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An Empirical Study on Information Integration System Maturity Model for an Airport

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Abstract

All organizations, especially airports, are doing business through Information Integration with various systems. In the era of big data, airports need to process large amount of data according to the requirements to create new value by means of Information Integration. In addition, Airports should provide reliable, uninterrupted service via Information Integration. Under these circumstances, systems surrounding the Information Integration System at airports are growing, and the inherent risks are increasing as the systems become more complex. However, there is no evaluation system for the integrated environment. This paper presents a maturity model of airport's Information Integration System that integrates nine processes systemized by Plan-Do-See and safety culture. This is performed by Case Study for Korean airport. Focus Group Interview is held for Information Integration System's managers. For 22 activities corresponding to Do and 3 objectives of safety culture, the weighted value according to the importance of organization is established, and their maturity levels are evaluated. Finally, the maturity level of Information Integration System is determined using final scores derived from weighted arithmetic average value. This allows person in charge to visually check the information of the Information Integration System and to easily notice the level of the organization. Furthermore, it is expected that information acquired through continuous improvement based on the maturity model will eventually contribute in quality enhancement of the system.

Keywords: Interoperability, Information Integration System, CMMI, Maturity Level, Process Measurement, Safety Culture

I. INTRODUCTION

The importance of Information Integration is growing in the era of big data, which the aviation information has to be combined and analyzed [1]. All organizations at airports are attempting to create new value in order to achieve their goals and to enhance passengers' travel experience by taking advantage of Information Integration [2]. For example, in March 2017, Malvern Airport built a situational awareness platform that enables real-time data sharing by integrating distributed systems [3]. In addition, in September 2017, Incheon International Airport constructed Information Integration System for both the existing first terminal and the new second terminal [4]. Information Integration System (**IIS**) is a type of Information System that supports information sharing, system connection, and system integration based on interoperability [5]. Airport manager needs to find ways to streamline information distribution and resource management through **IIS** [6].

As the number of systems surrounding **IIS** rise and become more complex, inherent risks are most likely to increase as well. Passengers' service satisfaction may drop if services are not provided normally due to IT disruptions. One example includes the case of Bristol Airport, which the flight information has not been appeared, in September 2018 [7]. The air traffic sector has a low probability of accident, but the prevention has to be extremely crucial as minor mistakes or technical errors may cause fatal consequences [8].

Organizations such as FAA, IACO, EUROCONTROL, etc., have been providing information on aviation safety, and related research has been conducted. However, there is no systematic approach for assessing and measuring airport's **IIS**. This paper hereby proposes airport's Information Integration System Maturity Model ($\mathbf{IIS^{MM}}$) that unites Ha and Lee's Information Integration System Process ($\mathbf{IIS^{Process}}$) with EUROCONTROL's safety culture. We assess the maturity level of the **IIS** in Korean I Airport. Finally, the score is derived to identify the current level of **IIS**. The purpose of this paper is to verify the $\mathbf{IIS^{MM}}$ based on airport by examining $\mathbf{IIS^{Process}}$ with safety culture, and to apply empirical studies.

II. LITERATURE REVIEW

2.1 Information Integration System Maturity Model

Interoperability is the characteristic that allows communication among technically same or different systems and to perform information exchange accurately [9]. Interoperability is a technical concept for information sharing, system connection, and system integration.

Table 1. The definition of Information Integration System Process

Category	Definition
II Value Mgt	The process of linking rules, procedures, and verification of data values to improve the information quality for Information Integration System
II Timeliness Mgt	The process in which the Information Integration System provides information within a mutually agreed time
II Urgency Mgt	The process for response when a trouble or emergency occurs in the Information Integration System
II Service Change Mgt	The process of changing adding/deleting/modifying the information integration service and managing the alteration of Information Integration System's SW/HW
II Data Security Mgt	The process of protecting the information across Information Integration System's all sector
II Promoting Structure	The process for policy and organizational maintenance to perform information integration
II Mutual Cooperation	The process for cooperative system between agencies
II Process Performance Mgt	The process that measures the performance of selected Information Integration System Process and contributes to the achievement of organizational objectives
II Problem Mgt	The process of analyzing and improving the problem of Information Integration System's failure

*II: Information Integration
**Mgt: Management
***Reconstructed based on the Ha and Lee's paper

Table 2. The definition of Information Integration System Maturity Level and its included elements

