

Article

A Study on Information Strategy Planning (ISP) for Applying Smart Technologies to Airport Facilities in South Korea

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Abstract

This study aims to develop an information strategy plan (ISP) for the integrated management of airport facility information in South Korea by applying smart technologies such as building information modeling (BIM), digital twins, and openBIM. As the demand for intelligent lifecycle management and efficient facility operations continues to grow, airport infrastructure requires standardized and interoperable systems to manage complex assets and stakeholder collaboration. This research addresses three core challenges facing Korean airports: the lack of sustainable maintenance environments, the absence of data standards and systems, and the insufficiency of user-oriented platforms. Through system analysis, benchmarking, and SWOT assessment, the study proposes a stepwise implementation roadmap consisting of development, integration, and advancement phases and designs a “To-Be” model that incorporates 37 component technologies and a standardized information framework. The proposed ISP supports data-driven airport operations, enhances collaboration, and accelerates digital transformation, ultimately contributing to the development of smart and globally competitive airports.

Keywords: information strategy plan (ISP); airport facilities; BIM; digital twin; OpenBIM; smart airport



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1. Introduction

1.1. Background and Necessity of the Study

Building information modeling (BIM) was initially applied to general buildings, and its scope has recently expanded to civil structures related to social overhead capital (SOC), such as railways [1], roads [2], dams [3], and airport facilities [4]. The Smart Construction Technology Roadmap 2018 argues that a framework for traditional civil engineering and construction technologies becomes increasingly convergent with smart technologies such as BIM, the Internet of Things (IoT), big data, drones, and robotics, maximizing construction productivity or safety through approaches such as the digitalization of the entire construction process, automation and virtualization of construction equipment, and on-site safety management [5]. Per the Fifth and Sixth Framework for Promoting Construction Technologies, the domestic policy environment is transitioning to developing technologies in response to the Fourth Industrial Revolution, as well as smart civil engineering and construction technologies, and nurturing new industries accordingly [6].

Despite the increasing need for collaboration within the construction industry, where multiple entities are operating projects of rising scale and complexity [7], many difficulties are encountered owing to a lack of standards, procedures, and systems that are widely applicable to a common environment. Regarding these issues, the MOLIT published the Basic BIM Guidelines for the Construction Industry to secure and utilize the common data environment (CDE), in which multiple entities are required to jointly collect, manage, and distribute generated information to avoid duplication and confusion in securing common data. These entities must satisfy this requirement if an institution has prepared a system for this purpose, or otherwise submit methods for collecting, managing, and distributing data information [8]. Thus, a CDE for applying various smart construction technologies, including BIM, should be established and utilized for successful large-scale construction and SOC projects.

The international air transport market is recovering rapidly after the pandemic, reaching a record high of 128.37 million passengers in 2024 [9]. The Asia–Pacific region showed the highest growth rate of 17.2% year on year, and Europe also saw a significant increase in passenger demand in the short-haul domestic market [9]. Korea is experiencing a rapid increase in demand, with the number of air passengers expected to increase by 60.2% year on year to 89.308 million in 2024. In response, Incheon International Airport is promoting a four-stage expansion project to increase its annual passenger handling capacity from 77 million to 106 million. This increase in air traffic is not only expanding airport infrastructure but also deepening the complexity and uncertainty of operational management. Airports are complex spaces where various facilities, such as terminals, runways, aprons, and gates, are organically connected. Even if the capacity of only a specific facility is expanded, bottlenecks may occur in other facilities, limiting the improvement of overall capacity [10]. In addition, the development of future aviation technology is imposing new challenges on airport infrastructure and operational management.

Against this backdrop, interest in smart technologies for airports is growing globally. In particular, the application of building information modeling (BIM) and the development of digital twins are receiving increasing attention—not only in the construction industry but also in airport development and operations—driven by the expansion of domestic airport projects and international market entry initiatives.

In line with this worldwide trend, various attempts to utilize digital twins and BIM have been made in the airport and aviation industries [11–14]. Over the past 30 years, these technologies have been applied to many new airports, aircraft infrastructures, and pieces of equipment. As BIM data and linked information based on such geometric information are accumulated in numerous global airports, the integrated management of BIM-based information is increasingly important. However, there is a general lack of BIM information management and utilization cases by project owners who are facility management operators. In particular, airport facility management is limited by strict compliance with safety and security regulations, complex integration of landside and airside operations, and the need for accurate data collection and analysis, which can also complicate strategic decision-making on maintenance or expansion projects [15]. In addition, BIM data and related information technologies on airport facilities still have problems such as a lack of interoperability, limitations in real-time data linkage, and inefficient management of facility information, so systematic establishment of an information strategy and preparation of an implementation roadmap are required.

Airport facilities are infrastructure that serve a key role in national development and integration, as well as transportation. Furthermore, they are large-scale, complex facilities that link architecture, roads, railroads, and harbors. Thus, airport facilities require systemic management that adapts to and considers their lifecycles. Airports involve various

stakeholders who require close cooperation for efficient facility management, navigation, security, and safety management [4,16].

Airport facilities are functionally divided into takeoff and landing, safety, passenger handling, cargo handling, and passenger convenience facilities, and the goals of facility operation and maintenance vary depending on functional characteristics [17]. The introduction of BIM for airport facility management necessitates an analysis of the functions, characteristics, and operational goals of each airport facility, as well as the preparation of improvement directions. Moreover, when constructing a new airport, all lifecycle data on construction, including planning, design, implementation, and maintenance, must be integrated based on BIM and utilized to enhance the efficiency of construction management and airport operation [12,18]. This integration further requires links with smart technologies.

1.2. Purpose of the Study

This study aims to examine the component technologies required to build a CDE, mainly targeting maintenance tasks, to resolve the issue of integrated information management of airport facilities and thereby establish a foundation for the systematic planning and utilization of new technologies.

To facilitate the efficient management of airport facilities in South Korea, this study aims to address the following three issues. First, no sustainable environment for facility maintenance is available. To address the lack of basic technology and an efficient environment for facility maintenance, the component technologies required for efficient facility maintenance, such as the CDE, openBIM, and digital twins, can be classified by target for facility maintenance, and a directly applicable environment can be built to optimize their execution and effectiveness. Second, established standards and systems for the integrated maintenance of facilities are insufficient. Currently, the standards for creating and managing data for facility maintenance are not properly defined, making it difficult to integrate life cycle data due to compatibility issues between various systems [19,20]. To address the inadequate standards for creating and managing data for facility maintenance, new standards and application guidelines for maintenance can be developed. These should enable consistent data to be created, managed, and linked to systematically establish and technically standardize facility maintenance methods. Third, no current system reflects the functions needed by maintenance workers. To address this absence and that of the system interfaces required to efficiently perform facility maintenance, a new system can be developed and continuously updated by actively incorporating the desirable functions of similar systems and the requirements of business stakeholders [21,22].

Therefore, based on the technical analysis of airport facility information management following the ISP establishment procedure, this study aimed to establish a comprehensive strategy for applying BIM to airport facility information. The strategy was developed by identifying key environmental characteristics, analyzing the current status of facility information, defining an information vision, strategic goals, and stepwise implementation plans, and establishing system architecture principles, technical requirements, and information management objectives.

1.3. Research Methodology

ISP (information strategy planning) is a systematic approach to diagnosing the level of information in an organization and establishing mid- to long-term information strategies and implementation plans. In Korea, the Ministry of Economy and Finance and the National Information Society Agency (NIA) have been publishing common guidelines for establishing ISP and ISMP since 2017, with the latest revised edition released in 2025. These guidelines specify the methodologies and documentation standards required for ISP

development. When actually applied, the detailed composition and order can be flexibly adjusted according to the characteristics of each project. The procedure consists of a total of four stages, and each stage includes its own purpose and activities. In the first stage, environmental analysis, external and internal conditions such as policy and institutional status, technology trends, and stakeholder structure are comprehensively diagnosed. In the second stage, status analysis (AS-IS), the existing information system and work process are analyzed, and areas requiring improvement are identified through a SWOT analysis. The third stage, design of improvement model (TO-BE), sets the future information direction and strategic tasks, and redesigns the system architecture, functions, and work structure. In the final stage, establishing an implementation plan, an implementation strategy, including an annual roadmap, performance indicators (KPI), and risk management measures, is established to increase the effectiveness of ISP implementation. In this way, an environmental analysis for establishing ISP is an important stage that comprehensively diagnoses the external industrial and policy environment and internal capabilities of the organization and is a key foundation for determining the direction of subsequent strategy establishment and planning [23]. In the ISP establishment procedure, key tasks and outputs, such as SWOT and CSF analysis, the definition of existing and future business processes, analysis and proposal of IT infrastructure, and derivation of the information management structure and integrated system structure are performed [24]. Based on this, previous studies have divided the ISP promotion procedure into four stages: environmental analysis, current status analysis, goal structure development, and implementation plan establishment [25,26]. In the study on the establishment of the National Health and Medical Information ISP, the procedures of environmental analysis and current status analysis, the establishment of informatization vision and core principles, the derivation of promotion strategies and tasks, and the selection of priorities for key tasks were utilized. For this purpose, methodologies such as major issue analysis, policy analysis, the literature survey, expert demand survey, advisory meeting, and internal review were utilized [27]. In a case study [28] that applied the ISP framework of Ward & Peppard (2002) [29] to establish the ISP of the Indonesian Naval Academy (AAL), a multifaceted diagnosis was made through PEST analysis, SWOT analysis, surveys, and internal interviews, and based on this, mid- to long-term strategic goals were set. Then, a five-year implementation roadmap for establishing an integrated information system (SIM INTEGRA AAL) was presented. In this way, the ISP aims to systematize information strategies based on the organization's management strategy, establish user-centered work-based plans, set priorities for information needs, and establish an integrated information system that enables data sharing. In addition, it comprehensively utilizes various methodologies to set strategic goals, such as defining a technology structure that can effectively utilize the latest information technology and organizing an information management system within the organization.

These purposes and methods can also be effectively applied to large infrastructure organizations such as airports with multiple stakeholders and complex operating systems.

Based on this ISP establishment guide and the research procedures of previous studies, this study systematically establishes an airport facility information management system by conducting environmental analysis, current status analysis, and the four-stage ISP establishment procedure, consisting of analysis (AS-IS), improvement model design (TO-BE), and implementation plan establishment, was applied.

First, in the environmental analysis stage, the information management system of airport management facilities, information targets and classification, status of connection with legacy systems, major stakeholders, and organizational structure were analyzed to diagnose the facility information environment of Korean airports.

Second, in the status analysis (AS-IS) stage, the current information system and work process of the airport were diagnosed, and problems were identified through internal document review and interviews with field workers. In addition, risk factors and success strategies were derived through benchmarking and SWOT analysis, and based on this, strategic tasks and priorities necessary for establishing a future information strategy plan were set.

Third, in the improvement model design (TO-BE) stage, the requirements that the airport information system must have were structured into the technical environment, work standards, and organizational structure. Then, the work process was redesigned based on this, and the requirements for each element were defined in detail.

