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Smart Airport: Application of Internet of Things for Confronting Airport Challenges

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Abstract**—**As air traffic expands, many airports have evolved into transit centers for people, information, and commerce, and technology implementation is an absolute part of airport development. Several challenges are in the way of implementing technology in an airport. Airport 4.0 proposes the "Smart Airport" concept, which focuses on using modern technologies such as Big Data, the Internet of Things (IoT), advanced biometric systems, blockchain, and cloud computing to alter and enhance passengers' journeys. Several common IoT concrete topics as partial keys to smart airports are discussed and introduced, ranging from automated check-in systems to exterior tracking processes, with the goal of enlightening more and more insightful ideas and proposals about smart airport solutions. IoT will dramatically alter people's lives by infusing intelligence, boosting the quality of life, and assembling it smarter. This paper reviews the approaches to transforming an airport into a smart airport and describes several enabling components of IoT and challenges that can hinder the implementation of a smart airport's function, which require to be addressed.

Keywords**—**Airport 4.0, Digital Airport, Smart airport, IoT.

I. Introduction

AIRPORTS are becoming more functional, and the role of functional corporations is changing. As airport operators attempt to minimize the visible drop in revenue from the aviation sector, they are infrastructure operators and service providers (e.g., commercial business centers). A wide range of services expands the physical footprint of passenger facilities and reduces transparency; also, travelers must go through many procedures (owing to the tightening laws). The normal function of the airport as a standard terminal, allowing travelers to begin and end their air travel, is self-evident. Airport operation is getting more complicated regarding the growth of air travelers and the increasing population in terminals. In this regard, it can be a significant motivation for the airport's development. Airports can be seen as significant economic hubs exhibiting substantial growth and profits, which need four critical factors for development: connectivity, the economic possibility of the surrounding region, a context for sustainable development, and a commercial perspective of airport operator [1].

By the expansion of the air transportation industry, the airport as a city has been discussed as a new topic. This model depicts the structure of clustered functions extending beyond the airport's terminal and landside zone, and in some instances, refers to a planned integrated real estate development by an airport administration or other planning organizations [2]. In this case, an assessment of existing and expected types of an airport as a city are presented by Betz [3].

Regarding several aspects, the evaluation of an airport can be mentioned as a large urban planning project, which needs particular strategies and policies [4]. As a large urban planning project, the commercial zone in airports has been argued, and "airport city" projects, such as Akropolis Rossy, Airport City Bremen, Dublin Airport City, have been exemplified [4].

The future goal is to assemble the airport and services more appealing to passengers, as well as to streamline operations and minimize stress. To do this, high-quality technology and services that cover the entire transportation chain are required. In many circumstances, airport evaluation methodologies ignore information technology. The Smart Airport idea is the way of the future for airport operations, and it has the potential to alter the industry's approach to modern technology adoption drastically. The current rapid expansion of passenger numbers has already put pressure on airport operators to reconsider the infrastructure's ability and concentrate on terminal capability enhancement. As Zaharia and Pietreanu [5] noticed, airports confront many hurdles concerning digitalization, including establishing proper IT infrastructure regarding future resource allocation and developing automated passenger flow forecasting systems. Concentrating on enhancing procedures and innovation while improving passenger experience, airports utilize different visions such as airport operations center (APOC), airport collaborative decision making (ACDM), and total airport management (TAM), which benefit from the latest digital tools and technology.

The concept of smart airports is the way airport operations are conducted in technical and cutting-edge technology infrastructure. Passenger operations, luggage handling, and control by tools are examples of the critical operational areas mentioned in the passenger airport procedure to implement digital transformation. It should be noticed that the most vulnerable threat to airports with smart features is cyber security, and special management must be implemented. Smart check-in, indoor navigation, self-boarding, or airport mobile apps, exemplify application tools of a smart airport idea [6]. This point of view has been expanding all over the world as a result of the fourth industrial revolution, removing the limitations of the traditional airport system. As claimed by Bouyakoub et al. [7], Airport 4.0 is a theory that uses big data and open data to boost its own innovation. Operators at those airports gain operational efficiencies by gathering data on real-

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time passenger flow and analyzing passenger profiles. IoT allows users to engage with a range of smart devices, and this approach has resulted in a slew of new applications in domains as diverse as the environment, health, smart cities, and industries [7].

The internet's connectivity to airport operations will open up new opportunities; IoT and new technologies in a terminal will enable new functions that will make aviation operations more accessible, more efficient, and safer. In this context, the critical notion of a smart airport is connected to RFID technology and the IoT, which reflect future trends in the aviation industry and mobility applications. Considering the notion of the internet, which define as a link between everything, it can be helpful to connect items like transportation networks, transmission networks, etc. Objects will be linked via a network framework that allows channels to interconnect and be in touch easily. With the integration of RFID (Radio Frequency Identification) technology and the IoT, airports can be converted into smart airports. It allows all parties affected instant access to vital data about different actions required by visitors and staff and the use of smart airport facilities. It can provide more suitable efficiency and benefit from the airport services processes. Consequently, operations smartly will manage arrivals and departures, delivery of luggage items, welcoming passengers, or other actions. Thus, it will spur a slew of advancements in the transportation industry, boosting efficiency and production [8]. Utilizing mentioned technology considering noted ideas can allow airports to develop their actual potential through the urban context.