Maturity Level	Definition	Included elements
Initial	The step without structured process for Information Integration System	N/A
Managed	The management step for basic process	II Urgency Mgt, II Service Change Mgt, II Data Security Mgt
Defined	The step in which Information Integration System Process are defined and standardized	II Value Mgt, II Promoting Structure, II Mutual Cooperation
Quantitatively Managed	The step utilizing quality analysis of Information Integration System	II Problem Mgt, II Timeliness Mgt
Optimizing	The step to continue improvement	II Process Performance Mgt

*II: Information Integration
**Mgt: Management
***Reconstructed based on the Ha and Lee's paper

Past studies on evaluation and measurement of Interoperability and Information Integration are as follows. The Australian Government Information Management Department proposed a business process interoperability framework with maturity levels classified as Siloed Ad hoc, Tactical Collaboration, Re-use Shared Service, and Service Oriented [10]. Gottschalk presented an e-government interoperability maturity model composed of computer, process, knowledge, value, and goal [11]. Staden and Mbale presented a maturity model based on the data, software, communication, and physical technology elements of interoperability and it has been examined for Namibia government agencies [12]. Kang et al. suggested a maturity model for sharing information from a business perspective and has evaluated it with the stakeholders of the capital project [13]. However, the Australian Government's Business Process Interoperability Framework and Gottschalk's model are conceptually based, and there is no information on evaluating maturity models. In addition, Staden and Kang's models have obvious limits in implementation and evaluation in airport's **IIS**.

Ha and Lee's $\mathbf{IIS^{MM}}$ is a model that applies $\mathbf{IIS^{Process}}$ derived from the in-service manager to Capability Maturity Model Integration (**CMMI**) [5]. Table 1 shows the definition of $\mathbf{IIS^{Process}}$. They are derived from the preceding studies on four components of Information System - IT, data, people, process. Information Integration Value Management and Information Integration Timeliness Management are data driven. Information Integration Urgency Management, Information Integration Service Change Management, and Information Integration Data Security Management are IT based. Information Integration Promotion Structure and Information Integration Mutual Cooperation are people-centered. And Information Integration Process Performance Management and Information Integration Problem Management belong to the process.

Each process consists of business cycles categorized according to Plan-Do-See, and it does not come to an end, but it continually improves. Plan is the planning stage of process. Do consists of a total of 22 detailed activities for each $\mathbf{IIS^{Process}}$. And See is the step of reviewing and reflecting results into the plan in the future.

Table 2 defines the **IIS**'s maturity level using **CMMI**, and the $\mathbf{IIS^{Process}}$ are classified for each corresponding level. In this paper, nine processes are used as included elements for maturity levels.

2.2 Safety Culture

An organization's Information System is organized around its context, such as company strategy, its culture, and IT infrastructure [14]. In order to successfully operate an Information System, organizations need to understand the organization culture [14].

Following the crash of the Continental Express aircraft in 1991, suggestion has risen that the safety culture was the cause of the accident [15]. Since then, in the aviation field, various researches have been conducted on safety culture, a subdivision of organizational culture. Safety culture refers to attitudes, beliefs, perceptions and values shared by workers about safety.

Yoon et al. studied on safety culture and its relationship with service quality and service effectiveness for airline employees at Incheon International Airport, and found that among the constituents of safety culture, the fair culture had a statistically positive role [16]. Kim examined the fair safety culture in the field of aviation maintenance [17]. In order to build a fair culture, Kim suggests creating a non-discriminatory work environment, facilitating communication, and spreading awareness that neglecting procedure is illegal. Song et al. surveyed the safety culture of airport airside workers [18]. Safety culture is difficult to establish via short-term education or training because of the individual's cultural characteristics. Therefore, it is suggested that the safety culture should be improved by acknowledging safety motives and safety knowledge, etc. Oh and Jang analyzed the factors that influence safety culture in the aviation sector [19]. Assessment indicators of communication, employee engagement, education and training, the reward system, management's interests, and feedback system were derived to measure safety culture. Park suggested a safety maturity evaluation system, an integration of evaluation models of FAA-iCMM and EUROCONTROL, of which the system is classified into maintenance and safety management [20].