Fourth, in the implementation plan establishment (ACTION PLAN) stage, an information technology introduction and establishment strategy was established to effectively carry out the overall business strategy. To this end, we divided the annual goals, promotion phase, operation phase, system construction, and model design phase into stages and built a step-by-step integrated roadmap. The procedures and methods of this study are as shown in Table 1.

Table 1. Research framework and methodology.

Step	Research Procedure	Research Method
Step 1 Environmental Analysis	Analysis of airport facility information management systems, information targets, and legacy system linkage status	- Literature review - Analysis of organizational charts and system architecture
Step 2 Current State Analysis (AS-IS)	- Analysis of current airport information systems and business processes - Identification of issues requiring improvement - Derivation of core implementation tasks and priorities	- Review of internal documents - In-depth interviews with stakeholders - Benchmarking - SWOT analysis - Priority evaluation
Step 3 Target Model Design (TO-BE)	- Design of model based on technical environment, operational standards, and organizational structure - Derivation of detailed requirements	Requirements analysis
Step 4 Action Plan Formulation	- Establishment of phased implementation strategies and annual goals - Construction of an implementation roadmap	- Design of strategies for system implementation and model realization - Application of strategic roadmap development guides

In the status analysis (AS-IS) stage, interviews were conducted with field workers at the headquarters and the Jeju Regional Headquarters of Korea Airports Corporation to collect opinions from the field on airport facility information management. The Korea Airports Corporation headquarters consists of 5 headquarters, 15 offices, and 47 departments, and the Jeju Regional Headquarters consists of 16 branches, 9 divisions, and 72 departments. Among these, field workers in departments closely related to the research topic, such as smart technology introduction, facility maintenance, and information strategy establishment, were selected first and interviewed. In order to secure the reliability and validity of the interviews, an interview guide was designed in advance, and structured interviews were conducted after a preliminary review of key questions. The collected interview con-

tents were analyzed using the content analysis technique to derive key opinions, and the analysis results were verified through the research team's review and feedback.

2. Literature Review

2.1. Strategic Framework for Smart Airport Implementation

Previous studies emphasize that implementing a smart airport requires more than the mere adoption of technology; it demands an implementation roadmap that considers stakeholder acceptance, infrastructure readiness, and security issues [30]. Best practices from major airports in Asia, the Middle East, and Europe highlight the effectiveness of smart technologies and identify key concepts and priorities by application area [31]. Big data analytics has also been proposed to enhance operational efficiency and strategic differentiation, along with ongoing discussions on data-related challenges and solutions [32]. The importance of stakeholder-driven, customized strategies is noted, with studies applying AHP-SWOT methods in BIM-based facility management to address issues like smart maintenance, resistance to change, and cybersecurity [33]. Furthermore, integrated frameworks have been suggested for aligning stakeholder needs and enabling digital collaboration across the airport life cycle [13].

These studies support the necessity and methodological validity of deriving an information strategy for applying smart technologies to airport facility management, as proposed in this research.

2.2. Facility Information Integration and Maintenance Strategy

In terms of facility information and maintenance, previous studies emphasize the need for an integration of BIM and information management systems. In the case of an airport in the United States, BIM data was not linked to the existing maintenance management system, CMMS (computerized maintenance management system), resulting in a lack of accurate facility data and inefficient asset management issues. In addition, it has been reported that the post-recovery cost when a facility is damaged increases by an average of 3 to 10 times more than the pre-planned maintenance cost, showing that it is essential to build a preemptive maintenance system and establish an efficient asset management strategy based on information [34,35].

To solve this, the introduction of the BIM-FM integrated framework and the CO-Bie-based data transfer system has been reported to have significantly improved the timeliness and accuracy of facility information [19]. In addition, in airport facility management, elements with different management standards, such as runways and terminals, coexist, requiring advanced information collection and integrated management methods utilizing non-destructive testing (NDT) and remote-sensing technologies. Recent studies have suggested the possibility of building a BIM-based digital environment and developing an airport asset management system that integrates multiple data sources to respond to such a complex management environment [36]. BIM enables collaboration among stakeholders in a virtual environment [37] and supports integrated lifecycle management of facility data [38,39]. Its importance is increasing as the Korea Airports Corporation adopts ISO 19650 [40,41] certification. Prior studies show that BIM improves asset utilization [42], decision-making [43], data exchange [44], work efficiency [45], and maintenance safety [46].

These findings further support the validity of applying BIM processes to airport facility information systems, highlighting the critical importance of developing integrated and data-driven maintenance strategies. They also underscore the need to build BIM-based ISP models that enhance facility data accuracy and enable proactive airport infrastructure management.

3. Materials and Methods

3.1. Object and Scope of Airport Facility Information

The Korea Airports Corporation (KAC) manages 14 regional airports: Gimpo, Gimhae, Jeju, Daegu, Gwangju, Cheongju, Yangyang, Muan, Ulsan, Yeosu, Sacheon, Pohang, Gunsan, and Wonju [47]. The KAC is responsible for streamlining air transport by efficiently constructing, managing, and operating each airport and fostering and supporting the aviation industry. The facility information in this study was limited to the facility status of these 14 airports, including Gimpo Airport. The basic status, mid- to long-term development directions, and airport revitalization issues of the 14 airports under KAC management are shown in Table 2.

Table 2. Current status of airport management and major mid- to long-term airport revitalization issues in South Korea.

Airport	Site Area (m ²)	Length and Width of Runway (m)	Terminal Area (m ²)	Aircraft Departures (Times/Year)	Mid- to Long-Term Development Directions and Issues
Gimpo	8,440,923	3600 × 45 3200 × 60	Domestic: 77,776 International: 53,087	226,000	- Expanded airspace capacity to meet rapidly increasing demand for domestic flights - Improved facilities according to Gimpo Airport Basic Plan
Gimhae	3,697,435	2743 × 45 3200 × 60	Domestic: 37,282 International: 50,665	200,000	- Seeking facility expansion to meet five- to ten-year demand at Gimhae Airport based on the results of the preliminary feasibility study on new airports in the Yeongnam region
Jeju	3,497,380	3180 × 45 1900 × 45	Domestic: 45,145 International: 27,818	172,000	- Leading development of a new airport based on decision to build a second airport in Seongsan, Jeju - Ensured seamless satisfaction of demand according to Phase 1 and 2 infrastructure expansion project for the existing Jeju Airport
Daegu	6,617,283	2755 × 45 2743 × 45	Domestic: 11,985 International: 15,008	140,000	- Experienced an all-time high number of passengers due to rising options available after the entry of low-cost airlines - Faced a shortage of airport facilities to accommodate passengers at Daegu Airport due to increasing demand
Gwangju	5,854,564	2835 × 45 2835 × 45	Domestic: 10,561-	140,000	- Experienced an increase in airport visitors due to expansion of Jeju routes during summer peak season
Cheongju	6,739,778	2744 × 60 2744 × 45	Domestic: 8000 International: 14,406	140,000	- Added diverse routes to Japan, Taiwan, and Southeast Asia, aiming to become a hub airport in the central region - Seeking connections to international hub airports such as Hong Kong and Narita by expanding Chinese routes, as well as operating consumer-oriented slots and offering low-cost parking services
Yangyang	2,488,500	2500 × 45	Domestic: 10,083 International: 16,047	43,000	- Planning to continuously expand Southeast Asian routes, including routes to Thailand, Malaysia, and Indonesia
Muan	2,682,000	2800 × 45	Domestic: 20,000 International: 9106	140,000	- Reviewing airport revitalization, active development of routes considering demand, and connection to high-speed rail - Ensuring stable demand by opening regular routes and discovering new routes to accommodate the increasing number of users

Table 2. *Cont.*

Airport	Site Area (m ²)	Length and Width of Runway (m)	Terminal Area (m ²)	Aircraft Departures (Times/Year)	Mid- to Long-Term Development Directions and Issues
Yeosu	1,330,930	2100 × 45	Domestic: 13,328	60,000	- Reviewing the addition of flights and attraction of low-cost airlines according to the surge in tourists in the Gwangyang Bay area - Expanded transportation network connections and tourism infrastructure development to accommodate Yeosu Expo and Suncheon Bay National Garden
Ulsan	919,977	2000 × 45	Domestic: 8886	60,000	- Improving facilities to prepare for a feasibility study of new airports in the Yeongnam region
Pohang	4,035,563	2133 × 45	Domestic: 11,707	100,000	- Reviewing regional activation of Gyeongju and Pohang through tourism projects - Considering future expansion of routes to Southeast Asia and small- and medium-sized cities in China
Sacheon	4,039,465	2743 × 45 2743 × 45	Domestic: 4692	165,000	- Reviewing a launch of international flights to China - Planning to improve the airport-linked land transportation network, including intercity buses, for user convenience
Gusan	142,803	2743 × 45 2454 × 23	Domestic: 2852	140,000	- Remodeling and expanding old and narrow facilities aged 25 years or older after their completion
Wonju	5,675,650	2743 × 45	Domestic: 1896	115,000	- Reviewing addition of flights on the Wonju–Jeju route currently with one flight per day to avoid inconvenience to passengers

The integrated management of airport facility information includes the automatic quality review of BIM models, infrastructure monitoring, facility safety diagnosis, and inspection management functions to ensure the efficiency of system operation and facility management. Following the trend of increased emphasis on the integrated management of facility information based on digital twins, this scheme seeks integrated management incorporating component technologies such as smart technology.

By analyzing the construction, policies, and standards related to the integrated management of airport facility information, this study aims to establish a mid- to long-term plan suitable for constructing an infrastructure system, maximize the feasibility and effectiveness of related projects, and set the scope for the efficient analysis of airport facility information management.

3.2. Airport Facility Classification and Legacy Linkage in South Korea

The KAC has classified the facilities of 14 airports into passenger facilities and passenger-related facilities and derived the status of facility classification according to the airport design standards regarding the detailed facilities [48], as shown in Table 3.

The current status of legacy airport management systems in South Korea is shown in Figure 1. To facilitate future advanced facility management, current facility classification requires integrated management and operation encompassing addition and renaming, as well as the reestablishment of the mapping relations between the BIM library classification and the basic facility information classification for BIM-based integrated management. In particular, because the legacy system of airport facility information consists of 32 or more systems separated by task area, it is necessary to capture the linkages of existing systems to systematically manage facility classification.

Table 3. Current status of facility classification according to airport design standards.