Implementing technology in the airport terminals and conducting the airport to a smart airport in the urban context is significant issue governments can try to engage. Implementation of IoT in Saudi Arabia Airport and the concept of Smart Airport has been concerned along with a review on various analyses on systems executed [9].

This research explores the phenomena that indicate the relation of the smart airport in smart cities and airport transportation, pursuing to respond to the following study questions:

- RQ.01: How an airport transforms to a smart airport?
- RQ.02: What kind of technology can help to transform an airport to a smart airport?
- RQ.03: What is the role of IoT in a smart airport?

Answer RQ.01 can help us find the role of technology in developing an airport, and inspire to find new solutions for several challenges. In the next step, RQ.02 clarifies technology role in a smart airport, affecting managerial decisions and developing strategies. Responding to RQ.03 depicts the impact of IoT technology utilization in a complex digital and smart zone.

II. Research Methodological Approach

In order to provide answers to the research questions, the designed method was a comprehensive assessment and analysis of related academic publications and experimental processes. The selected publications are considered debating associated issues in the recent decade. The literature review delivers main ideas and variables from prior studies. At the same time, the analysis of the practical tools helps to operationalize some of the ideas and provides more detail on each component.

III. Technology Implementation and Its Challenges

While technology is an inseparable part of today's life, it is a crucial topic widely debated whether technological implements in people's lives are more of a benefit than a significant threat. Tempting government to utilize digitalized mechanisms and step in this approach is a straightforward consequence of mentioned effects. Implementing new ideas through high-tech infrastructures in the urban context can help integrate various fields and industries to develop several aspects regarding citizens' and organizations' interests. The implementation can be described in three terms, "Digitization", "Digitalization", and "Digital Transformation".

- Digitization: Briefly, it is the procedure of transforming data into a digital format. As an example, the outcome can be a representation of an object, sound, image, or document by generating a string of digits that define a discrete group of points. As Mergel et al. [10] mentioned, it underlines the service shifting analog to digital, with a 1:1 change in delivery and the addition of a technology delivery channel.
- Digitalization: As defined by the Oxford English Dictionary, it is "the adoption or expanded service of digital or computer technology by an institution, industry, state, or other entity." It can be defined as a process of transforming analog data into digital bits or as a set of digital media features [11]. Undoubtedly, digitalization can boost and manage the daily life cycles. Data creation, data connectivity, and data analysis are the three primary building elements of digitalization [12]. According to Mergel et al. [10], digitalization concentrates on prospective process modifications rather than just digitizing existing procedures and conditions.
- Digital transformation: It draws attention to the organizational, cultural, and relational changes discussed in the outcomes section to distinguish between different types of results. The fulfillment of new conditions of service delivery, customer requirements, and the increase of the user base are among the goals of digital transformation projects; therefore, this term is more extensive than the digitization of procedures [10].

Human resource training and education are crucial actions for implementing the digitization process. It is required to understand the benefits and the objectives of the process by the employee and develop an organizational digitalization culture; moreover, for a significant improvement of this procedure and to secure new multidisciplinary qualifications, it is vital to anticipate the ability and skills required [5]. Considering literatures cited by Machado et al. [13], the development of technologies in the digitalization approach may face several challenges and barriers, including:

- Automation improvement of the individual or all business operations
- Distributed decision-making methods
- Reengineering current business models

- Integrating the organizational structure
- Competitive forces to change
- Workforce with various ages
- Finding the proper technology
- Absence or insufficient of digital skills
- The balance between strategic, tactical, financial, and operational KPIs to predict the future
- Developing incentive plans shared for all involved partners
- Lack of appropriate management
- Lack of strategy
- Too many priorities

This process affects multiple aspects of an organization, such as strategy models, products and services, or operations processes; the aim of this paper is to clarify this approach in airports.

IV. Digital Airport

Along with the physical development of airports in the urban context and reconfiguring airport as a city, implementing digital technologies is considered beneficial to improve performance.

As stated by Zaharia et al. [5], the following classes of airport digitalization reflect the objectives concerning passenger experience enhancement and functional efficiency:

I) Airport operations: Airport operations efficiency reduces delays and other operational risks by optimizing resources and improving processes linked to maintenance, handling operations, and security services.

II) Passenger journey: The goal is to improve customer perception and experience by reducing congestion and guaranteeing a continuous flow, reducing lines, and increasing passenger time spent in retail areas.

III) Ancillary revenues: Non-aviation revenue can be boosted by improving the attractiveness of retail areas, providing commercial information via mobile applications or digital walls, and using digital capabilities to complete online orders.

In accordance to Nau et al. [14], four waves of digitization have occurred, which affected digitalization as a method for airports; consequently, these four waves led to the emergence of four classes of airports:

- *Airport 1.0:* A "traditional" airport where all operations are manual, with a limited Information Technology implementation for specific solutions such as primary resources control.
- *Airport 2.0:* Self-service and extensive deployment are the significant characteristics of this type of airport. Airports 2.0 are partial self-service adopters, with self-service confined to the check-in process and Wi-Fi technology.
- *Airport 3.0:* At all levels of the passenger journey, self-service is used. On the terminal and airside, processes control is automatic and predictive, and mobility solutions are widely deployed (particularly in apron areas).
- *Airport 4.0:* To improve its innovation, the 4.0 airport uses open data and big data. Operators aim to extract value from data by adapting procedures to real-time traveler flow, anticipating needs, and better understanding client profiles.