EUROCONTROL conducted a survey of regulatory agencies and navigation service providers in European countries to ensure that the requirements of air traffic management (**ATM**) were fulfilled after air accidents in Linate 2001 and in Überlingen 2002 [21]. Since then, they have developed and measured an evaluation model using the **ATM** safety framework maturity survey. The study area follows the Safety Management System (**SMS**) developed in cooperation with EUROCONTROL and Civil Air Navigation Services Organization (**CANSO**). **SMS** consists of safety culture that measures the extent to which a positive and proactive atmosphere is established for cultural development, and the sub-components (safety policy, safety achievement, safety assurance, safety promotion). Safety culture, also called the system enabler, has the greatest impact on the components, thereby requires all organization members' commitment on safety.

The maturity level of **SMS** was developed by adopting **CMMI**. It is consisted of Initiating-Planning-Implementating-Managing & Measuring-Continuous Improvement. First, the organization does not measure and monitor safety performance in the initiating phase. Second, organization plans on obtaining information on safety performance in the planning phase. Third, safety reports are acquired under controlled process and responds to safety issues identified according to individual incident investigations in the implementating phase. Forth, safety performance is measured in the managing & measuring phase. Fifth, organization can demonstrate improved safety performance and manage key safety risks in the continuous improvement phase.

In this paper, the safety culture of **ATM** safety framework survey is applied to organizational culture of airport's **IIS**.

III. RESEARCH APPROACH TO EVALUATE MODEL BASED ON AIRPORT

3.1 Airport's Information Integration System

Developing the concepts of the previous studies in Chapter 2, this study proposes a model based on the airport. Figure 1 describes **IIS** within the organizational culture of the airport.

Fig. 1. Airport's Information System in safety culture

IIS, which is one of the airport's Information System, consists of nine $\mathbf{IIS^{Process}}$ and safety culture surrounds the **IIS**.

Figure 2 shows the scope of airport's **IIS** composed of consumers and providers involved internally and externally of the organization.

System integration is essential as an airport may cover more than 1500 systems depending on the degree of automation [22]. Since airport acts as physical interface of the passengers, information is shared among various internal and external systems. The external systems are composed of various air service and government agencies such as airlines, customs

office, immigration office, etc. Internal systems like Baggage Handling System (**BHS**), Flight Information Display System (**FIDS**) are responsible for functional aspect of the airport, and Incheon International Airport's Asset Management System can be an example [23]. Henceforth, number of systems connected to airports is likely to increase due to new requirements that may occur from technological development, for instance, big data, Internet of things (**IoT**), etc. [24]. As mentioned above, scope of this paper covers nine processes of **IIS** and safety culture, which is the sub-factor of organizational culture at airport.

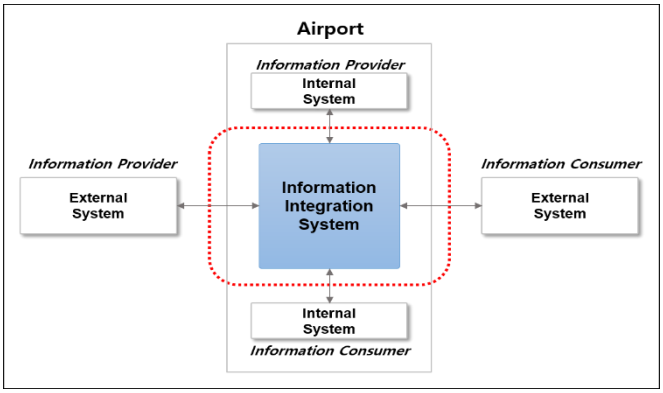


Fig. 2. Scope of Airport's Information Integration System

3.2 Maturity Level Evaluation Approach

Assessment of maturity level of airport's **IIS** follows the procedure as shown in Figure 3.

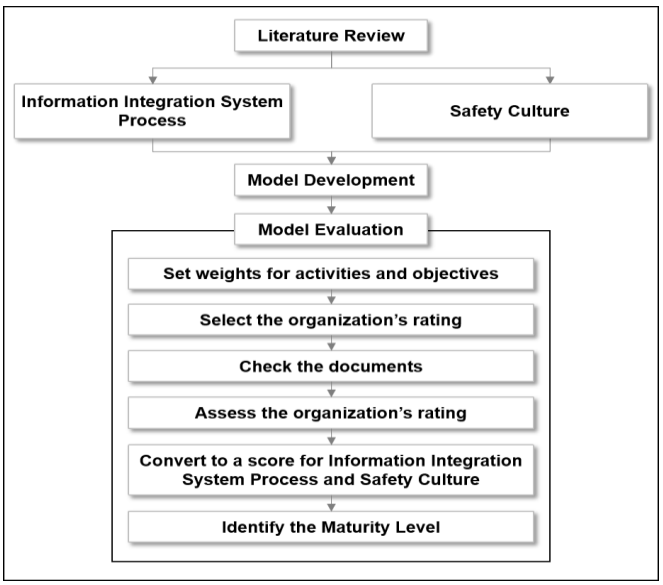


Fig. 3. Evaluation Approach

A model consisting of $\mathbf{IIS^{Process}}$ and safety culture is conceptualized through review of the previous study in advance to the development.