Facility Classification According to Airport Design Standards				Remark
Large Category	Mid-Category	Small Category	Detailed Facilities	
Passenger facilities	Check-in and Ticketing	Departure	Self-check-in	Newly added
			Self-baggage drop	Newly added
			Ticketing and baggage check-in	
			ID check	Newly added
			Departure security check	
			Departure passport check	
			-	
		Arrival	Alien/immigrant quarantine	
			Alien/immigrant passport check	
			Arrival security check	
			Baggage claim	
			Customs clearance and animal and plant quarantine	
		Connection	-	
	Transfer security check			
	Transfer counter			
	Gate areas	General	Departure gate area	
			Arrival gate area	
		Separated	Boarding area	
			Hallways	Departure hallway
		Arrival hallway		Facility classification
	Public facilities		Public hall, open hallways, stairs, elevators, fixed boarding bridges, and restrooms	Facility classification
Commercial and convenience facilities		Infant and child facilities, Internet zones, various information booths, duty-free shops, duty-free shop storages, business lounges, and food stalls		
Passenger-related facilities	Airline facilities		Airliner offices, ground crew offices, airline lounges, and hallways within airline facilities	
	Government facilities		Resident agency offices, break rooms, gyms, and hallways within governmental facilities	
	Airport management facilities		Employee facilities, employee cafeterias, VIP/CIP lounge, and hallways within management facilities (separately planned for airport management facilities)	
	Support facilities	-	Baggage claims	Facility classification
		MEP facilities	Mechanical, electrical, telecommunications, firefighting facilities, and water tank room	

	Strategic Planning		Operations		Construction Technology				Aviation Business			Safety and Security				Airport Operations							
	Planning and Coordination	Smart Airport	Airport Management	Administration	Airport Planning	Airport Facilities	A/S Operations	Environment Energy	Navigational Facilities	Aviation Marketing	Commercial Facilities	Aviation Research Institute	Safety Planning	Disaster Prevention and Response	Security Planning	Counterterrorism Response	Operations Center	Operations Planning	Customer Service	Security Management	A/S Operations	Mechanical Facilities	Environmental Management
KAC-BIM																							
	Integrated Operations Center System (Real-Time Situation Information, Trend Analysis Information, etc.)																						

Enterprise Resource Planning(ERP)	One-Stop Aircraft Flight Schedule Complaint Handling System	Greenhouse Gas System	Flight Information Display System (FIDS)
KAC-Project Management Information System(KAC-PMIS)	General Declaration(GD)	Parking Management System	Electronic Exchange
Self-boarding gate system	AIRISE	Commercial Facility Embedded Management System	Low Visibility Guidance System
Integrated Operation Information System	Slot Management System	Voice of Customer(VOC) System	Public Address System (PA)
Airport Collaborative Decision Making (A-CDM)	Obstacle Management System	Passenger Boarding Bridge Monitoring System	Video Surveillance System (CCTV)
Airport Underground Facility Integrated Geographic Information System	National Integrated CCTV Surveillance System	Conveyor Monitoring System	Perimeter Security Automation System
Safety Management System	KAC Integrated Disaster Safety System	Enterprise Building System(EBI)	Access Control (Facial Recognition) System
Flight Operation Information System(FOIS)	Airport Noise Information System	Lighting Control System	Wireless Eavesdropping Detection System

Figure 1. Current status of legacy airport management systems in South Korea.

3.3. Current Status of Stakeholders and Related Organizations

Figure 2 shows the stakeholders in airport operations related to the facilities and environment, safety and security, aircraft and ground operations, and common systems. There are various stakeholders in airport operations, requiring a mutually supportive cooperation network for efficient facility management, operations, security, and safety management [49].

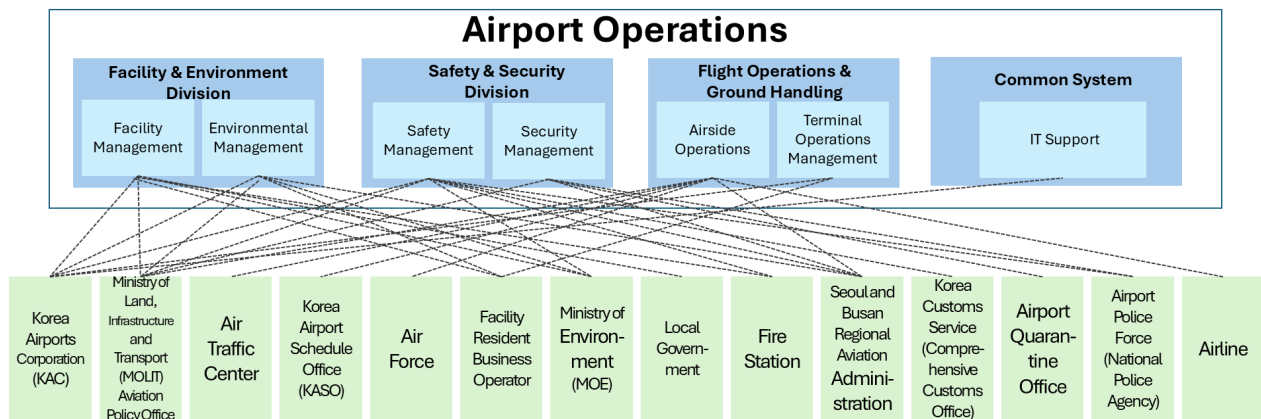


Figure 2. Current status of airport operation stakeholders.

The KAC is broadly divided into its headquarters and branches. The personnel structure is concentrated at the headquarters, which is composed of 5 divisions, 15 offices and centers, 47 departments, and 16 branches, with a total of 9 forces and centers, and 72 departments [50]. There is a particular need for an efficient facility information management system capable of integrated management of airports in the aforementioned 14 regions through the headquarters and branches.

4. Analysis of Management System for Domestic Airport Facilities and Derivation of Priority Tasks

4.1. Analysis of Airport Work Classification System and Standards

The current task standards and system of the KAC were analyzed by examining the internal classification system and the related standards, as well as the guidelines necessary for conducting maintenance and operational management of airport facilities.

This analysis was conducted by examining the major task system of the corresponding departments in the KAC, as well as the drawing information system and drawing management status within the actual construction. In addition, based on these data, interviews with relevant managers were conducted to analyze the inefficiencies and issues of the existing task system.

First, according to the status of drawing management, the KAC, despite its internal management of drawings through a drawing management ledger, failed to maintain the latest versions of drawings registered therein.

Furthermore, the drawing information system, which was created ten years ago, was found to be no longer functioning. Each project manager is likely to hold the latest drawings from the service providers. However, in many cases, they delayed registering the latest versions onto the drawing management ledger, resulting in missing drawing information.

There are many cases where an in-house design was employed in executing a project, and the management of the latest files could become inadequate owing to design changes. Moreover, each regional headquarters manages small-scale airport drawings in the form of handwritten files, which were improperly managed.

Subsequent interviews with department managers raised three issues regarding enterprise resource planning (ERP): an aged facility history management system, duplicated work due to inadequate system linkage, and improper interface configuration. In the case of guidelines and checklists, there is a need for handling practical usability at business sites, precise monitoring through 3D modeling, and work integration. The results of these findings are illustrated in Figures 3 and 4.

The current status of work standards and guidelines by the KAC is as shown in Table 4, and problems were identified based on this. The existing work breakdown structure (WBS) and project classification system of each department, which were developed to manage a new airport construction project considering the initial airport construction process, were deficient in the classification system for asset management after the completion of the construction project. Moreover, because this was a classification system prior to the introduction of BIM in the airport industry, there was a need to establish criteria or improve the classification system such that it could be utilized in conjunction with a BIM-based object classification.

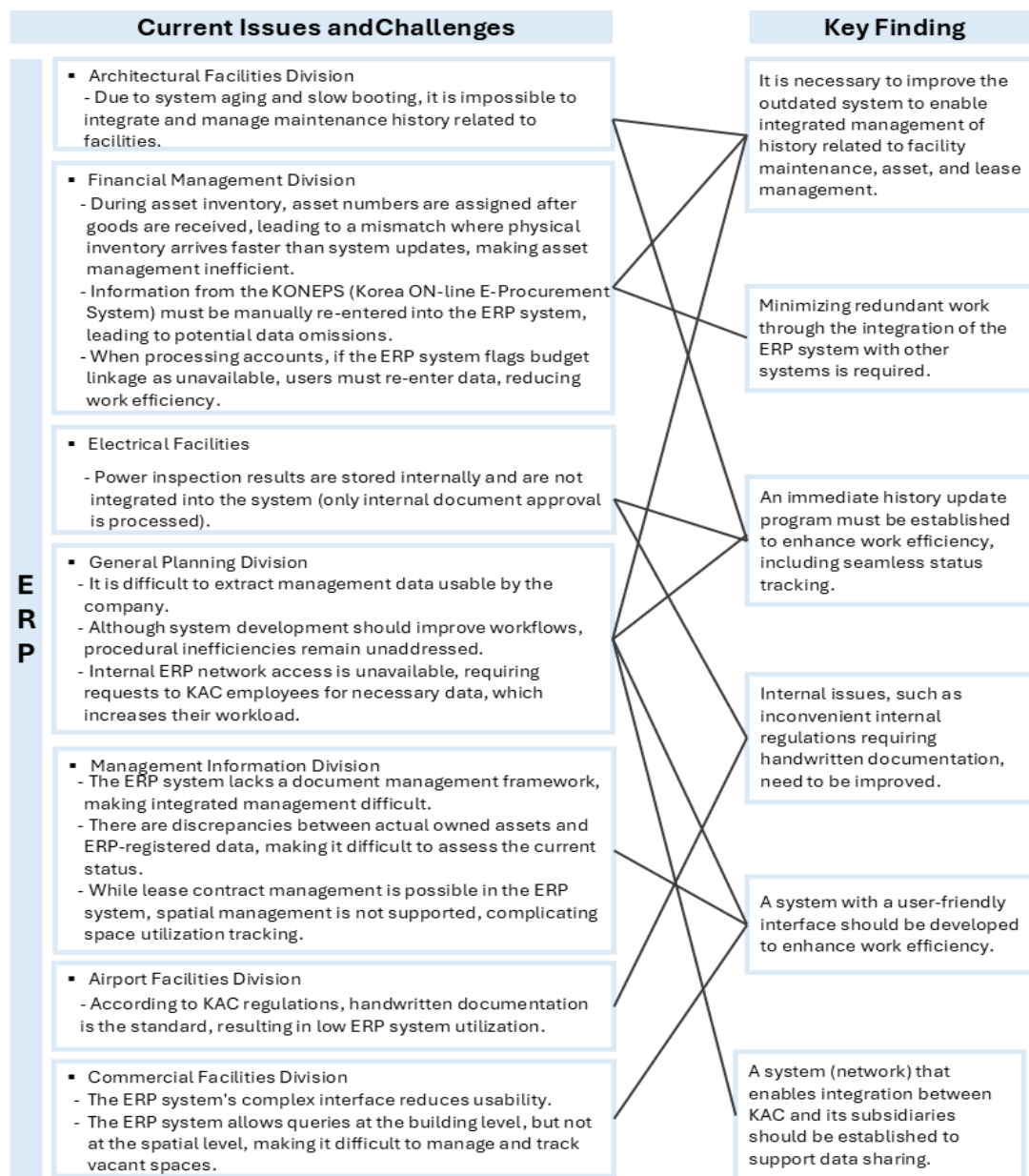


Figure 3. Interviews related to task system of each department linked to ERP.