According to the four airport classes regarding technology usage, actions in the airport would vary.

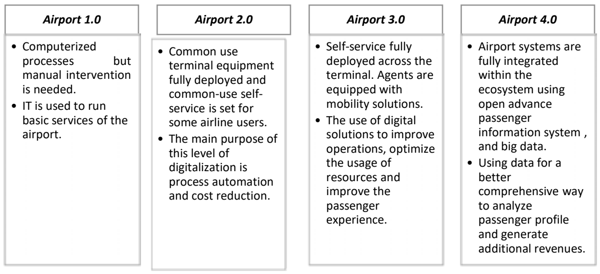

Fig. 1 The airport transitions at various stages of digital maturity [14] (redrawn by the authors)

Airport 4.0 is based on digitally linked networks and physical commodities that may receive and share data digitally in order to help decision-making [15]. An airport that has been upgraded to 4.0, delivers added-value services by integrating IoT components, and its services paradigm has shifted to focus on the customer's specific benefits, called a “Smart Airport” [16].

V. Smart Airport

Most existing descriptions have focused on defining a domain-specific characteristic of a smart airport, for instance, the operations, business, or passenger experience part. As reported by Nagy and Csiszár [17], the definition for Airport 4.0, the fourth evolution of the airport, is still being developed, and the term "Airport 4.0" or the equivalent "Smart Airport" has a number of different definitions in the literature. Its description links to the “Smart City” definition in a unique attitude, utilizing technology to improve the quality of life in metropolitan areas and result in a more convenient and sustainable environment. A smart airport is a subsystem in which the urban environment and aircraft motions link in such city, and data are transferred between city transportation controller, air traffic management, and airline companies. Individual process and airport operation optimization and customer pleasure are all strived for via this link [17]. As claimed by Yaqoobi [18], an airport that can track its employees in real-time and communicate with all stakeholders in real-time to ensure that the right people and services are on the right situation at the right time, all while ensuring traveler safety and keeping everyone informed in the event of a disruption or change, called smart airport; it also knows who its customers are, what their needs are, and when they are traveling so that it can provide personalized service to them. It can also predict peak demand, help passengers guide to boarding gates in real-time, decrease queues in the terminal, and increase non-aeronautical gains by dealing the "right" products to the "right" passenger at the "right" time based on their preferences. Briefly, it can be assumed as a complex that fully utilizes emerging technologies like big data, the IoT, and mobile apps to optimize infrastructure and improve the customer experience, and its goal is to be modernized, improve operational efficiency, and improve the customer experience. The most essential components in delivering any of these are technology and management vision.

According to Rajapaksha et al. [6], along with the benefits of a smart airport, its applications can be elaborate, as mentioned in Table I.

TABLE I
SMART AIRPORT ADVANTAGES AND APPLICATIONS [6], ADAPTED BY THE AUTHORS

Advantages of a smart airport	1. Improved aviation security 2. More convenience of passengers 3. Enhanced operational efficiency 4. Optimizing limited resources
Smart airport applications	1. Smart check-in 2. Self-boarding 3. Indoor navigation 4. Biometric services 5. Smart wearable 6. RFID baggage tags 7. Self-baggage tagging 8. Kiosks for lost luggage 9. Border control 10. Airport apps for mobile devices

The smart airport structure contains 1) Mobile applications, 2) Counters that help passengers get their needed services using the smartphone, 3) Travelers. Reducing time waste is the first consequence of this method, regarding and implementing this structure [8].

Based on an in-depth examination of existing studies and the investigation of various technologically advanced airports, it is clear that new technologies, which are as same as in the technological aspect of a smart city, have a significant role to play in the smart airport. Smart features and any instruments linked to smart networks that lie externally and internally to an airport's physical area can also be included in this scope. Thus, it encompasses critical functions supporting network transmission systems among airports, aircraft, air traffic control (ATC), other contact forms, and standard services.

Smart technology application is no more a characteristic of high-end airports, but rather a significant instrument in today's aviation business.

By considering several tools for transforming an airport into a smart airport, just a few airports are trying to use the related tools to become smart. Dubai International Airport (DXB), Hartsfield-Jackson International Airport of Atalanta (ATL), Heathrow Airport of London (LHR), and Cairo International Airport (CAI) are four airports, mentioned by Mohamed et al. [19], which are utilizing instruments to convert into a smart airport (Table II). Moreover, the International Airport of O.R. Tambo (JNB) in Johannesburg includes socio-technical infrastructure designed to provide ubiquitous and seamless access to dynamic information, allowing individuals to have a better airport experience. This includes electronic car parking systems that display parking spaces and enable comfortable navigation in a large parking lot [20].

As reported by the European Union Agency for Network and Information Security [21], there are three standards involved in determining the scope of the airport frame, which the smart airport is an intersection of them, “Ownership”, “Smart Components”, and “Airport Functions” (Fig. 2). This perspective emphasizes the interconnections relevance, interactions among assets, and activities relevant to the overall functioning of a smart airport, rather than the ownership location of such functions or assets. Consequently, assets or functions that are not owned or situated within the airport but are critical to the smart airport's overall operation are evaluated.