Development of model includes classification and allocation of activities into appropriate phases. Activities of $\mathbf{IIS^{Process}}$ are verified based on the characteristics of each phase, and the maturity level is evaluated. The characteristics of each phase are as follows.

First, in the **initial phase**, there is no strategy, and it is performed temporarily when necessary.

Second, in the **managed phase**, each activity of the process is documented. Therefore, the expected same result is achieved by performing the process described in the documentation. However, since there is no measurement, it is impossible to know whether the activity is defective or not.

Third, in the **defined phase**, activities are measured and managed by the person in charge. Staff's role and responsibility for each activity in the process are defined. Staff can monitor and determine whether the activity was performed correctly.

Forth, in the **quantitatively managed phase**, time and quality measurement of the detailed stages of the activity are made and analyzed. This allows organization to find and correct the cause of the anomaly such as bottleneck effect.

Finally, in the **optimizing phase**, activities are quantified, and continuous improvement is performed based on the quantified result. Furthermore, the knowledge gained in this phase is shared throughout the organization.

The safety culture consists of three objectives, and to evaluate the safety culture, we used identical criteria provided by the **ATM** Safety framework maturity survey.

Evaluation of the developed model for airport has been performed as below.

First, we set the weight for each activity of $\mathbf{IIS^{Process}}$ and objectives of safety culture. There are 3 levels of weight - high, medium, low - determined according to judgment that organizations deem it important. Maturity level of each activity suitable for the organization is then selected. Hereupon the output is reviewed, and evaluation is done as to whether it is appropriate. After assessing the maturity level of each activity and objective, we used the weighted arithmetic average as the following equation to derive the scores for each $\mathbf{IIS^{Process}}$ and safety culture.

$$\text{IIS}^{\text{Process}}\ \text{Score} = \frac{A_1*W_1+A_2*W_2+\cdots+A_n*W_n}{W_1+W_2+\cdots+W_n} \quad (1)$$

(A: Activity, W: Weight)

$$\text{Safety Culture Score} = \frac{O_1*W_1+O_2*W_2+O_3*W_3}{W_1+W_2+W_3} \quad (2)$$

(O: Objective, W: Weight)

The nine $\mathbf{IIS^{Process}}$ and safety culture were calculated into final score using the weighted arithmetic average as follows.

$$\text{Final Score} = \frac{P_1*W_1+P_2*W_2+\cdots+P_{n-1}*W_{n-1}+SC*W_n}{W_1+W_2+\cdots+W_n} \quad (3)$$

(P: Process, SC: Safety culture, W: Weight)

The level classification is determined as shown in Table 3.

Table 3. The criteria for Maturity Level

Level	Score
Initial	0 ~ 20
Managed	21 ~ 40
Defined	41 ~ 60
Quantitatively Managed	61 ~ 80
Optimizing	81 ~ 100

IV. EVALUATION OF AIRPORT'S INFORMATION INTEGRATION SYSTEM

The assessment of the maturity level was conducted from July 16 to August 5, 2019 at Korean I Airport. The **IIS** of I Airport was introduced with Enterprise Integration Application (**EAI**) software, and built in Hub & Spoke method. **EAI** is middleware software that connects applications to support the flow of data and information [25]. This consists of platforms for data delivery, adaptors for interface with heterogeneous systems, data brokers for data conversion, and business workflows for operation flow [26]. The **EAI** of I Airport is divided into Management EAI and Operation **EAI**. In this study, the first Focus Group Interview (**FGI**) has been done with Operation **EAI** personnel, and the output was reviewed. And through the second **FGI**, we finally assessed the maturity level of activities and objectives. Evaluation has been done for weight and maturity level of both 22 activities corresponding to Do and 3 objectives. As it is difficult to derive statistically significant values from a small number of staffs' interview, the safety culture has been arbitrarily set with highest weights.