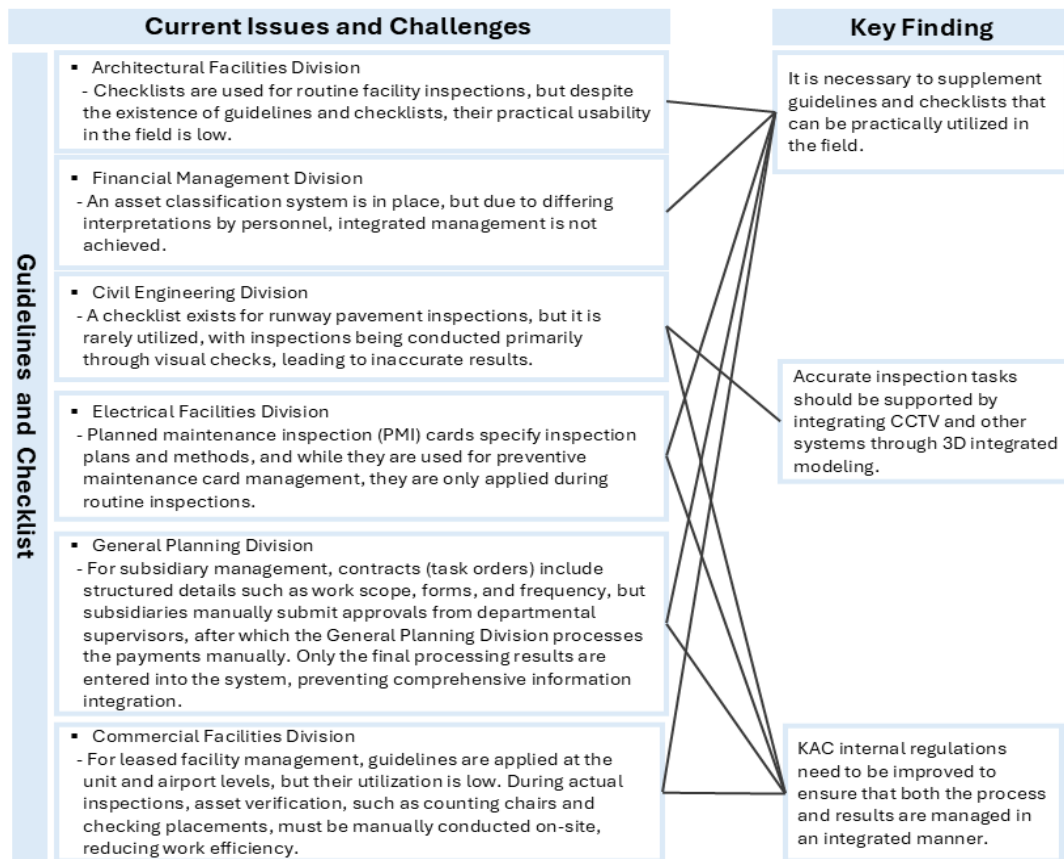


Figure 4. Interviews related to the task system of each department in connection with guidelines and checklists.

Despite the existence of various standards and manuals for operating and managing facilities, these tools cannot be integrated because of the lack of unified object-level classification codes for facility management. This results in low practical usability, as shown in the management drawing.

The analysis results highlight that resolving existing problems and achieving future BIM-based integrated operation requires the development of a new BIM library classification system, attribute specifications, and information requirement level, which can be utilized in coordination with the existing classification system of the KAC.

Furthermore, the existing BIM guidelines used by the KAC may lead to confusion due to the lack of distinct versions for the client and the service provider, as well as difficulty in field applications because they do not consider classification codes for the integrated use of BIM and maintenance management. Because independent application guidelines are applied to the design and construction stages, and no application guidelines are available for the maintenance stage, it would be difficult to create and manage a BIM model that can be used in coordination with the integrated management system for airport facility information. Thus, additional guidelines for the maintenance stage are needed to facilitate stage-wise facility operation management.

The work classification system for airports was established to effectively achieve project goals and systematically manage the necessary information by maximizing communication and management efficiency between project organizations. This work classification system clearly defines the overall scope of a project and systematically classifies facilities and tasks for efficient project management. Producing the necessary deliverables necessitates the systematic management and operation of a hierarchical structure that divides the facilities and tasks to be performed by the project team based on the deliverables.

Table 4. Current status of work standards and guidelines by KAC.

Category	Title	Created in	Objectives	Major Detail
Rental Management Manual	Rental Manual	September 2011	Intended to describe how to use a rental agreement so that users can easily process the rental agreement	- Rental work processes (termination/expiration of rental contracts, transmission of rental fees, and annual carry-over of rental contracts) - Rental work procedures - Detailed description of transactions (details on rental contracts, on-site business fees, collateral status, additional rental fees, and transmission of monthly and local rental fees)
Property Management Manual	Standard Information Management	-	Intended to enable users to easily apply procedures in managing the assets of the KAC on the master level	- Asset Master Management - Standard information management (trees/buildings/non-building structures/facilities/donations/artworks/major items) - Standard information management (standard asset master—applicable to item assets) - Standard information management (customer master/useful life for items/land specification for acquisition/closed land specification/location code change)
	Standards for Processing Property Tasks	October 2015	Intended to promote efficient property management by preparing standards for handling property work that occurs during airport development projects	- Current property handling process related to airport development projects - Issues in property tasks cases related to airport development projects - Standards for handling property tasks related to airport development projects
	User Reference for Property Tasks	April 2014	Intended to enable users to easily apply procedures in managing the assets of the KAC	- Acquisition/operation/sale (disposal) cycle for fixed assets - Budget process - Purchase process - Order settlement and fixed-asset acquisition process - Asset management process - Asset sale and disposal process
Environmental Management Manual	Airport Environmental Inspection Handbook	October 2018	Intended to train environmental management personnel at each airport in eliminating blind spots in inspections and implementing environment-friendly airports by producing and distributing a response manual for repeatedly emerging issues during environmental inspections by MOLIT, local governments, and other related organizations	- Airport environmental management system and status - Response measures by case in point
Facility Maintenance Manual	Maintenance Guidelines for Building Facilities	May 2019	Intended to facilitate the smooth operation of air transport and passenger services through efficient management and maintenance by establishing inspection and maintenance procedures for building facilities managed and operated by the KAC	- Guidelines for facility inspection and maintenance work - Targets and details in regular inspections - Targets and details in special inspections - Designation criteria and inspection cycle for statutory facilities

4.2. Risk Factors and Success Strategies Through Benchmarking Leading Cases

This study analyzed BIM and openBIM cases applied to the maintenance and facility management of leading airports, both domestically (Incheon International Airport) and abroad (including The Netherlands, United States, Denmark, Norway, and the United Arab Emirates), to develop an openBIM-based integrated management system for the airport facility information of the KAC. The analysis results regarding leading cases are presented in Figure 5.

Country	Airport Name	Project Duration		Scale	OpenBIM Implementation	BIM-Based Facility Maintenance Details
		Start	End			
Netherlands	Schiphol Airport	2017	2027	45,000 m ²	O	Facility Management Using Digital Twin Management through OpenBIM-Based Facility Information and GIS-Based Real-Time Location Guidance
United States (USA)	Denver International Airport	2018	2025	137,270 m ²	O	Integration of BIM Technology with Maintenance Management Systems (Facility information updates using BIM)
Norway	Gardermoen Airport terminal 2	2010	2017	117,000 m ²	O	Utilization of OpenBIM Throughout All Phases of Terminal 2: Design, Construction, and Maintenance
Denmark	Copenhagen Airport	2018	2020	1180ha	O	Implementation of OpenBIM-Based Integrated Management Automation (Automated Quality Control)
United Arab Emirates (UAE)	Abu-Dhabi International Airport	2013	2017	700,000 m ²	X	Collaborative BIM Platform with Integrated Web Functionality Development of a Facility Business Support Application for Easy Integration, Management, and Reporting of 3D, 4D, and 5D Information
Saudi Arabia	Prince Mohammed Bin Abdulaziz International Airport	2013	2015	156,940 m ²	X	Integration with Systems Used Throughout Facility Management (FM) Workflow and Lifecycle
Kuwait	Kuwait International Airport	2017	2022	750,000 m ²	X	Rapid Adjustment of Design Scope in Large Scale Airport Projects Management Through Information Extraction Design Coordination with Geographically Distributed Teams Structural Design Verification
Turkey	Istanbul Airport	2015	2018	900,000 m ²	X	Centralized Management Coordination Through a BIM Platform (Delivered to the site via BIM cloud services)
China	Daxing Airport	2014	2019	700,000 m ²	X	Utilization of BIM Data Used in Airport Construction for External Maintenance Systems and Information Management
Singapore	Changi Airport	2014	2030	1080ha	X	Creation of 4D-BIM Models at LOD 300 Level and Impact Assessment of Surrounding Buildings During Construction

Figure 5. Analysis results regarding leading cases.

First, the Incheon International Airport Corporation Integrated Spatial Management System (ASMS) has been separately established and operated in addition to the 14 airports under the control of the KAC [51–53]. The ASMS operates in a configuration consisting of three main modules. These are the main viewer, which is a 3D viewer; a web-based management module, which provides information for specific space management tasks; and a field survey system using a mobile system. This ASMS does not support a standard system for the attributes of BIM data or the integration of multiple BIM data because service providers deliver products in their respective software file formats. Rebuilding 3D shapes without utilizing BIM data and the necessary information results in a waste of resources in the duplication of the work of inputting attributes to the system during system uploading. The absence of coordination between shape and attribute information demands continuous information input upon any modifications. This results in inefficient system utilization due to limitations in the timely updating of information and physical memory handling large volumes of data. The system is further limited by a lack of linkage with the legacy system due to the lack of standardized information.

According to facility operation and maintenance cases for applying BIM technology at leading overseas airports, these airports appropriately respond to the increasing demand for on-site safety, in addition to supporting various types of facility lifecycles [54–64].

The risk factors and success strategies determined by analyzing leading cases are as shown in Table 5. The analysis of leading cases implies that it is necessary to support various types of facility lifecycles and respond to the increasing demand for on-site safety through the operation and risk management of airport facilities. Airport operation asset management is disadvantageous because of the difficult communication between project execution groups in asset management using BIM, which is dependent on specific fields and software. Thus, it is necessary to foster collaboration between the building maintenance group and the asset management group, and to save time and cost in resolving various problems occurring at airports by supporting asset and quality management. This

collaboration can meet the demand for the integrated management of facility maintenance information by offering data in a shareable format across fields. This will enable integrated management without losing the efficiency of specialization and division of labor by airport maintenance stages.

Table 5. Risk factors and success strategies determined by analyzing leading cases.

Risk Factors	Success Strategies
Difficulty in securing existing data	Securing shape data and classifying attribute data through new BIM application projects
Difficulty in developing internal standards	Establishing an openBIM-based system through early construction of a library linked to national and international standards
Difficulty in responding to high technological innovation speed	Expanding the system stepwise through the down/up method with a system module unit (puzzle strategy—e.g., Schiphol Airport)
Difficulty in building a perfect digital twin	Deriving a buildable model through setting a short-term scope

In particular, the utilization of openBIM through industry foundation classes (IFC), as shown in the terminal expansion of Denver International Airport and Oslo Gardermoen Airport, can facilitate data exchange across various software applications according to the type of construction and company [65–68]. In this respect, these two overseas cases demonstrate the applicability of integrated maintenance by building BIM data using 3D-scanning technology for existing facilities, rather than expansion.