TABLE II
A COMPARISON BETWEEN SMART AIRPORT TECHNOLOGIES IN CAIRO INTERNATIONAL AIRPORT AND OTHER INTERNATIONAL AIRPORTS [19]

Smart Airport Tools	Airport			
	Cairo International Airport	Dubai International Airport	Hartsfield-Jackson International Airport	Heathrow Airport
Smart wallets		✓		
Smart lanes			✓	
Positive boarding				✓
Finger print			✓	
Smart screen				✓
High-tech mirror				✓
Smart gates (E-gates)	✓	✓	✓	
Sophisticated motion sensor systems		✓		
Self-check-in points	✓			
Airport mobile applications	✓			

A. Challenges of a Smart Airport

Digital transformation plays a pivotal role for smartness at airports where current, and arising technologies are utilized for a scope of solutions concerning customer engagement, process automation, predictive solutions, intelligent building managing, flow monitoring and control, and collaborative decision making [22]. Due to the disruptive possibility of change, the transformation requires strong assets across the organization, mainly for additional mature digital transformation steps extending beyond technologies. It depicts a paradigmatic move in how technologies exist and operate at an executive level; as a result, the extent to which airports handle organizational challenges associated with corporate transformation is projected to influence digital change [23]. In accordance to Halpern et al. [15], enabling technology in airports may face issues that encompass those associated with passenger acceptance of them, or their impact on passenger behavior, airport service quality or airport capacity, and airport size directly affects digital transformation; moreover, there might be challenges associated with executing and maintaining them, doubt about their long-term viability, potential supplier lock-in implications, gaining stakeholder buy-in and market approval, and vulnerability in terms of cybercrime, privacy, and other ethical and social issues concerns. On the other hand, some other risks are related to strategic challenges, including cyber security, return on investment of smartness, changing the mindset, and maintaining standards [6].

With limited resources, dealing with internal and external agencies, maintaining on-time service delivery, maintaining passenger and visitor security, and safe aerodrome operation while providing regulatory compliance, airport management is essential in airport operations [24].

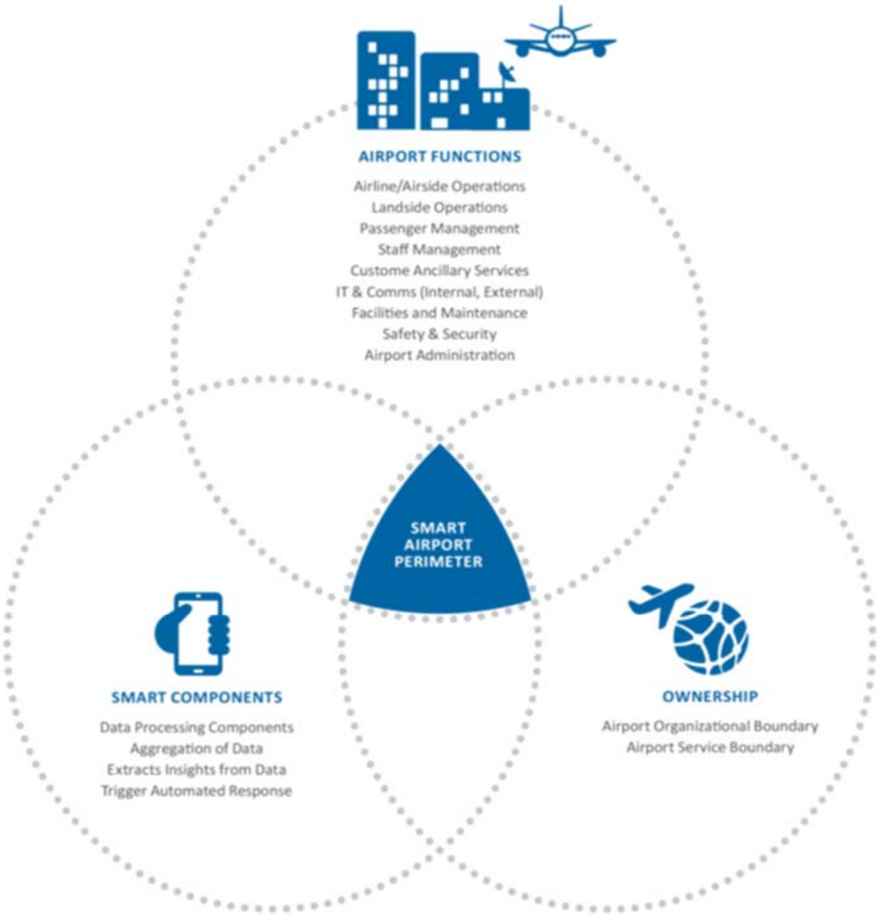

Fig. 2 Scope of the Smart Airport Perimeter - Criteria [21]

As claimed by Pell and Blondel [25], overcoming mentioned issues requires four keys, including sufficient partnering and cooperation to comprehend technologies; strategic transparency and visible supervision support that is necessary to drive change; a digital attitude that is capable of recognizing, prioritizing, and executing effective solutions; and internal qualifications concerning digital talents and resources. Smart airport operations need a platform for optimizing performance and capacity, passenger experience, and customer service through the usage of integrating ICT infrastructures [14]. Smart airports benefit from greater resilience, effectiveness, and control thanks to IoT-powered services and infrastructure managed by real-time observation and analytics. IoT technologies track and monitor the environment inside the airport, automate passenger actions, and aid airport security [26]. Enhancing airports using IoT-powered automation systems has a substantial impact with an operational and productivity aspect. IoT devices can play a vital role in a smart airport to elevate the performance of execution and operation, from the exterior parts to the interior. They commonly interact with each other via bridging connections and interactions.

