

عنوان البحث

تقييم جاهزية المطارات نحو التحول للتشغيل الذكي Smart Airport
Airports Readiness for Transitions to Smart Operations

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شكر وتقدير

الى أمي العزيزة ..

نبض قلبي الاول ، وسندي الذي لا يميل ، ونور حياتي الذي لا ينطفئ.

إليك يا من منحني القوة قبل الظلماء ، والدعم قبل الطلب ، والدعاء قبل أن أهرع بالحاجة إليك.

إليك يا من غرس في قلبي الإصرار ، وفي روحي الطمأنينة ، وفي طريقي الأمل .

كل خطوة أنجزتها ، وكل إنجاز أحققته..

هو امتداد لجمالك ، ولصبرك ، ولعطائك الذي لا يقارن.

أشكرك هذا العمل ،

تقديرًا لروحك العظيمة ، ومحبة تملأ قلبي ، وامتنانًا لا يحده وصف.

دمم مصدر فخري وأمان قلبي دائماً

أتقدم بخالص الشكر وعظيم الامتنان الى كل من ساهم في انجاز هذا البحث ، ووقفه بجانب طوال مرحلة دراستي. أود ان اعبر عن تقديري العميق لجامعة الجميع الذكية (Midocean) وأساتذتي الصرام على ما قدموه من علم وتوجيه والماء ، ولجهودهم المستمرة في دعم مسيرتنا الأكاديمية .

وأخس بالشكر مهنري الأكاديمي الذي منحني من وقته وخبرته ما ساعدني على اتمام هذا العمل بأفضل صورة ممكنة .

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Abstract

The abstract for this study will be prepared and incorporated upon the completion of the research in the upcoming semester. It will provide a concise synthesis of the research problem, the conceptual framework, and the methodological approach used to assess airport readiness for transitioning to smart operations.

Deferring the Abstract until the study's completion ensures that it accurately captures the empirical findings, analytical insights, and final conclusions regarding the factors influencing airports' preparedness for smart operational transformation, as well as the implications for future airport management and operational efficiency.

Introduction:

In recent years, the aviation sector has experienced accelerated digital transformation driven by the need to enhance operational efficiency, improve passenger experience, and optimize resource utilization.

Airports worldwide are increasingly adopting smart technologies such as internet of things (IoT) systems, artificial intelligence (AI), advanced data analytics, and automated passenger processing solutions to transition toward smart operations. This shift aligns with global trends in smart mobility and sustainable airport management, aiming to create connected, efficient, and resilient airport ecosystems.

As airports serve as critical national infrastructure, their readiness to implement smart operational systems has become a strategic priority for improving service quality, supporting economic growth and strengthening competitiveness within the global aviation landscape.

Despite the growing interest and investment in smart airport initiatives, the readiness levels among airports vary significantly based on organizational capabilities, technological maturity, workforce skills, and regulatory frameworks. Understanding how prepared airports are for this transformation is essential for developing a clear roadmap and identifying Gaps that may hinder the successful transition towards smart operations.

Problem Statement:

Although smart technologies offer significant opportunities for operational enhancement, many airports face challenges in assessing their readiness to transition towards smart operations.

Current readiness levels remain unclear due to varying degrees of digital infrastructure, inconsistent adaptations of automated systems, limited integration between operational units, and concerns related to data management and cybersecurity.

This uncertainty makes it difficult for airport leaders and policy makers to evaluate whether their existing systems, workforce competencies, and organizational processes are sufficient to support smart operational models.

Therefore, the core problem addressed in this study is the lack of comprehensive assessment of airport readiness for smart operations, which may impede strategic planning, delay digital transformation initiatives, and limit the airport's ability to meet evolving industry expectations.

Importance of Study:

The significance of this study lies in this contribution to understanding the extent to which airports are prepared to transition toward smart operational models. As global aviation continues to embrace digital transformation, assessing readiness becomes essential for ensuring successful implementation and long-term sustainability of smart technologies.

This study provides valuable insights for airport leaders, policy makers, and operational managers by identifying strengths and weaknesses and capability gaps within current airport system and processes.

Furthermore, the study supports strategic planning by offering evidence-based recommendations that can guide investment decisions, workforce development initiatives, and technology adoption strategies.

By evaluating readiness levels, the research also contributes to enhancing operational efficiency, improving passenger experience, and supporting national and regional digital transformation agendas.

Ultimately, this study aims to advance the understanding of smart airport development and support airports in building resilient, data-driven, and future-ready operational environments.