Figure 4 depicts $\mathbf{IIS^{Process}}$ and safety culture distinguished as 3 different colors based on weight level.

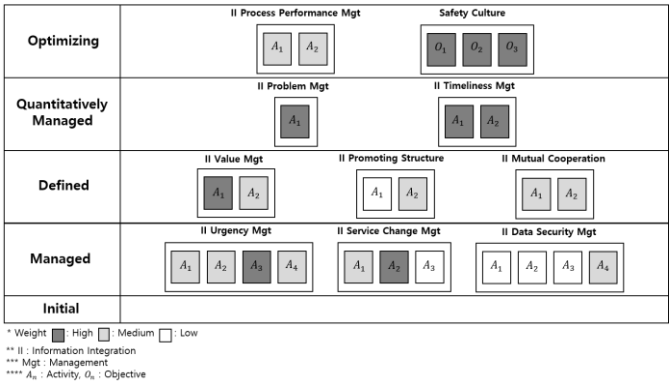


Fig. 4. The weight of Airport's Information Integration System Process and safety culture

From Figure 5 through 8, the evaluation tables of activities and objectives according to maturity levels are represented. Such evaluation charts provide easier sight on the current situation and level of organization in terms of **IIS**.

Managed level consists of IT-centered processes. Details on each activity are as follows.

Information Integration Urgency Management

Activity1: Management for the fault checking of Information Integration server

Activity2: Management for the fault checking of external/internal system

Activity3: Management for the fault alarm

Activity4: The procedure for Information Integration in case of emergency

Information Integration Service Change Management

Activity1: Service management for Information Integration (Add/Delete/Modification)

Activity2: Test management for Information Integration

Activity3: Monitoring management

Information Integration Data Security Management

Activity1: Key's generation and management

Activity2: Key's backup and recovery

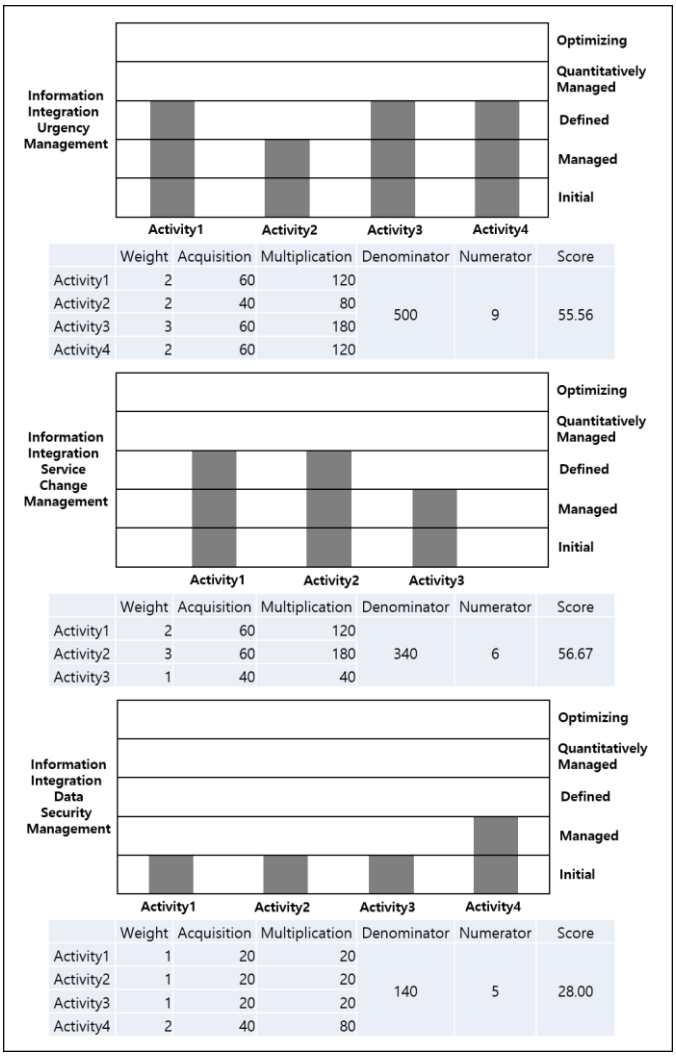
Activity3: Confirmation of information itself for encryption/decryption

Activity4: Confirmation of connected section for encrypted information

Figure 5 is a scorecard for activities at the managed level. Most activities of Information Integration Urgency Management and Information Integration Service Change Management have obtained defined or managed. However, activities of Information Integration Data Security Management - encryption key's generation & management, key's backup & recovery, and information's encryption/decryption verification - are in the initial stage as it was confirmed that the activities were performed only when the organization faced inevitable necessity including failure. Since there is no further use of integrated information, importance of these activities is shown lower than that of information providers and consumers. In case of connected section for encrypted information, there was a document of section's encryption method and procedure for external system, but it has been confirmed that it is not managed by designated person.