B. Intelligent Technologies Application at a Smart Airport

The use of intelligent technologies for smart airport management systems as customer service, assists in improving legacy and redundant systems and processes. This system implies complicated implications to improve airport operational efficiency [27]. The next part will give an overview of smart airport management technologies categories.

I) Artificial Intelligence (AI)

AI has been considered one of the pioneered techniques ever devised by humans, and it is expected to dominate the technological spotlight for decades to come. Owing to advancements in computing power, big data, IoT, and breakthroughs in machine learning and deep neural networks, AI will be one of the most disruptive technologies in the next decade. Moreover, the main tasks and innovations for big data descriptive analytics and prescriptive analytics that will evaluate big data and IoT data from various sensors include statistics and modeling approaches, data science, and analytics using computing techniques [27]. The basis for enabling essential AI technologies such as machine learning, deep learning, natural language processing (NLP), and computer vision is laid by big data characteristics such as large volume, significant velocity, and enormous diversity [28]. Business managers all around the world consider AI as a way to boost their competitiveness and keep their market share [29]. AI has a tremendous ability to spread the technologies by conducting all the big data through smart connections to boost the learning and performance of businesses and individuals.

II) Big Data and Intelligence Analytics

Big data is not worth much without big data analytics. Nevertheless, when big data is processed, deep processed, smartly processed, and intelligently processed, the commercial value of big data grows [27]. Processing, deep processing, second-time processing, and multi-processing of massive data are all supported by big data analytics. As a result, big data analytics takes precedence over big data [30]. Productive companies rely on the proper use as well as structure of intelligent big data and analytics because they have a significant impact on innovation, competitive advantages, and, consequently, a company's total productivity [31]. Implying big data and intelligence can bring a novel way to promote general decision-making in management, especially airports, as smart cities.

III) Cloud Computing

In the 21st century, cloud computing has been at the forefront of enterprises, people, and government agencies. Cloud computing refers to allocating on-demand computing services through the internet, such as storage, applications, and processing power. Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) are the most prevalent cloud computing services [27]. PaaS is the next level of cloud computing services. Consumer-made or bought applications produced utilizing programming languages, libraries, services, and tools provided by PaaS can be deployed onto the cloud infrastructure. The revenue from cloud computing services was $22.2 billion in 2016, and it is expected to reach $53.3 billion by 2021 [27].

IV) The IoT

The IoT is made up of two interrelated terms: first, "Internet," and the second is "Things." A human, a computer, a smartphone, a device, a sensor, an electron gadget are all instances of "things." They may all engage with one other [32]. It refers to a large number of appliances that are linked to the internet in order to share data with other devices such as IoT apps, connected devices, industrial equipment. The IoT can offer up a world of possibilities as airports become increasingly technologically linked. It can alter the visitor experience and produce new income and increase efficiency. Moreover, it can be a method of putting together many enabling technologies in a specific way to accomplish something more intelligent. As illustrated in the main types of benefits from deciding on the IoT capability or set of capabilities that are "right" for them that can provide operational efficiency, strategic differentiation, and boosting new revenue streams, the growing presence of IoT has had a significant impact on how business models have been adjusted to meet these challenges [33]. As Zhang [34] mentioned, IoT is a collection of objects that must be constantly tracked, connected, and interacted with using various technologies and devices, for example, global positioning systems (GPS), RFID technology, and other communication devices and technologies. IOT allows regular physical things to build an intelligent, interconnected network on their own.

As a result, IoT is becoming an increasingly important component of the latest era of information technology, with numerous concrete applications in a variety of fields, particularly in smart airport solutions, which require modern technologies to solve a variety of real-world problems and issues [34].

C. IoT and Implementation Challenges

According to Chen et al. [35], in addition to the potential advantages of incorporating and integrity IoT systems into various fields, their implementation is complicated and challenging. As a result, concerns and difficulties associated with the IoT must be evaluated from a variety of perspectives, including enabling technology, application services, marketing strategies, and environmental and social consequences; moreover, Table III demonstrates significant challenges and their fields when viewed through the lens of technology [36]:

TABLE III
IoT Key Challenges and Fields [36], Adapted by Authors

Area	Field and Content
Standardization	o Definition, vision, and structure for the IoT o Standardization of architecture o Software platform validation o Protocol stack standardization
System Architecture	o Conceptual model o Hardware architectures o Cloud centric architecture o Application frameworks o Process architectures
Interoperability and Integration	o General interoperability issue o Gateway support o IoT platform and architecture o Technical interoperability issue o Semantic interoperability
Availability and Reliability	o Availability of IoT application o Seamless connectivity o Mobility and routing issue o Implementation and delivery performance o Reliability of infrastructures
Data Storage, Processing and Visualization	o Computing and data analyzing o Data visualization
Scalability	o Massive scaling issue o Discovery service for the IoT
Management and Self-configuration	o Devices & networks management o Management of applications and data o Trust management
Network Performances	o Transportation loads and a traffic model o Application layer protocols o Transport layer protocol o Network layer protocol o Assessment of the link layer guidelines
Unique Identification	o Techniques of recognition and labeling o Services discovery protocols
Power and Energy Consumption	o Low-power communications o Chipsets and connectors with low energy consumption
Security and Privacy	o Security issues o Privacy issues
Environmental Issues	o Green IoT technologies

D. IoT and Smart Airport

Airlines are required to adopt IoT advances to improve the passenger experience [37]. Figs. 3-5 show an abstract view of the IoT network and propose the exterior and interior architecture of a smart airport utilizing IoT devices, respectively.