4.3. Improvement Directions and Implementation Tasks Through SWOT Analysis

Based on the results of the interviews with practitioners conducted in Sections 4.1 and 4.2 and the analysis of advanced overseas cases, the SWOT technique was applied to systematically derive the strengths, weaknesses, opportunities, and threats of the airport facility information management system and to derive priority tasks. SWOT analysis is a strategic technique that analyzes opportunities and threats to maximize strengths and supplement weaknesses and establishes capabilities and development strategies [69,70]. SWOT analysis has also been used as a major analysis tool in previous studies on the strategic planning of information systems [71–73]. Therefore, this study systematically derived key implementation tasks and execution priorities based on the internal and external factors derived through a SWOT analysis to establish specific strategic directions in connection with project goals.

The SWOT analysis was derived based on analyses of the previous airport work system and airport information management cases with reference to various issues and improvements in facility information management. The results of the derived SWOT analysis are presented in Table 6, and the SWOT strategies and key success factors are listed in Figure 6. This analytical approach can contribute to increasing the feasibility and practicality of the proposed model in airport facility information management.

Comprehensively considering the internal capabilities of the KAC, based on the policies, industries, markets, and trends in advanced technology development related to airport facility information, this study derived integrated implementation tasks centered on key success factors. Three integrated implementation tasks and seven implementation tasks were derived from the SWOT analysis results derived from the current status analysis, improvement opportunities, information risk factors, and success strategies, as shown in Table 7.

Table 6. SWOT analysis information.

Distinction		Analysis Results
Internal capabilities to be considered	S	- Promoting continuous service improvement using customer experience information - Major achievements in successful overseas airport projects based on experience and technological comparative advantages in airport construction and operation - Service provision capabilities and usage records for smart airports - High domestic R&D performance capabilities, including sufficient professional research personnel and various industry, academia, and research institutes - Possessing various in-house systems for airport operation management, such as ERP and Project Management Information Systems (PMIS) - Some guidelines for facility operation, management, and maintenance
	W	- Aging airport terminal infrastructure and spatial limitations - Absence of an integrated airport platform for integrated airport operation and security management - Absence of a system for accommodating new services and supporting cutting-edge technology - Absence of an integrated work support system for construction, operation, and service management - Insufficient real-time status management and preemptive response by airport facilities - Absence of an integrated management system for integrated operation and facility management at 14 airports - Demand for information sharing, collaboration, and mutual growth among stakeholders - Absence of personnel in charge of specific tasks such as drawing, data, and material management - Low utilization of legacy systems due to lack of user convenience - Absence of management system and technology for asset tracking, information history, and drawing updates - Absence of an airport-wide integrated smart operation system based on an upcoming technology platform - Absence of 3D information technology for facility operation management
External environment to respond to	O	- The new airport construction market continues to grow rapidly due to the surge in global airport demand - Governments at home and abroad are raising R&D investment and applying policies supporting airport digitalization - The construction industry, with its focus on digitalization of the entire construction process, is promoting practical applications aimed at conversion and expansion - Stakeholders are striving to realize integrated operation management technology based on future technology platform - Stakeholders are maximizing airport information technology capabilities by utilizing future technologies, including cutting-edge technologies - Markets are demanding the establishment of a customized information strategy plan that can respond to policy changes
	T	- No standard system for new airport construction is available - IM and digital twins are already being applied at overseas new airport construction sites, with heightened competition for new airport construction and operation management based on digital twins - Demand exists for smart airport growth through data integration technology, according to airport integrated operation - A system utilizing information technology is continuously applied, thereby enhancing airport competitiveness, according to cutting-edge technology advancement - Demand exists for the development of standards to ensure the sustainability of information production management

Table 7. Integrated implementation tasks for applying smart technology to airport facility information.

Integrated Implementation Tasks	Implementation Tasks		Detailed Description
Asset Integration Management	1	openBIM-based integrated asset operation management	- Supporting asset and business management, such as integrated monitoring, integrated operation analysis, integrated operation planning, integrated history management, and various support tasks - Supporting platform operation management and resource information management through CDE - Implementing asset integration management for 14 airports through asset and business management, as well as platform operation management
	2	openBIM-based facility and space use management	- Supporting operation and use management of airport leasing, work facilities, and space - Implementing efficient facility asset operation management of airport groups
Facility Maintenance	3	openBIM-based facility status monitoring	- Supporting openBIM-based monitoring of KAC asset status and usage status - Supporting monitoring of operating equipment status, disaster prevention and security status, and construction facilities and civil structures status - Maximizing maintenance work efficiency through facility status monitoring
	4	openBIM-based facility control	- Controlling operating equipment and disaster prevention and security through linking various equipment attributes of BIM models - Securing technical capabilities and maximizing work efficiency through airport facility control utilizing cutting-edge component technologies
	5	openBIM-based facility inspection and maintenance	- Supporting inspection and maintenance of operating equipment, disaster prevention and security, construction facilities, and civil structures - Maximizing the efficiency of facility inspection and maintenance through linking BIM model information and facility information

Table 7. Cont.

Integrated Implementation Tasks	Implementation Tasks		Detailed Description
Facility Use Support	6	openBIM-based facility use guide	- Offering user facility guidance and vehicle guidance services - Enhancing customer satisfaction services through facility use support using cutting-edge component technologies
	7	openBIM-based event occurrence guide	- Providing guidance services in response to events, such as emergencies and dangerous situations - Supporting rapid on-site response to events by offering alerts and evacuation route guidance upon event detection

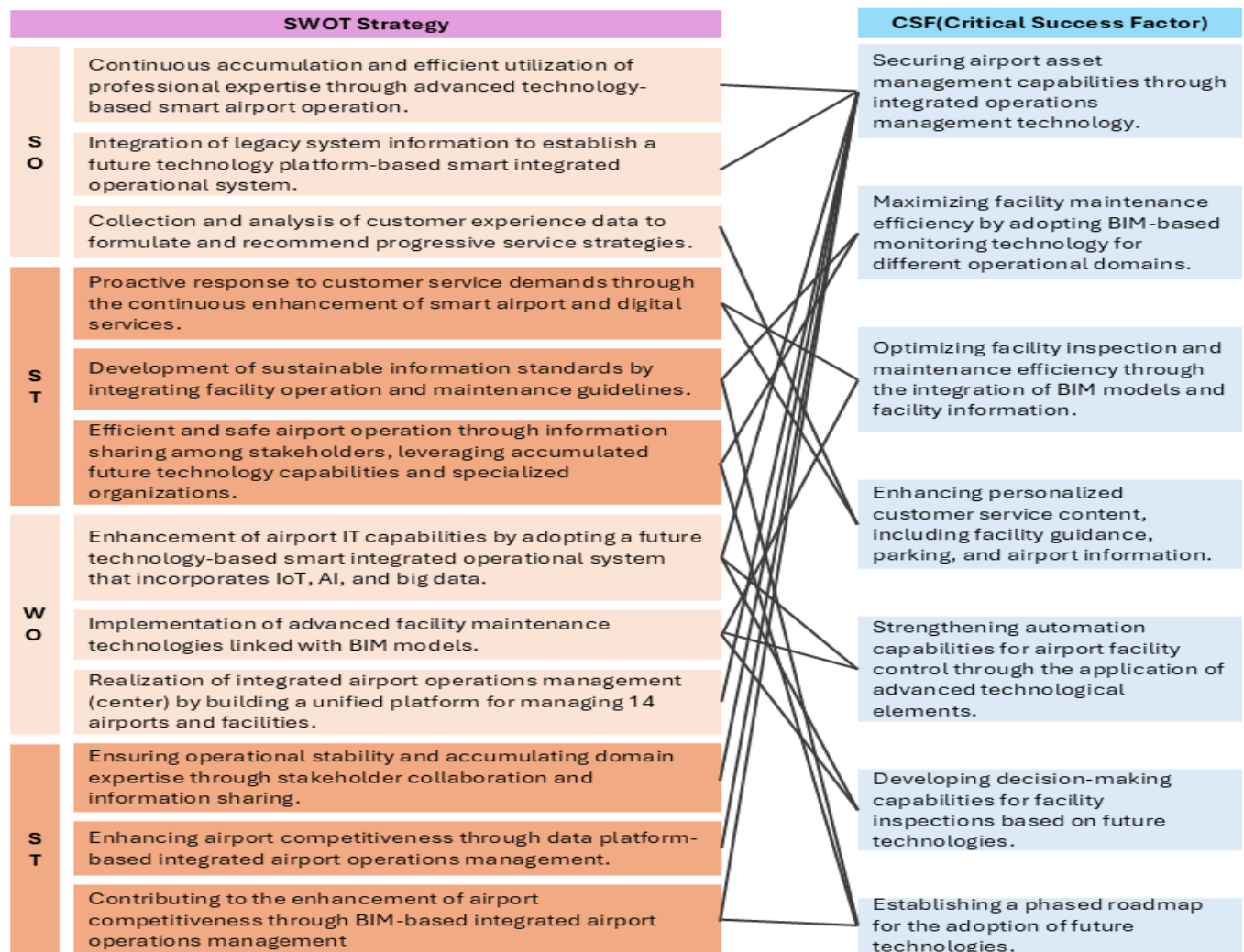


Figure 6. SWOT strategies and key success factors for applying smart technology to airport facility information.

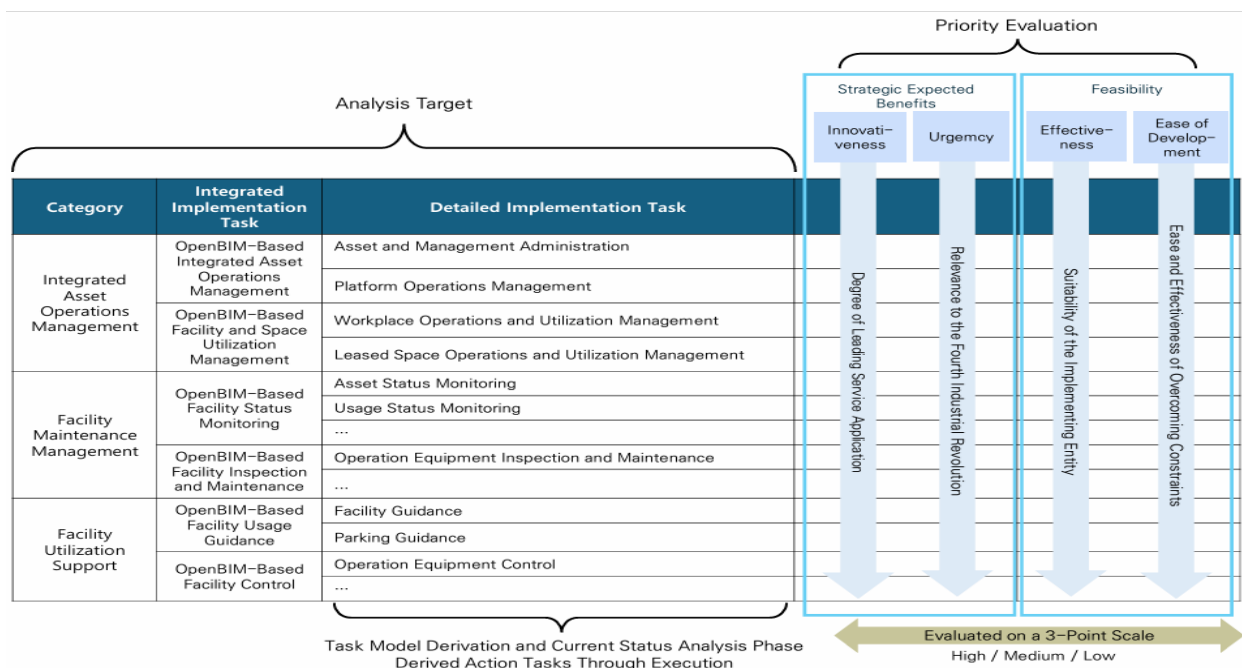
4.4. Core Implementation Tasks and Priorities for Airport Facility Information

The core implementation tasks listed above were applied to the three integrated implementation tasks of asset integration management, facility maintenance, and facility use support to derive detailed implementation tasks, as shown in Table 8. These detailed implementation tasks should be performed stepwise to complete each according to the integrated implementation tasks.