Having activities in concern, which have been assessed as Initial level by the Information Integration Data Security Management process, the plan will be judged to be improved as follows. For the section where encryption key is applied, the **IIS**'s person in charge should establish the data security-related

activity through consultation with organizational security and network representatives.



	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	2	60	120	500	9	55.56
Activity2	2	40	80			
Activity3	3	60	180			
Activity4	2	60	120			

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	2	60	120	340	6	56.67
Activity2	3	60	180			
Activity3	1	40	40			

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	1	20	20	140	5	28.00
Activity2	1	20	20			
Activity3	1	20	20			
Activity4	2	40	80			

Fig. 5. The activity's evaluation of Managed level

Defined level consists of organizational and data-driven processes. Details on each activity are described below.

Information Integration Value Management

Activity1: Management for rules of information (Type, cycle, method, etc.)

Activity2: Management for the information flow and its impact upon changing

Information Integration Promoting Structure

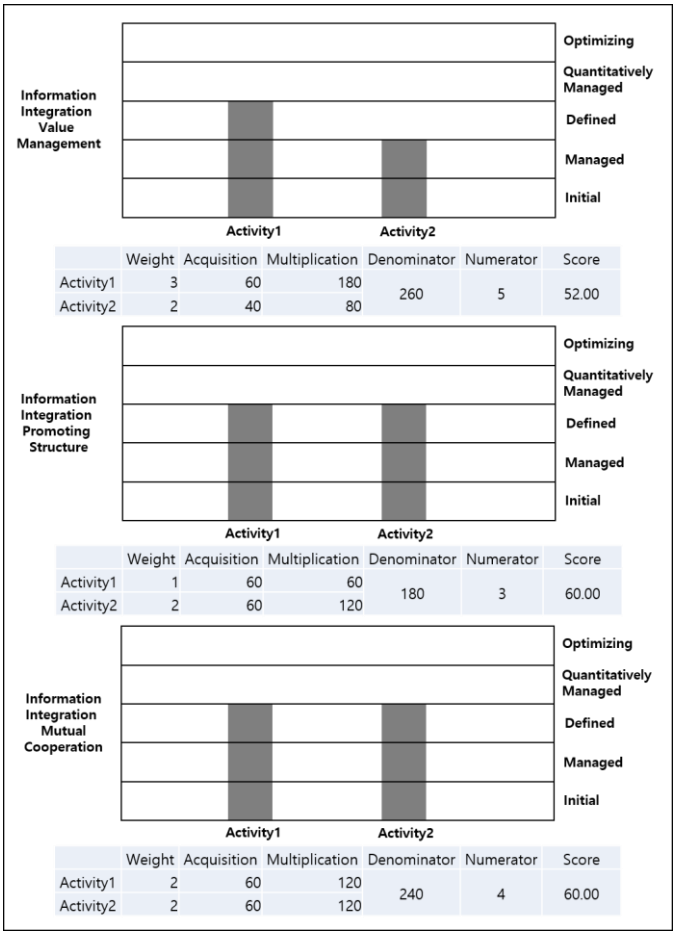
Activity1: Management for review of policy and ordinance document

Activity2: Organizational management (role, responsibility, decision making, etc.)

Information Integration Mutual Cooperation

Activity1: Agreement management (system manager, information scope, written agreement, etc.)

Activity2: Technology management (standard, diagram, interface specification, etc.)



	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	3	60	180	260	5	52.00
Activity2	2	40	80			

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	1	60	60	180	3	60.00
Activity2	2	60	120			

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	2	60	120	240	4	60.00
Activity2	2	60	120			

Fig. 6. The activity's evaluation of Defined level

Figure 6 is a scorecard for activities at the defined level. Most of the activities were given a level of defined level as systematic management has been performed by the person in charge. In the information flow of Information Integration Value Management, there are documents of URL call, procedures, etc. between internal/external system and **EAI** adaptors. However, the subject of implementation and management of the above is the staff in charge of internal/external system. Therefore, it was evaluated as managed level.