The following are some existing applications and examples of IoT technology in the smart airport:

- Automated Check-in

In accordance to [38], [16], and [26], travelers can bypass long lines and get their travel documents by scanning in on their cellphones before their flights and finishing the process online or at smart kiosks located throughout the airport. Another trend associated with these check-in systems is automatic luggage drops, in which travelers print the requisite barcode tags, attach them to their bags, and drop them off at designated spots to be assessed by the airport's technology.

- E-gates

Passengers must pass through border checks before boarding an aircraft. This method entails a police officer manually scrutinizing a pedestrian's ID and confirming their identity. Rather than depending on manual processes, modern smart airports use an automatic gateway known as the electronic gate (e-gate). "Smart Gate" is the name given to e-gates in Australia. Via RF-enabled contactless smart card tech, e-Gates detect the microprocessor in e-Passports. The verification at an e-gate requires obtaining a passenger's biometric information, such as face detection or a fingerprint scan, and matching that data to the data collected in the e-Passport [26].

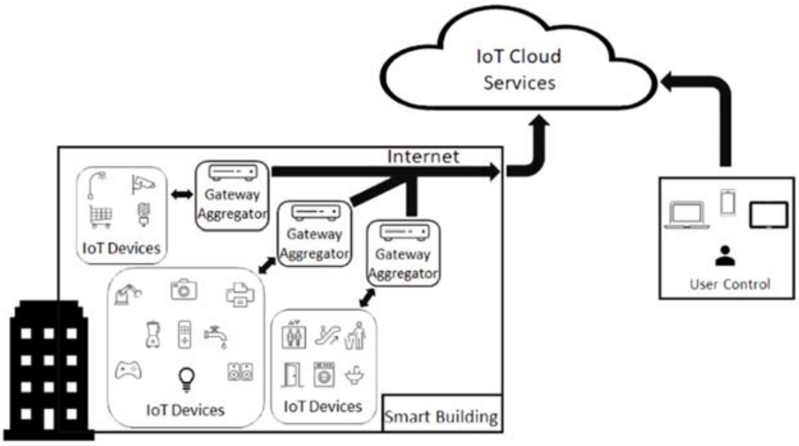

Fig. 3 A typical IoT network abstract view [26]

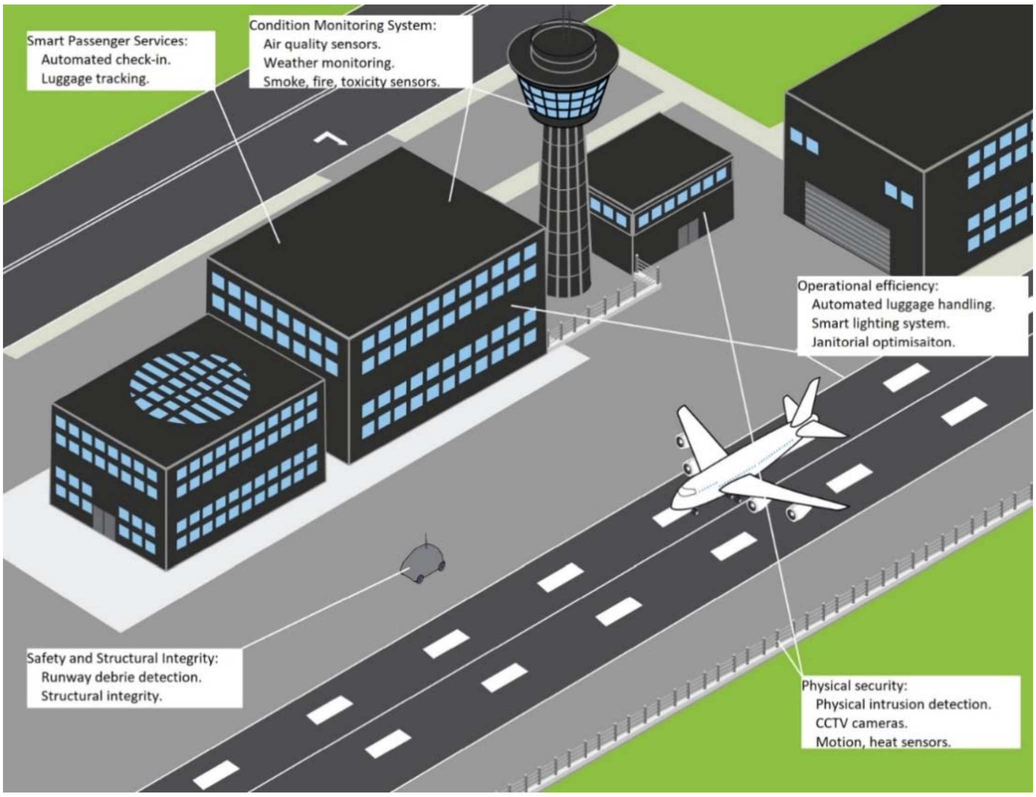

Fig. 4 Proposed architecture of a smart airport [26]