Research Objectives:

Main Objective

To assess the readiness of airports to transition towards smart operations and identify the key factors that influence successful digital transformation in the aviation sector.

Specific Objectives

1. To evaluate the current technological infrastructure and its capability to support smart operational systems within airports.
2. To assess organizational readiness, including leadership support, workforce skills, and change management practices related to smart transformation.
3. To examine the level of integration and utilization of smart technologies, such as automation, AI, IoT, and data analytics in airport operations.
4. To identify gaps, challenges, and barriers that may hinder the transition toward smart operations.
5. To propose strategic recommendations that enhance airport readiness and facilitate successful implementation of smart operational initiatives.

Research Questions:

1. To what extent is the current technological infrastructure in airports adequate to support the transition toward smart operations.
2. What is the level of organizational readiness-including leadership commitment, workforce competencies, and change management practices- for adopting smart operational systems?
3. How extensively are smart technologies such as automation, IoT, AI, and data analytics currently integrated into airport operations?
4. What are the main challenges and barriers that may limit airport's readiness for smart operations?
5. What strategic actions can enhance airport readiness and facilitate a successful transition toward smart operations?

Research Hypotheses:

- Main Hypothesis:

There is **no significant relationship** between airport readiness factors and the successful transition toward smart operations.

- Alternative Main Hypothesis:

There **is a significant relationship** between airport readiness factors and the successful transition toward smart operations.

Specific Hypotheses:

H1:

Technological infrastructure has a **significant positive effect** on airport readiness for smart operation.

H2:

Organizational readiness, including leadership support and employee digital competencies, has a **significant positive effect** on the transition toward smart operations.

H3:

The integration of smart technologies (AI, IoT, Automation, analytics) has **significant positive impact** on operational readiness for smart airport initiatives.

H4:

Challenges and barriers (e.g. cybersecurity, budget constraints, system integration issues) have **significant negative affect** on airport readiness for smart operations.

Previous studies

1. Organizational Readiness & Digital Transformation by Halpern et al.(2021)

This study examines how organizational readiness, innovation culture, airport size, and ownership affect the pace of digital transformation in airports.

The Key Finding in this study is that organizational readiness has the strongest direct impact on digital change, the degree of organizational readiness refers to the preparation degree of enterprise's ability to adopt AI.

Innovation acts as mediating factor, meaning readiness drives innovation which then drives digital transformation. It acts as bridge between readiness and digital change.

Airport size affects readiness, while private ownership vs Public shows no difference to readiness or digital progress. This study finds that larger airports adopt digital technologies faster due to greater financial and operational capacity.

2. Airport Digital Transformation (DX) Maturity Assessment Model ICAO Working paper (2025) Developed by Incheon International Airport.

This model evaluates readiness across multiple aspects including smart operations, data utilization, digital services, strategic governance and workforce readiness.

As Airports around the world accelerate their digital transformation to enhance operational efficiency and passenger experience, the absence of standardized framework for evaluating digital maturity has become a growing concern. Incheon International Airport recognizes this gap and has developed an airport specific digital transformation (DX) maturity assessment model that enables structured evaluation and benchmarking of digital capabilities across key operational domains.

It provides a **Five-Level maturity scale** that airports can use to benchmark their smart-operations readiness.

What makes this working paper stand out is its assessment model that is tailored to the unique characteristics of the airport industry and evolving technological trends.

3. Smart Airports: Analyzing Digital Transformation (Beijing & Ponta Delgada Cases 2024)

This study also assesses how major and smaller airports transition toward smart capabilities and demonstrates how infrastructure scale, governance, and investment patterns affect readiness to adopt smart operations.

The main objective of this study is to investigate the importance of investing and implementing technology in airports and compare how different sized airports strategically leverage technological advancements to enhance operational efficiency, passenger experience, and overall safety.

The study analyzed and compared growth and improvements made over time for two different airports which are **Beijing Capital International Airport and Joao Paulo II Airport**.

Highlight if the result was some of the goals sought to achieve were not met due to budget limitation, weak KPI's, and growth data for each airport.

Examining how policy frameworks and regulatory mechanisms contribute to the implementation of smart airport initiatives will enrich the background knowledge needed to understand the broader ecosystem in which such development take place. Also examining topics like data privacy, data security rules and regulations, and international standards could pinpoint obstacles to implementation and develop strategies for overcoming regulatory hurdles.