Quantitatively managed level consists of analysis-oriented activities of data and process.

Information Integration Problem Management

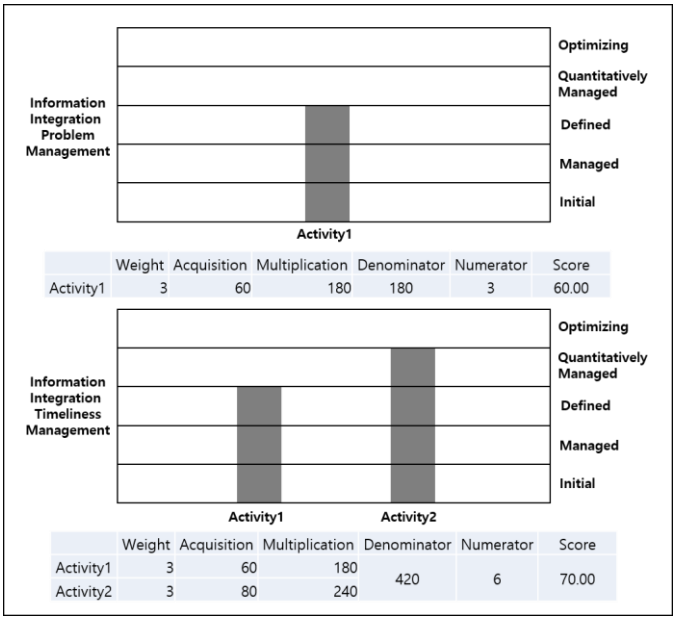
Activity1: Failure analysis

Information Integration Timeliness Management

Activity1: Management for the performance criteria of Information Integration

Activity2: Performance analysis

Figure 7 is a scorecard for activities at the quantitatively managed level. The performance analysis of Information Integration Timeliness Management was evaluated as quantitatively managed level. The organization has various dash-boards, which are used to improve the efficiency of activity. The activity is performed using tools such as Application Performance Management (**APM**), and the quality (availability, reliability, serviceability, etc.) of **IIS** is measured. And it was confirmed that such tools and information serves useful background on failure analysis of Information Integration Problem Management.



	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	3	60	180	180	3	60.00

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	3	60	180	420	6	70.00
Activity2	3	80	240			

Fig. 7. The activity's evaluation of Quantitatively Managed level

Following is description on activities of optimizing level.

Information Integration Process Performance Management

Activity1: Management for the measurement criteria of process performance

Activity2: Prediction of process performance

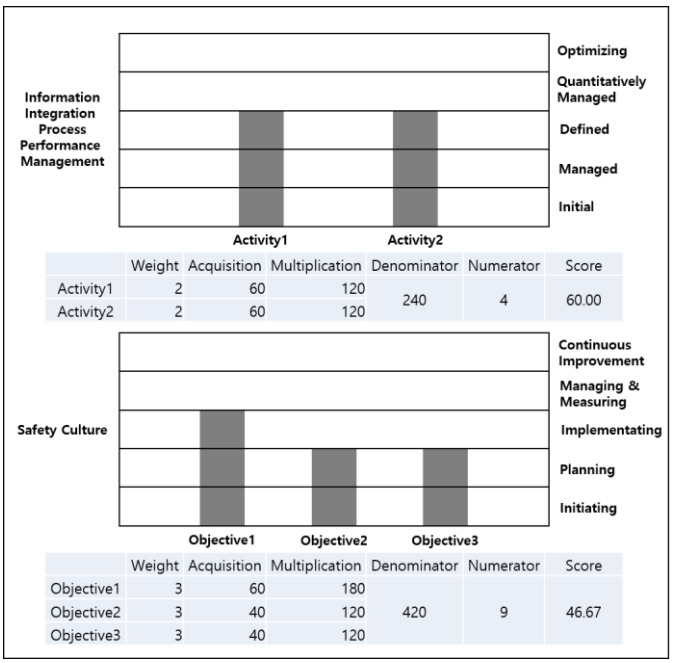
Safety Culture

Objective1: Positive, proactive, flexible and well-informed safety culture that supports reporting and learning led by the management

Objective2: Regular measurement of safety culture and improvement program

Objective3: Supportive reporting and investigation of occurrence

Figure 8 is a scorecard for activities and objectives at the optimizing level. The activities of Information Integration Process Performance Management are evaluated as defined level. Objectives of safety culture have been evaluated as either planning or implementating. Objective 1 has scored implementating stage, as the members judged that they did not plan and perform safety management actively. Objective 2 has scored planning stage, as they perceived that measurement results were not available. Objective 3 has scored planning stage, as they recognized that data sharing and presentation policies on safety were no supported.