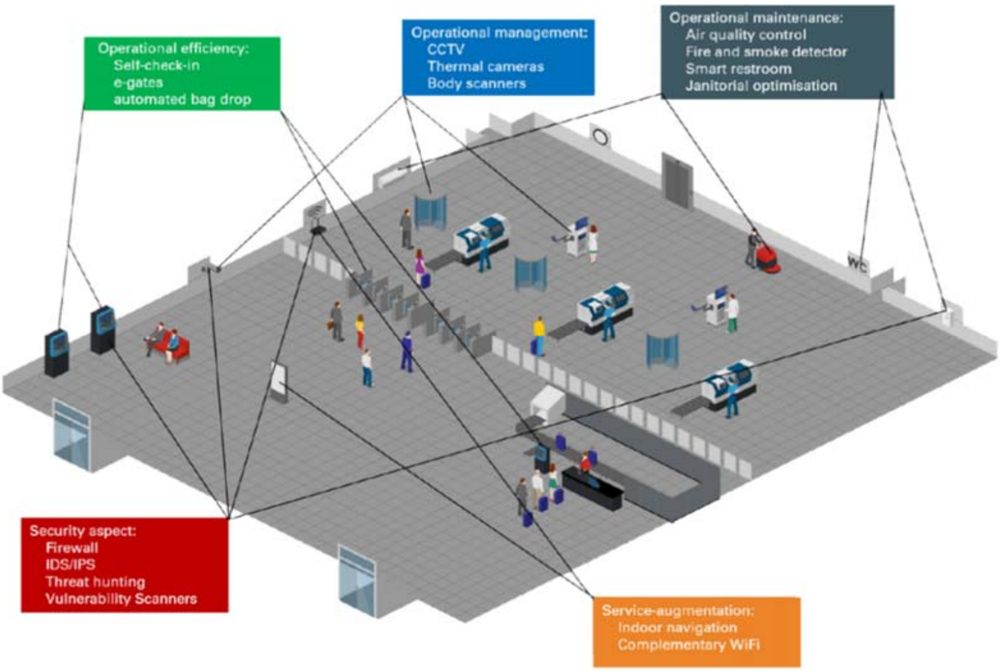

Fig. 5 Proposed interior architecture of a smart airport [26]

- Luggage Tracking and Handling

According to definitions described by [39] and [40], implementation of technology for facilitating luggage handling and tracking is defined as follows:

I) Tracking

Luggage misplacement and mishandling is a challenge that modern airports have encountered due to increased passenger flows and operator error. RFID technology usage for luggage labeling and monitoring has acquired some popularity in recent years as a solution to this issue. The RFID tag contains data on the traveler and their belongings and a unique ID generated at check-in. During a flight, the RFID tags on luggage are detected at the source, middle, and destination airports; the information is exchanged across airports, allowing passengers to track their luggage using smartphone apps and web platforms.

II) Handling

Integrating robotic arms for moving heavy luggage is an IoT usage used in luggage handling. These technological solutions respond to classifying, carrying, and storing checked luggage, prioritizing space efficiency, and managing huge loads that might otherwise require manual handling. At the same time, security screening is performed on the luggage to check for dangerous and forbidden items. A remote software-based system controls the machine, and received information regarding system performance and luggage can be obtained via a web-based platform or a hand-held device.

- Physical Airport Security

Various sectors of an airport are only accessible by certified employees as part of the physical security mechanisms. In order to enforce these required limits, airports, like other businesses, use electronic gates in cooperation with CCTV and movement sensors. These IoT-based security apps, which check an airport's boundary and identify unauthorized entry to high-risk zones, depend on networked technologies that could be accessible via the airport's intranet or the internet [41].

- Janitorial Optimization

Smart airports can estimate when substantial flows of travelers will arrive and in which airport region they will be focused on by using sensors that count the number of people that move through a place and combine this information with airline arrival timetables. The use of sensors to count the restrooms' population is one instance of such an application. Existing technologies are pre-programmed to count up to a certain threshold. The counter restarts and adjacent cleaning workers automatically tell that restrooms require cleaning and sanitization via IoT innovative technology [26].

- Runway Structural Integrity Monitoring

It is vital to maintain that the runway is clear of obstructions and that any structural defects are quickly detected and repaired, as they may lead to accidents both landing and takeoff. Traditionally, airports have relied on visual inspections performed by airport workers to verify the integrity of their runways. The human mistake was a risk in such inspections, necessitating the development of an automated, dynamic, and trustworthy inspection procedure. For this reason, modern smart airports have resorted to the use of automation systems, such as heat sensors implanted in the runway and ground drones that use light-based detection technologies [42].

- Smart Lighting

Smart lighting systems are another key IoT usage in smart cities, smart homes, and smart airports. The lights on large parts of the airport may be controlled via a web-based interface or a smartphone application. Their status can be checked, alerting airport employees immediately if there is a problem. Moreover, IoT-based solutions that connect runway illumination to the control tower have been developed, informing about hardware issues [26].