Theoretical Background of the Study:

1. The concept of smart operations

Smart operations refer to the use of digital technologies, automated systems, and artificial intelligence to enhance the efficiency of airport operational processes, improve safety, and increase the quality of services provided to passengers and operational stakeholders.

Smart operations rely on real-time data analytics, system integration, and autonomous or semi-autonomous decision-making.

Smart operations in general terms combine a manufacturer's information technology (IT) and operational technology (OT) with artificial intelligence (AI), creating a continuous feedback loop that can help improve operations.

OT data from factory production lines, specialized equipment, and Internet of Things (IoT) sensors mixed with IT data from manufacturing execution systems (MES), enterprise asset management (EAM) systems, and applications for finance, HR, sales, marketing, and the supply chain. the combined data is analyzed using AI, and the resulting insights are fed back into systems that adjust operations automatically. This continuous feedback loop injects automation into the production process, helping boost efficiency and drive continuous improvement.

To sum up, smart operation breaks down the divide between the OT systems that run a manufacturer's factories and production lines and the IT systems that run the rest of the business. Combine and analyze data from across the company using AI-based analytics, automate low-level tasks.

Smart Airport Operations refers to the application of advanced digital technologies including AI, IoT, Private 5G, biometrics, automation, and real-time analytics to optimize all airport processes such as passenger handling, security screening, baggage operations, airside\landside coordination, and resource management.

These technologies convert the airport into a connected, data-driven ecosystem that enhances safety, efficiency, sustainability, and passenger experience.

Smart Airports are airports that use advanced technology, connected systems, and real-time data to improve processes, communication and efficiency. As passenger numbers rise and the

demand for digital services grows, airports face pressure to deliver faster, safer and more seamless experiences.

A smart Airport combines operational excellence with passenger-focused services by making use of innovations such as IoT, automation, artificial intelligence and private 5G networks. These technologies not only enhance passenger journeys, from check-in to boarding, but also make operations more efficient, secure and sustainable.

Examples of technologies that support smart operations in airports include:

Internet of Things (IoT).	Artificial intelligence and machine learning.
Computer vision.	Robotics.
Smart gates and self-service travel solutions.	Crowd management systems.
Predictive analytics for operational processes.	Integrated monitoring and crisis management systems.

Table 1. technologies that support smart operation in airports

2. The concept of organizational readiness for digital transformation

Digital transformation readiness refers to the extent to which human, technical, and organizational capabilities are available to enable an airport to adopt and operate smart technologies effectively.

Readiness includes five key dimensions:

2.1. Technological readiness

- Availability of digital infrastructure
- System integration
- Availability of analyzable database
- Use of modern, scalable technologies

2.2. Organizational readiness

- Clarity of strategy and vision
- Existence of transformation leadership policies
- Support top management

2.3. Human readiness

- Employee skills
- willingness to accept change

- availability of training and technical support

2.4.operational readiness

- preparedness of processes for smart transformation
- automation potential
- level of manual task repetition

2.5.security readiness

- data protection
- cybersecurity
- digital identity management

3. Digital transformation Theories Used as Basis for this Study

First: the TOE Framework (Technology – Organization - Environment)

This framework is one of the most important theoretical models for assessing transformation readiness and covers:

Technological factors, Organizational factors, Environmental factors (regulations, partners, service, providers, etc.)

This framework is developed in the field of information systems to explain how the adoption and use of new technologies are influenced by various factors, including the characteristics of the technology itself, the organizational context in which it is used, and the external environment in which the organization operates.

The framework has been widely used in research on technology adoption and implementation in organizations, and it has proven to be a valuable tool for understanding the complex interplay between technology, organization, and environment.

One of the strengths of the TOE framework is that it provides a holistic perspective on technology adoption and implementation. Rather than focusing solely on the technology itself or the organizational context, the framework recognizes that both internal and external factors are important in shaping technology adoption and use. This allows to take a more nuanced approach to studying technology adoption, and it helps organizations to better understand the complex interplay of factors that influence technology decisions.

Second: The Digital Maturity Model

This model measures the stages of digital development within an organization, ranging from Limited transformation to Full smart operations.

It focuses on :

Leadership, Digital capabilities, Organizational culture, Processes, Technology.

A Digital Maturity Model (DMM) is structures framework for assessing ho effectively an organization deploys digital, data, platforms, and ecosystem capabilities to create value-today and overtime. It defines a small set of dimensions (e.g.,strategy, customer experience, data\AI, platforms, ways of working, governance) and levels (usually 1-5) with clear, evidence-based criteria.