Table 8. Detailed implementation tasks for applying smart technology to airport facility information.

Integrated Implementation Tasks	Implementation Tasks	Detailed Implementation Tasks
Asset Integration Management	1 openBIM-based integrated asset operation management	1.1 Asset and business management 1.2 Platform operation management
	2 openBIM-based facility and space use management	2.1 Workspace operation and use management 2.2 Leased space operation and use management
Facility Maintenance	3 openBIM-based facility status monitoring	3.1 Asset status monitoring 3.2 Usage status monitoring 3.3 Operating equipment status monitoring 3.4 Disaster prevention and security status monitoring 3.5 Building facility status monitoring 3.6 Civil structure status monitoring
	4 openBIM-based facility control	4.1 Operating equipment control 4.2 Equipment control 4.3 Disaster prevention and security control
	5 openBIM-based facility inspection and maintenance	5.1 Operating equipment inspection and maintenance 5.2 Disaster prevention and security inspection and maintenance 5.3 Building facility inspection and maintenance 5.4 Civil structure inspection and maintenance
Facility Use Support	6 openBIM-based facility use guide	6.1 Facility guidance 6.2 Parking guidance
	7 openBIM-based event occurrence guide	7.1 Event occurrence detection guidance 7.2 Evacuation route guidance

To derive priorities for each integrated implementation task, this study introduced four criteria: innovativeness (to determine the degree of application of leading services), urgency (to respond to the Fourth Industrial Revolution), effectiveness (to determine whether the theme of a project is appropriate), and agility (to determine the ease and effectiveness of overcoming constraints). Priorities were derived using a three-point scale based on the expected strategic effects and feasibility for each of these four criteria, according to experts' opinions, as shown in Figure 7.

**Figure 7.** Evaluation items for deriving priorities by task.

As priorities by implementation task, “civil structure status monitoring” and “disaster prevention and security inspection and maintenance” exhibited the highest strategic expected effects, while “parking guidance” and “building facility inspection and maintenance” showed the highest feasibility.

As shown in Figure 8, when comprehensively judging the stepwise feasibility of each task, facility management for operating existing assets, such as workspaces and leased spaces, should come first. This goal can be achieved mainly by ensuring the monitoring of systems for the maintenance of fixed assets, such as operating equipment, building facilities, civil structures, and disaster prevention facilities.

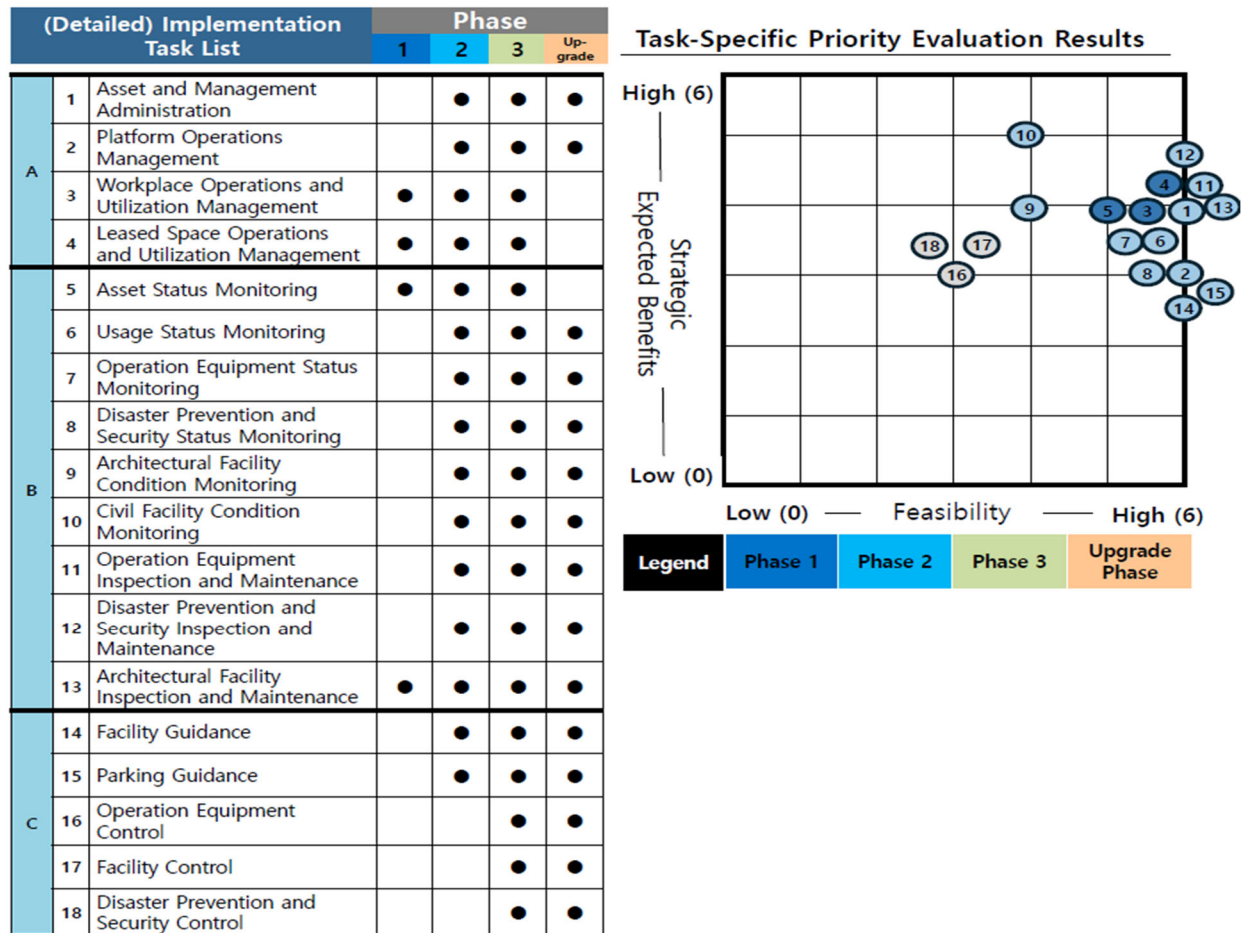


Figure 8. Results of deriving priorities by implementation task.

4.5. Model Concept Design and Data Acquisition According to Standard Component Technology

The implementation elements for deriving the scenario of the previously mentioned implementation tasks can be devised broadly by securing work standards, organizational capabilities, and a technology environment.

First, there is a need to develop various standards based on the standard framework to systematically support BIM-based information management and standardization, as well as standards for information required for the work, technology, and maintenance of the KAC. In this respect, the standard framework and information standards must meet the guidelines of the MOLIT and the requirements of ISO and must include the fields of on-site work, technology, and maintenance, as well as asset information requirements (AIR), exchange information requirements (EIR), and organizational information requirements (OIR). The guidelines include the general matters, basic matters, goals, and scope of BIM application, work execution procedures in the BIM application, and the creation standards for BIM data, as well as supporting two versions for management and supervision and service use. Furthermore, detailed appendices, such as library production standards, provide practical application methods.

The component technologies to be developed for applying smart technologies to airport facilities can be categorized as CDE management, digital twin visualization and information management, the facility information integration interface, facility status recognition and processing, the digital twin-based simulator, information security, and hardware. CDE management technology integrates and manages facility information based mainly on digital twin data and supports a collaborative environment, whereas digital twin visualization technology visualizes and manages facility information in AR/VR/MR environments. Facility information integration interface technology utilizes the Internet of Things (IoT) and sensors, mainly based on digital twins, to enable real-time data linkage, whereas facility status recognition and processing technology uses sensors and devices to identify the facility status in real time and to predict abnormal situations. Moreover, digital twin-based simulator technology supports various scenarios by using BIM models, and information security technology enables data protection and wireless-based information sharing. Finally, hardware technologies such as sensors, cameras, and drones serve a role in effectively implementing the digital transformation of airport operations.

The data to be secured to realize these technologies are divided into collection data, digital twin data, design documents, and basic data. Among these types, digital twin data are efficiently and systematically collected depending on the situation: if there is existing BIM data, if there are 2D CAD drawings, if there are only paper drawings, and if there is no paper drawing.

If existing BIM data are available, they are reviewed, and any differences from the standard framework creation criteria are corrected and updated by adding library attributes. Furthermore, if the level of development (LOD) is insufficient, the BIM model is corrected or updated [74].

If 2D CAD drawings are available, the entire layout and existing longitudinal and cross-sectional CAD drawings are linked to Revit to create working views [75].

Subsequently, the project coordinates are set, and BIM is performed for each process based on the CAD drawings. If necessary, the model is updated using 3D scan data. If only paper drawings are available, they are reviewed to identify the missing elements required for BIM design. Based on these results, the project coordinates and working sets are configured. Subsequently, BIM is performed with the same structure as the paper drawings, and the model is updated using 3D scan data [76].

If no paper drawing is available, the 3D scan area of the target facility is set, and then, 3D scanning is performed according to the survey plan. After registering the scan data and checking their quality, reverse engineering is performed based on the generated point cloud to create a drawing and generate BIM data [77].

Generally, when collecting data, minor discrepancies between the 3D scan data and the drawing are adjusted to the drawing. The collected data are utilized to develop a library according to the guidelines, if necessary, and are further loaded into the general matters file. After applying the BIM, an initial review is conducted in the 3D view, a table is created for each library, and the final model is exported to the IFC through a second review [77].

5. Detailed Design of ISP Model for Applying Smart Technology to Airport Facility Information (To-Be Model)

5.1. Technology Environment Design

The design of the technology environment for the integrated management of airport facility information considers three categories (asset integration management, facility maintenance, and facility use support) derived from the integrated implementation tasks. Asset integration management is responsible for integrated operation, space operation, and use management, whereas facility maintenance involves facility status monitoring,

facility control, facility inspection, and maintenance. Facility use support provides user convenience through facility use guidance and event occurrence guidance.

In the current asset integration management model, because of the lack of a standardized information management system, there is no linkage among the internal systems, such as ERP, groupware, and PMIS, and the management efficiency is low because of the individual management of information at facility sites. In particular, the absence of 2D drawings and location information prevents information retrieval and access by facility and space, as well as the limited integrated use of asset, leasing, and maintenance information due to decentralized data. In contrast, the future model provides an efficient management system that can perform various tasks in an integrated manner, such as asset management, lease management, facility management, and operation management, based on BIM models and digital twin technology. This system can digitize facility and space information, track worker locations, manage spaces and areas in real time, and further support sophisticated management and decision-making through the creation of 2D drawings, the identification of space occupancy and vacancy status, the preliminary review of space divisions, and the review of related laws and regulations.