- Airport Asset Tracking

Modern airports divide into parts, each of which is designed to perform a specific function. Specialized assets (tools) are frequently utilized at these airport sectors, such as baggage trollies for transferring travelers' luggage from the parking area to the conveyor belts or the baggage drop-off zone. Other instances involve ground-associated equipment that is used before or after an aircraft takes off or lands, aiding with luggage loading and unloading, fueling the aircraft, and general maintenance. As a result, the capacity to quickly discover, manage, and make these resources available for re-use is critical for an airport's sustained effective processes [43].

- Air Quality and Environmental Conditions Tracking

The security of travelers and airport employees is a top issue for airports. A modern smart airport must have observation and prevention methods to deal with many dangers. One such hazard that needs to be tackled is the deterioration of environmental conditions. To that end, IoT-based sensors have been set up to monitor air quality (radiation, toxicity, etc.) identify and detect emissions and smoke. Apart from security uses (such as preventing chemical attacks), these detectors can be used in conjunction with air conditioners to automatically control the temperature in various airport regions and improve passenger comfort; Furthermore, environmental sensors installed on the exterior of an airport can be set up to offer regular weather reports, which is a valuable resource. IoT sensors and actuators are designed to be dispersed in remote sections of a building, complex, or city while maintaining contact with their cloud backend infrastructure via a sensor gateway or a network, allowing users to track their status and send commands. Hardware limits and installation location influence the efficiency of protocols and technologies employed in smart airports. The abovementioned IoT smart airport applications are powered by a variety of network and communication technologies [44].

- RFID

RFID is a technology that has seen many uses in short-range wireless communication systems. A scanner, a tag, and an application component that controls the acquired data, sometimes using a backend database, are the three major parts of an RFID application. The reader sends out electromagnetic signals of a specified frequency according to the system's application. Active tags employ a small battery to power confined processors with some store capacity inside the tag. In contrast, passive tags use ambient electromagnetic energy to power themselves and communicate data back to the reader, with a limited storage capacity. Active RFID chips with restricted sensors that collect data from the environment, such as humidity and temperature, have been created inside some applications [45].

- LoRAWAN

It is defined as a Low Power Wide Area Network (LPWAN) technology that enables incredibly long bandwidth compared to specific other low-speed standards (Bluetooth, RFID, ZigBee). Multiple receivers link to a gateway, which collects information and transfers it to a cloud backend, forming a star topology. Because forcing transitions can lead to higher energy usage, this technique is sensitive to force assaults, and it is one of the prominent features that can empower this protocol [26].

The practicality of one of the IoT components mentioned above in a smart airport is primarily determined by its application and depends on the capability of airport operation. For the airport, where the operations are facilitated and automated, the number of staff required can be decreased, and they will interfere just in case. Moreover, the security is greatly enhanced by providing airport authorities complete control of all travelers at all transit stages. Consequently, the travelers can be tracked or monitored throughout their transit, permitting officers to detect and manage any issue early. In addition, the airport management strategy is favorably optimized.

VI. Conclusion

As airports are continuing to face rising passenger numbers and increasing capacity challenges, dealing with these problems, airports have considered adverting smart airports as a solution. Meanwhile, digital transformation through a logical and systematic approach can play an essential role in the advent of a new generation of airports. Some factors have been enumerated as main steps in transforming into digitalization. On the one hand, training and educating human resources and, on the other hand, implying ICT infrastructure to provide a platform for improving passenger's experience through performance and capacity optimization are considered crucial actions for implementing the digitization process. While airports have a specific situation separately, they each have unique technology requirements and objectives for digital transformation depending on their infrastructures and capacities; becoming a smart airport looks to be far more complicated than simply being digitized or forward-thinking. Although a better explanation would probably be ready to set strategic initiatives based on strengths and limitations, and taking into account airport context and limitations is vital, the smart airport systems optimize traveler and flight processes, resulting in a better passenger experience and increased airport operating efficiency.

According to this research, activating technology in airports appears to be a viable strategy for achieving smart airports. Based on an in-depth analysis of existing knowledge and a study of various researches, defined that new technologies, AI, cloud computing, big data, and specifically IoT have a significant role in the evolution of smart airports. The adoption of new technology could aid in increasing an airport's capacity as much as feasible to improve operational efficiency. Because digitalization is crucial for airports to enhance their functionality, it would be at the top of their priority list. Also, airports must handle several difficulties when seeking digital transformation. This study attempted to shed light on the impact that Airport 4.0 solutions can play in assisting airports in lowering their total operational costs and facilitating the holistic upgrading of airport value offerings.

When technology is implied, IoT is a crucial enabler of digitalization trends, significantly influences airports, and improves operational efficiency. IoT's research findings in the air transport industry have shown that it can bring benefits, including customer satisfaction, comfort, and productivity, lowering costs by reducing labor, developing security activities, and reducing travel time on airplanes. In addition, a traveler's trip to a smart airport can be managed intelligently through this technological system, from arriving at the airport to checking in, flying, and exiting the terminal. This research mentions various common IoT examples and implications as partial solutions to smart airports, ranging from IoT-based baggage to exterior conditions tracking. While this emerging paradigm (IoT) has an advantage and is crucial for transforming traditional airports into smart airports, its application and implication, along with various challenges and limitations, are considered and mentioned in the technological base.

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