	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Activity1	2	60	120	240	4	60.00
Activity2	2	60	120			

	Weight	Acquisition	Multiplication	Denominator	Numerator	Score
Objective1	3	60	180	420	9	46.67
Objective2	3	40	120			
Objective3	3	40	120			

Fig. 8. The activity and objective's evaluation of Optimizing level

Weighted arithmetic average of activities and objectives has been computed, and the result is as below. Information Integration Timeliness Management acquired quantitatively managed level, Information Integration Data Security Management obtained managed level, and the rest gained defined level. Figure 9 is the radial bar chat which represents scores of $\mathbf{IIS}^{\mathbf{Process}}$ and safety culture.

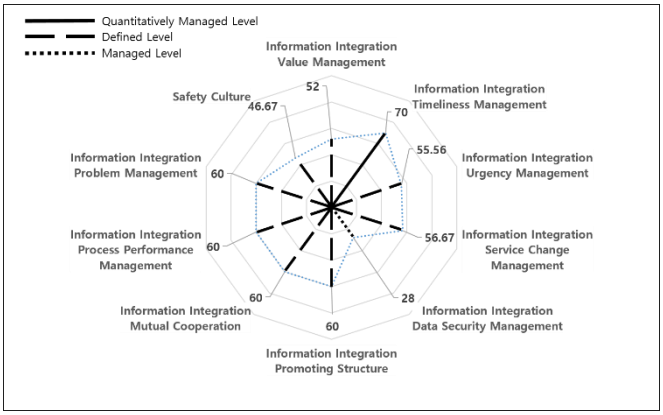


Fig. 9. The radial bar chart about Information Integration System Process and Safety Culture

Finally, the weightage for $\mathbf{IIS^{Process}}$ was based on the importance suggested by $\mathbf{IIS^{MM}}$. And the safety culture was arbitrarily set at the highest level, equal to Information Integration Process Performance Management. The final score was derived, and at the time of evaluation, **IIS** at I Airport was determined as defined level. Table 4 describes the final score.

Table 4. Evaluation Chart

	Weight	**Final Score**
II Integration Value Mgt	Medium	56.56
II Timeliness Mgt	High	
II Urgency Mgt	Low	
II Service Change Mgt	Low	
II Data Security Mgt	Low	
II Promoting Structure	Medium	
II Mutual Cooperation	Medium	
II Process Performance Mgt	Very High	
II Problem Mgt	High	
Safety Culture	Very High	

*II: Information Integration
**Mgt: Management

V. CONCLUSION

In the age of big data, airports are faced with the requirement of creating value through Information Integration. In addition, due to the nature of the organization, an airport must provide reliable and consistent service without interruption 24/7, through Information Integration. This paper proposes the maturity model of airport's **IIS** that combines nine $\mathbf{IIS^{Process}}$ with safety culture, and applies **CMMI**. The model was assessed for Korean I Airport. A total of 22 activities in the $\mathbf{IIS^{Process}}$ were weighted and measured according to the level-specific characteristics of Initial-Managed-Defined-Quantitatively Managed-Optimizing. Three objectives of the safety culture were measured in accordance with characteristics of Initiating-Planning-Implementating-Managing & Measuring-Continuous Improvement provided by **ATM** safety framework maturity survey. And the organization's maturity level was determined by the derived final score.

This paper is an empirical study of measuring and evaluating the maturity level of **IIS** at the airport. Organizations can visually identify information on the current level and reflect improvements in future plans. This continuous improvement may eventually improve the quality of **IIS** and contribute to fulfilling the organization's purpose. As mentioned earlier, limitation does exist - it is difficult to derive statistically significant values from the safety culture surveyed by a small number of staffs. Therefore, it is inarguable that the evaluation has been performed somewhat subjectively. Future studies may include application of the model for various countries, analysis of local specificity, and development of an airport's **IIS** with regional specificity in consideration.

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