In the current facility maintenance model, each department individually manages data related to facilities and inspections, such as ERP, CCTV, integrated operation information systems, heating and cooling equipment, and air-handling units. Each department relies on on-site operations and manually written documents, with consequent limitations in terms of data integration and real-time monitoring and control. In contrast, the future facility maintenance model to be constructed according to the ISP will integrate and manage all facilities and facility information based on digital twins (BIM modules) and IoT sensors to monitor the asset status, facility status, inspection, and maintenance data in real time and support central control and data-based decision-making. This system can perform integrated control of facilities, precise inspections using MR and AR technologies, and automatic data updates and analysis, realizing smart and integrated management by maximizing the efficiency, precision, and predictability of facility management.

The current facility use support model is incapable of providing customized information and utilizing real-time data, owing to its use of 2D web-based guide maps and CCTVs. By contrast, a BIM-based facility uses a support model that tracks customer movements in real time based on a precise 3D model using digital twins, big data, and AI analysis to guide customized movements and escape routes. Furthermore, this system can employ integrated monitoring and on-site processing based on digital twins through technology that automatically recognizes situations by analyzing the data collected through real-time monitoring via CCTVs, detachable cameras, and IoT using big data and AI.

In order to efficiently implement this integrated management system for airport facility information, the existing KAC technology environment and overall information flow must be redesigned. For example, when establishing a space use plan, the work process must be reorganized so that legal standards can be reviewed in advance based on the BIM model according to the change in the zoning. In addition, for asset and land management, it is recommended to reestablish a data flow structure that integrates the existing individual cadastral systems and links them in real time with KAC cadastral information.

The technological elements required to achieve these goals for the integrated management of airport facility information are listed in Table 9.

Table 9. Essential technical elements for realizing the goals of integrated management of airport facility information.

Large Category	Middle Category
HW	Constructing system support hardware
CDE management technology	OpenBIM-based digital twin data management module, web-supported OpenBIM viewer and information content module, facility change response/management technology, BIM model update and history management technology, BIM model—electrical system management technology, BIM model category/condition quality assurance technology, design document/document management system, big data management and analysis technology, AI-based data analysis technology, external system linkage
Integrated asset operation management	Integrated monitoring technology, integrated operation analysis technology, BIM library distribution and utilization system, digital twin-based path search/visualization, digital twin-based facility/equipment control, on-site work procedure support technology
Mobile-based maintenance management	On-site work procedure support technology, mobile AR-based facility inspection, and maintenance
Facility status information collection technology	Simple fixed-type shape collection device, building facility status information collection technology, facility user tracking, security issue occurrence factor tracking, automatic tracking of physical changes in space, IoT sensor-based information collection (temperature/humidity/others), unmanned aerial vehicle image collection technology (mobile robot/drone), asset/material status identification technology, device/equipment operation information collection technology
Digital twin-based simulator	Disaster evacuation route simulator technology, facility heating and cooling simulator technology, anti-terrorism simulation technology, facility space movement path simulator technology, electrical/equipment simulator (inspection/diagnosis) technology, facility operation optimization simulator
Customer service	Service support based on digital twin details
Information security technology	Building wireless environment for mobile equipment support, information security management technology

5.2. Work Standards Design

To apply smart technology to maintenance work, it is necessary to develop BIM-based standards and criteria that can be integrated with the existing KAC standards and criteria, as shown in Table 10. To comprehensively apply airport facility BIM technology, there is a need to develop a standard information framework for the integrated management of airport facilities and further derive a list of new developments by analyzing the existing standards and criteria of the KAC. Here, the BIM information framework is a comprehensive framework for the lifecycle of an entire facility, ranging from design to implementation to maintenance, as well as a collection of interrelated standards for sharing and exchanging information in the BIM execution environment [78].

This framework is a comprehensive collection of standards in which individual standards are interconnected. The key to success is establishing relationships among individual standards to achieve information integration. The development of the Standard Information Framework has been expanded by adding the list necessary for application to airport facilities, further requiring connectivity by linking with the BIM guidelines of the MOLIT and introducing existing national and public standards, such as the MOLIT construction information classification system and the Public Procurement Service's standard construction code.

For the redesign of work standards, it is recommended that, in the short term, KAC prioritize the development of three foundational documents based on the KAC BIM Information Framework: the BIM Guidelines for KAC Clients, the BIM Guidelines for Service Providers, and the KAC BIM Library Development Standards. The development of these guidelines should be preceded by a systematic analysis of existing business, technical, and maintenance requirements. Furthermore, the process should incorporate the alignment and establishment of ISO 19650-compliant information requirement structures, namely asset information requirements (AIR), exchange information requirements (EIR), organizational information requirements (OIR), and project information requirements (PIR), tailored to the unique needs of the Korea Airports Corporation (KAC). Given the vast and complex nature of airport facilities, minimizing data formats and managing information based on linked property information is essential to building a sustainable, BIM-based maintenance

system. This approach is expected to significantly enhance the practical applicability and data usability for facility managers in the future.

In addition, it is necessary to derive a list of items for either references or citations through comparisons with international and national/public standards. To develop the standard information framework, a list of standard sets and a schema for each list should first be prepared, and the classification system and other components should be created in an expandable format.

Moreover, in addition to securing international connectivity by introducing international standards, such as ISO 19650, PAS 1192 [79,80], and COBie, the domestic uniformity of related standards must be secured, as well as the possibility of exporting to other countries to develop the BIM model and integrated management system of the KAC.

Table 10. Design of module-based development plan for criteria and standards of the KAC.

Development List		Development Plan	
Category	Item		
Standard document	Information requirement level (BIM information level [BIL])	-	Define the optimal expression level for the KAC and airport facility management beyond general LOD
		-	Incorporate minimum 3D shape + most attributes into DB
		-	Define shape mainly based on BIL30 and continuously update through sample data testing
		-	Define the design and maintenance information requirement level
	Quality criteria (design quality criteria and legal quality criteria)	-	Link SW development with quality review
Information standard		-	Check existing design standards and laws and regulations on airport facilities
		-	Select priority development scope because development cannot meet all design standards and legal requirements
		-	Create quality standards within the scope
		-	Provide criteria for developing quality review SW in linkage
	BIM guidelines for clients	-	Derive the elements of guidelines for application of MOLIT standards and ISO 19650 procedures (including annexes and related template lists)
Information classification system		-	Refer to leading airport guidelines and national standards for development
		-	Develop annexes and related templates
	BIM guidelines for service providers	-	Derive the elements of guidelines for application of MOLIT standards and ISO 19650 procedures (including annexes and related template lists)
		-	Refer to leading airport guidelines and national standards for development
		-	Develop annexes and related templates
Information standard	Production criteria for BIM library	-	Derive the elements for library production criteria
		-	Develop standard production criteria: Set the production criteria scope (setting criteria such as whether to describe the production criteria for each object)
	Classification system and list for BIM library	-	Follow the KBIMS object classification and library classification, and in handling objects for airport facilities not defined in KBIMS:
		-	Add classification and update the list
		-	Select priority for library creation after defining the entire classification and list
Information classification system	Attribute Specifications for BIM library	-	Define common attributes and attributes by usage
		-	Define attributes mainly for maintenance (manage them through detailed groups due to various maintenance purposes)
		-	Define attributes to ensure the linkage with implementation technology based on basic codes such as Public Procurement Service's standard construction code and space classification code
		-	Utilize attribute analysis data for maintenance: ERP system analysis, LCC attributes, and COBie
	Spatial classification system (function)	-	Update the existing space classification system (function) after mapping the airport facility space with improvement
Information classification system		-	Utilize analysis data for airport facility space classification: KAC ERP asset list and airport facility drawings
	Facility classification system	-	Map the existing WBS and facility classification in the construction information classification system
		-	Derive the optimal facility classification system

5.3. Organizational Environment Design

The operation of a smart information management system for airport facility information requires a dedicated organization under the smart information technology integrated management team, as well as organizational functions in five areas: integrated manage-

ment operation, system management, information management, service management, and standardization management, as shown in Table 11.

Table 11. Roles in organizational environment design by area.

Areas of Organizational Functions	Roles and Major Details
Integrated management and operation	Future planning, external cooperation, securing standards, organizational capacity management
System management	System development, introduction of AI and XR
Information management	BIM model, big data, linkage of related systems
Service management	Operation management and support
Standardization management	Standards and guidelines, ISO 19650

The integrated management and operation organization is responsible for tasks such as future planning, external cooperation, securing standards, and managing organizational capabilities. The system management organization oversees system development and the introduction of AI and XR, whereas the information management organization serves its role in BIM models, big data, and related system linkages. The service management organization is responsible for operational management and support, and the standards and management organization is in charge of the standards and guidelines, as well as ISO certification management.

In the organizational environment design stage, the existing personnel structure also requires redesign of the entire job system and operating procedures beyond simple technical education. For example, the existing department-centered information management method should be converted to a BIM model-based integrated data management system, and the role definition for each work stage, information flow definition, and inspection process should be newly established. To support this, a job standard system reflecting the technical level of personnel should be introduced, and participation from level 5 (practical level) to level 2 (management level) is recommended, depending on experience in the BIM field. To ensure the effective implementation of this redesigned organizational environment, a comprehensive BIM training curriculum must also be established. The BIM training curriculum includes the concept of BIM, training to acquire the role of BIM CM Coordinator, basic modeling (Revit), and quality inspection practices of BIM deliverables for planning and implementation design.

6. Discussion: Detailed Information on Goals and Steps

This study has analyzed airport facility information management systems in South Korea and derived implementation tasks. Based on the results, a stepwise implementation strategy is proposed to realize the integrated management of airport facilities and projects based on OpenBIM, along with the establishment of a hyper-connected intelligent information utilization system, as shown in Figure 9.

The ISP for applying smart technology to airport facility information in South Korea requires the establishment of a two-stage plan, followed by an advancement stage. The stepwise integrated model promotion strategy can be divided into a stage-2 strategy (development, introduction, and pilot operation), a stage-3 strategy (expansive integration and full application), and an advancement stage strategy (advancement and leading future airports). Stage 2 is intended to help with becoming a domestic leader through development, introduction, and pilot operation, setting the major tasks of securing a facility management base and building a BIM model for a pilot airport. In stage 3, the pilot project progresses to the international level through expanded integration and full application, further completing facility–project integrated management and building a BIM model

for national airports. Finally, the advancement stage aims for an international leadership level, thus creating a system that spearheads the global competitiveness of future airports, mainly through hyper-connected intelligent operation management and the construction and integrated management of a new airport BIM model.