The assessment produces a baseline, highlights gaps that matter value, and guides a prioritized roadmap.

In plain terms: a DMM turns “we should be more digital” into a practical diagnosis and plan. It shows where you are strong (e.g., modern cloud platforms) where you are behind (e.g., product management or data quality), and which moves will most improve growth, cost, resilience, and speed. Crucially, a good DMM is anchored to business outcomes, not technology for its own sake.

4. Smart Operations in Airports Globally

This research study aligns with the global trend toward 5G airports and smart airports, which aim to enhance operational efficiency, improve crowd management, strengthen safety and security, and provide a fully connected and autonomous travel experience.

These efforts also include the integration of predictive analytics to reduce delays, improve scheduling, and manage airport resources more accurately.

Research Methodology:

The methodology used in this Study outlines the overall research design and the procedures used to collect, analyze, and interpret data in this study. Given the complex nature of assessing airport readiness for smart transformation- an area that involves technological, organizational, operational, and regulatory dimensions – a single methodological approach would not sufficiently capture the depth and breadth of the research problem.

Therefore, this study adopts **mixed-methods approach**, which integrates both quantitative and qualitative methods to achieve a more comprehensive understanding of the phenomenon under investigation.

Mixed-methods research combines the strengths of quantitative and qualitative approaches, allowing measurable patterns as well as contextual explanations that enrich the interpretation of results.

The quantitative component of this study is represented by structured survey distributed to employees within the Operation Department at King Khalid International Airport (KKIA).the survey will provide numerical data that enable the assessment of readiness levels, the identification of significant factors, and the analysis of relationships among variables.

At the same time, the qualitative component will be conducted through document analysis, which includes reviewing official strategies, modernization frameworks, and digital transformation policies issued by organizations such as GACA,IATA, and ACI. This analysis helps contextualize the quantitative findings, offering deeper insights into the policies, standards, and strategic directions shaping smart airport transformation in Saudi Arabia.

By integrating these two forms of data, the mixed-methods approach enhances the validity, reliability, and richness of the study. Quantitative results offer generalizable patterns, while qualitative evidence provides depth, meaning, and alignment with industry standards. This combination allows for holistic examination of airport readiness and ensures that the research findings are grounded in both empirical measurement and real-world documentation. Ultimately, this methodology supports a more accurate and robust assessment of KKIA's readiness for smart airport transformation.

Research Instruments:

In this study, the primary research instrument is **structured questionnaire** composed of **closed-ended Likert-Scale items** (strongly Disagree, Disagree, Neutral, Agree, Strongly Agree). The instrument is designed to quantitatively measure airport readiness across multiple dimensions related to transitioning into smart airport operations. A Likert-scale format is selected because it allows respondents to indicate their level of agreement, thereby enabling statistical analysis of attitudes, perceptions, and organizational readiness levels.

The questionnaire aims to assess key readiness factors identified in the literature, including:

Organizational readiness (leadership support, strategy alignment, staff competencies)

Technological readiness (existing digital infrastructure, IoT adoption, data management Ability)

Innovation capability (Openness to new technologies, past digital initiatives)

Operational readiness (process automation, system integration, smart-operation procedures)

These dimensions reflect successful digital and smart-operation transformation in airports.

Research Limitations:

Although this study provides valuable insights into airport's readiness to transition toward smart operations, several limitations must be acknowledged to contextualize the findings. As with most research relying on perception-based assessments which relies on people's opinions, feelings, beliefs, or personal judgments rather than on direct measurement or objective data, the results are influenced by the subjective judgments of participants, which may not fully capture the complexity of actual operational readiness. Additionally, the study utilizes a closed-ended Likert-scale questionnaire, meaning it will be effective for quantifying attitudes and benchmarking readiness level, but inherently restricts respondent's ability to elaborate on nuanced or emerging challenges faced within airport environments. This limitation is due to multifaceted factors that may be entirely measurable through standardized survey items.

Another limitation relates to the sampling approach. The study collects responses from airport professionals who were accessible and willing to participate, which may not fully represent the

broader diversity of airports in terms of size, governance structure, technological maturity, or geographical region.

Differences across airports- such as resource availability, regulatory environments, and leadership priorities- can significantly influence readiness for smart operations.

While the findings will offer meaningful patterns and contributions, they should be interpreted with an understanding that generalization may be limited. Future research could benefit from combining quantitative and qualitative techniques, cross-regional comparative analysis, or applying longitudinal designs to better capture the dynamic nature of digital transformation in the aviation sector.

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