as X-ray scanning, explosive trace detection (ETD), and advanced imaging technology to ensure the detection of prohibited items or substances concealed within non-metallic objects.
- e. Exploring the implementation of blockchain technology in airport security to enhance passenger identity management, improve supply chain transparency, and strengthen cybersecurity measures through decentralized and tamper-proof systems, ensuring efficient and secure operations while addressing regulatory and privacy considerations.

#### **Regulatory Framework:**

- a. Foster closer collaboration between aviation authorities and industry stakeholders to develop consistent and harmonized regulations.
- b. Encourage regulatory bodies to adopt agile and flexible approaches to accommodate technological advancements.

- c. Promote industry engagement in regulatory decision-making processes to ensure a balanced and practical regulatory framework.

#### **Workforce Development:**

- a. Collaborate with educational institutions and industry associations to develop comprehensive training programs for aviation professionals.
- b. Establish partnerships with aviation training organizations to bridge the skills gap and provide job placement opportunities.
- c. Implement initiatives to attract and retain diverse talent, including women and underrepresented groups, in the aviation industry.
- d. Implement "catch-them-young" programs that offer specialized training and mentorship to secondary school students, aiming to cultivate their interest in aviation, develop essential skills, and create a pipeline of talented individuals for future employment in the industry.

#### **Collaboration and Partnerships:**

- a. Encourage collaboration among airlines, airports, and industry associations to share best practices and collectively address common challenges.
- b. Foster public-private partnerships to leverage expertise and resources for infrastructure development and research initiatives.
- c. Engage with international organizations, such as ICAO and IATA, to promote global cooperation and harmonization of standards.
- d. By implementing these recommendations, the air transport industry can navigate the challenges it faces, promote sustainable growth, and ensure a safe, efficient, and environmentally responsible aviation sector.

#### **CONCLUSION**

In conclusion, the air transport system has experienced significant advancements while facing ongoing challenges. The industry must prioritize sustainability by adopting eco-friendly practices and technologies to mitigate environmental impact. Investments in infrastructure and regional



cooperation are essential to address capacity constraints and enhance operational efficiency. Embracing digital transformation and exploring emerging markets will enable the air transport system to unlock new opportunities for improved efficiency, enhanced passenger experiences, and sustainable growth. By capitalizing on these advancements and opportunities, the air transport system can evolve into a more efficient, resilient, and inclusive mode of global transportation.

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