Category	Phase 2	Phase 3	Upgrad Phase
Goal	Establishment of a World-Class OpenBIM-Based Airport Facility and Business Integrated Management System with a Hyperconnected Intelligent Information Utilization Framework (*)		
Implementation Objective	Development Introduction and Pilot Operation	Extended Integration and Full Application	Advancement and Leadership in Future Airports
Level Phase	Domestic Leading Level(**)	International Equivalent Level (***)	International Leading Level
Operation Phase	Testing and Pilot Operation	Fully Applied	Establishment
System Development Phase	Establishment of Facility Management Infrastructure	Complete Facility-Business Integrated Management	Establishment of a Hyperconnected Intelligent Operations Management System
Model Development Phase	Development of a Pilot Airport BIM Model	Building a BIM Model for National Airports	Establishment of New Airport BIM Model and Integrated BIM Model Management

(*) Construction of an Advanced Future-Oriented Airport Based on AI and Big Data in Response to the Fourth Industrial Revolution

(**) (***) Includes Research and Development of Internationally Leading Experimental Core and Component Technologies

Figure 9. Stepwise integrated model promotion strategy and roadmap.

This stepwise implementation strategy enhances the efficiency and innovation of BIM-based airport facilities and integrated project management. It is based on open BIM and was designed with reference to the Integrated Information System Plan (ISP) for airport facility management of Korea Airports Corporation in South Korea. The specific roadmap for realizing this strategy is given in Figure 10.

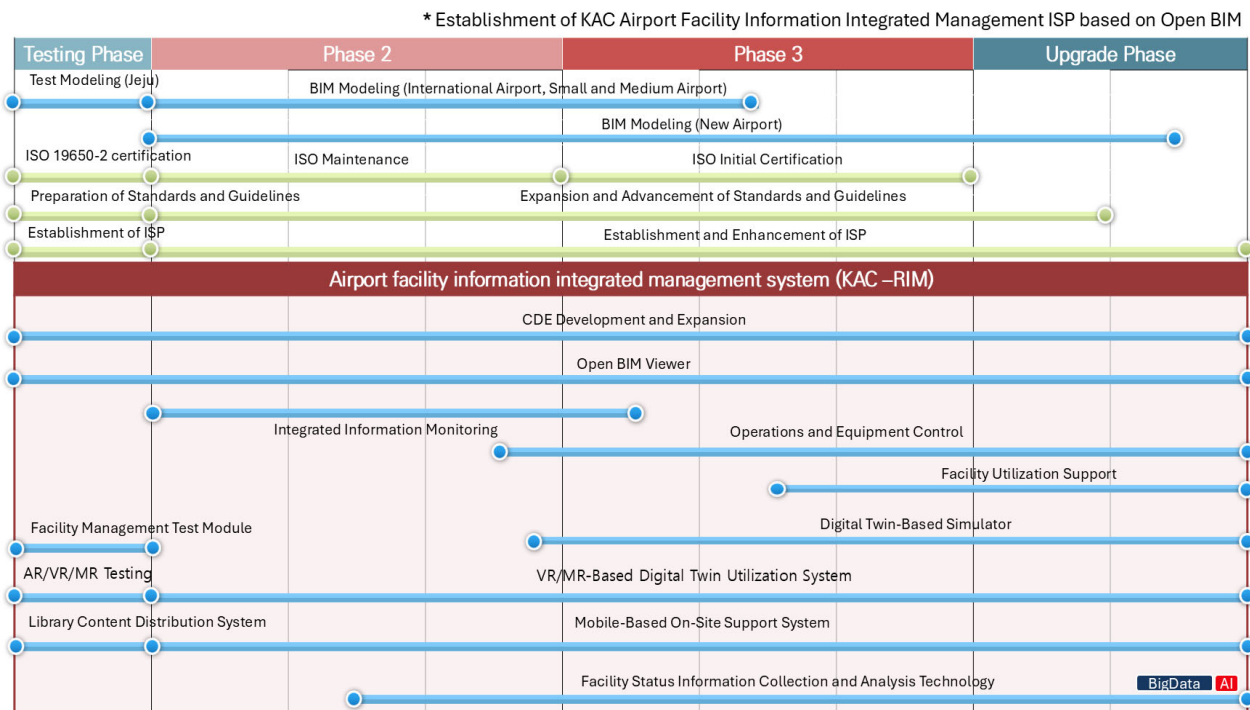


Figure 10. Stepwise criteria and implementation details for facility information and management system.

In stage 2, a data-based management system will be formed through the establishment of a CDE and the openBIM viewer. BIM is introduced for international, small and medium-sized, and new airports, laying the foundation for the application of information integration monitoring, VR/MR-based digital twin utilization systems, and mobile-based on-site support systems. Furthermore, pilot operation is enhanced through ISO maintenance, standard/guideline expansion, and ISP establishment.

In stage 3, the integrated management system will be advanced through the operation/equipment control system, facility use support, and construction of a digital twin-based simulator. The application of BIM will be expanded to new airports, and expanded integration and full application will proceed through the new ISO certification, the expansion of standards/guidelines, and the upgrading of ISP.

In the advancement stage, big data and AI technologies will be applied to increase the applicability of VR/MR-based digital twin utilization systems, mobile-based on-site support systems, and facility status information collection and analysis technologies. This roadmap presents a direction for building the latest future-oriented airport based on big data at an internationally leading level.

The implementation time of the entire project was planned in stages, reflecting the development trends of airport infrastructure in Korea and government policies. Currently, eight new airports are under construction in Korea, and the government plans to support research and development for new airport life cycle management. BIM modeling is being conducted at major existing airports, including Gimpo Airport and Gimhae Airport, according to the ISP promotion plan. The Ministry of Land, Infrastructure, and Transport aims to achieve 130 million international air traffic events by 2030 and is actively responding to changes in future transportation demand and technological advancements through the ‘Korean Urban Air Mobility (K-UAM) Roadmap’. In line with these government policies and infrastructure development plans, this project planned a second (3 years) and third (3 years) promotion schedule to flexibly respond to future technologies and changes in passengers and planned system optimization in the subsequent advanced stage.

7. Conclusions

7.1. Summary of Key Findings

This study analyzed the environmental characteristics of airport facility information management based on the ISP establishment procedure and created an information-oriented vision and goals by linking facility information status. Based on this, a stepwise implementation strategy, information system construction principles, technical requirements, and an information management goal design strategy are proposed. Through this approach, a practical direction contributing to the efficiency and systematic development of airport facility information management is presented.

In particular, this study highlights the increasing complexity of airport infrastructure caused by growing air traffic and emerging aviation technologies and emphasizes the need for a smart technology-based information strategy plan (ISP). The adoption of electric and hydrogen-powered aircraft, urban air mobility (UAM), and drone integration is expected to significantly transform airport systems [81,82]. In response, the ICAO promotes its global air navigation plan (GANP) to optimize airspace use and reduce delays, urging regional and national-level implementation. The proposed ISP—leveraging OpenBIM, digital twin, and common data environment (CDE)—offers a viable strategy to manage complexity and support sustainable, future-ready airport development.

The analysis of the classification of airport facilities and personnel status in South Korea revealed the need for systematic classification and linkage for the integrated management and operation of facility information. The investigation into the classification system and

standards for airport work affirmed the inefficiency of the existing system, as well as the lack of a classification system and guidelines in the maintenance stage.

In particular, the decentralized operation of drawing and asset management has resulted in insufficient management and utilization of the latest data. The examination of leading cases affirmed the possibility of the digital transformation of airport facility information management and the introduction of cutting-edge technologies to respond to the increasing demand for life-cycle support of various types of facilities and on-site safety. Then, based on the analysis of the airport work system, various problems and improvements in facility information management and airport information management cases, a SWOT analysis was conducted to derive the integrated implementation tasks (integrated asset operation management, facility maintenance, and facility use support) and prepare evaluation items to derive priorities for each task. Based on this result, a detailed design targeting the integrated management model for airport facility information was devised to derive the elements of the stepwise integrated model promotion strategy regarding the technology environment, work standards, and organizational environment.

For the technology environment, 37 component technologies, corresponding to eight core technologies required for asset integration management, facility maintenance, and facility use support, were derived. For work standards, a development plan was designed according to standard documents, information standards, and information classification systems by developing a standard information framework applicable to the KAC. For the organizational environment, dedicated organizational roles in five areas—integrated management operation, system management, information management, service management, and standardization management—were derived for the operation of the BIM-based integrated management system.

Based on the analysis results, this study designed a stepwise promotion strategy and roadmap and established an implementation plan using stage 2 (development introduction and pilot operation), stage 3 (expanded integration and full application), and the advancement stage (leading future airports). This scheme presents a practical and specific implementation plan for domestic airport facilities to become smart and competitive at the international level. Stage 2 focuses on establishing a data-based management system through the establishment of a CDE and the openBIM viewer and on increasing the completeness of the pilot operation by introducing information integration monitoring, VR/MR-based digital twin utilization, and a mobile-based on-site support system. Stage 3 aims to build a digital twin-based simulator and an operation/equipment control system to advance the integrated management system and expand the application of BIM to new airports (achieving full application through international standard certification and standard expansion). The advancement stage was devised to establish an operation management system for the latest future-oriented airport by strengthening digital twin and analysis technology using big data and AI technologies.

The smart technology application of airport facility information by following these procedures can be expected to have economic effects. The ratio of operation and management costs in the facility life cycle (planning–design–construction–maintenance–demolition) is 80% of the total cost, so it is possible to reduce the facility life cycle cost through efficient operation and management. In particular, the integration of BIM and maintenance systems was reported to have a return on investment (ROI) of approximately 64%, and the investment recovery period is only approximately 1.56 years [38].

This study is a basic study on the information strategy plan (ISP) for introducing smart technology to airport facility management. It has academic significance through the process of deriving strategies and selecting priorities through interviews with stakeholders, the analysis of the status of work standards and guidelines, and the SWOT analysis. In

particular, the proposed specific implementation strategy and priority matrix provide policy value as basic data for establishing ISP establishment guidelines and evaluation criteria necessary for establishing airport policies. In addition, it presents a BIM-based management system that can be directly referenced by domestic and foreign airports that are promoting the construction of smart airports, and it has practical significance in that it presents a practical utilization plan that can be expanded and applied to the construction of ISPs for other SOC infrastructures such as ports and railways in the future. Ultimately, this study analyzes the limitations of airport facility information management and proposes a phased implementation strategy to support the digital transformation of airport operations using BIM and digital twin technologies.

7.2. Future Directions

In future studies, in order to analyze the feasibility and expected effects of the information strategy plan (ISP), in-depth research is needed according to specific implementation stages, such as data structure design, security system structure design, total construction cost calculation, and effect analysis. Based on the strategies derived from this study, future research plans to contribute substantially to the smartening of airports and the improvement of operational efficiency are as follows. First, it is necessary to secure technical and economic feasibility for actual system construction based on a high-level strategic plan by conducting business process reengineering (BPR) in parallel to fundamentally reestablish the existing work system and information flow. Second, a testbed airport is selected to apply the proposed ISP model in practice, and the effectiveness and feasibility of strategy implementation are evaluated through quantitative verification based on key performance indicators (KPIs). Third, the economic feasibility and expected benefits of strategy introduction are systematically analyzed through a cost–benefit analysis (CBA) and a cost–effectiveness analysis (CEA), and the basis data necessary for policy decision-making are provided.

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