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A Study on the Selection of UAM Pilots and Establishment of Training

JiHun Choi*, Sang-yong Park**

ABSTRACT

UAM(Urban Air Mobility)은 가까운 미래에 현실이 되는 항공교통 체계로 미래 첨단 기술의 결정체이다. 비행은 인간의 생명을 절대 보장하는 숭고한 철학에 기반한다. 성공적인 UAM 개발을 위해서는 비행안전에 기초한 개발철학이 필요하며 올바른 방향을 제시해야 한다. UAM 체계와 유사한 항공교통체계는 민간항공 운항체계이며 UAM 체계의 개발을 도모하는 효과적 비교 연구대상이다. 본 연구는 민간항공 운항체계와 민간항공 조종사의 경험을 토대로 안전한 UAM 체계 개발의 방향을 제시하는 데 있다. 그중에서도 UAM 조종사 양성과 교육훈련체계 수립을 위한 방안을 제언하였다. 현존 관련법규를 검토하여 UAM 조종사 양성기준을 제시하였으며 초기 혼란을 방지하기 위한 대안을 포함하였다. 또한 민간항공기의 접근구간 항법성능을 측정하여 UAM 운항환경을 비교 예측하였다. 이를 통해 SMS 기법에 기반하여 UAM 체계의 위해요인(hazard)을 식별하여 미연에 사고를 예방할 수 있는 안전 방법론을 제시하였으며 UAM 로드맵의 올바른 정책 수립을 돕고자 한다.

Key Words : UAM(Urban Air Mobility, 신모빌리티), Pilot(조종사), Education & Training(교육훈련), Safety(안전), Hazard(위해요인)

Ⅰ. INTRODUCTION

1.1 Background

UAM (Urban Air Mobility) is a future air transportation system that operates in urban areas. For establishing a safe system of future air transportation, UAM operation requires extensive research and preparation. Before the establishment of the UAM system, it is essential to conceptualize the UAM operation philosophy, and to establish a UAM flight philosophy so hazards can be avoided beforehand.

Currently, the domestic UAM operating environment is in the preparation stage, and related industries are conducting research on the development of aircraft in Hyundai Motor Group and Hanwha System, as well as research into the operating environment of UAM conducted by the government and research institutes. According to the government's K-UAM Roadmap[1)]

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* Ph. D. Candidate, Department of Flight Operation, Hanseo University / Jinair B737 Captain
** Professor, Department of Flight Operation, Jungwon University
Corresponding Author E-mail : parksy@jwu.ac.kr
Corresponding Author Address : 85, Munmu-ro, Goesan-eup, Goesan-gun, Chungbuk, 28024, Korea

1) On April 1, 2021, the Ministry of Land, Infrastructure and Transport announced a roadmap for Korean-style urban air transportation (K-UAM) technology. The roadmap for Korean urban air transportation technology is being promoted in three stages: the initial stage ('25~'29), the growth stage ('30~'34), and the maturity stage ('35~).

for the UAM era, autonomous flight requires pilots. Therefore, research applying the pilot's actual operating experience and procedures will be very effective in establishing a UAM safe operating environment.

1.2 Purpose

Concerning UAM, the following definitions apply. The FAA (Federal Aviation Administration) defines an unmanned aircraft as a device that is used or intended for use in the air without an onboard pilot. This device excludes missiles, weapons, or exploding warheads, but includes all classes of airplanes, helicopters, airships, and powered-lift aircraft without an onboard pilot. It is a mobile aircraft used for flight without an onboard pilot. In addition, it specifies that it includes all types of aircraft, helicopters, airships, and powered buoyant aircraft without pilots. The classification of unmanned aircraft is based on the first edition of the RPAS manual (2015), which is divided into "Remotely Piloted Aircraft (RPA)", "Autonomous Aircraft", and "Model Aircraft". A Remotely Piloted Aircraft is an unmanned aircraft controlled by a remote control station, while an Autonomous Aircraft is an unmanned aircraft without any pilot interaction or involvement in flight operations (Kim et al., 2017). Pilots are still required from the point of commercialization of UAMs to the point of complete autonomy and unmanned operation. According to the UAM technology Roadmap of the Ministry of Land, Infrastructure and Transport, pilot operation is essential from the stage of preparing the commercialization base to the preparation for the commercialization (2025-2029) stage and the growth period (2030-2034). Yet it has not yet been discussed whether pilots suitable for UAM operations should be selected and trained. However, it should be noted that the UAM operating environment and the technical system of the existing transport aircraft are not significantly different and that the experience accumulated in the macro-flight environment can be prepared by applying it to the micro-flight environment of the UAM operating system. The purpose of this study aims to provide a plan on how to best prepare and train pilots who will be most effective in UAM flight environments.

1.3 Overseas Trends

Research and regulation for UAM aircraft are currently focused on VTOL (Vertical Take-off and Landing) aircraft, which combine rotary and fixed wings to provide economic feasibility. However, the development of VTOL aircraft and related UAM certificates is not based on an understanding of flight principles, flight control technology, or flight environment. A certificate is a dangerous idea since it aligns with the technology development trend, that is, aircraft.

In the case of Europe, The European Aviation Safety Agency (EASA) classifies VTOL-type airframe into new types. In the case of the United States, The FAA is promoting a plan to qualify the VTOL model according to its form by classifying it as a type certificate in 14 CFR 61 61.31. This study, however, does not take into account eligibility criteria based on the new airframe, such as VTOL. The UAM flight system, including the International Aviation Organization (ICAO), is said to be similar to the rotorcraft flight system (Kim et al., 2022). The answer to granting this, UAM eligibility criteria are given. Flight control is not an area of classification according to the type of aircraft. This is because the control technology does not vary based on the type of aircraft. UAM should be reviewed by focusing on the operating environment rather than on the qualification criteria related to flight operation.

Ⅱ. ENVIRONMENT OF UAM FLIGHT OPERATION

2.1 Characteristics of UAM Flight Operation Environment

UAM aircraft is a complex operating system that requires overcoming topography, obstacles, and weather conditions in urban areas and ensuring safety. A safety plan should be established in this operating environment by anticipating risk factors that have not yet been identified for paid operations through UAM commercialization.

There are many unfavorable factors in the UAM operating environment. UAM operations are low-altitude flights, which must precede the risk of collision and the safety of the aircraft. Our analysis of the UAM operating environment consisted of measuring the required navigation performance (RNP) of the route and approach sections by operating the actual B737 flight.

As a result of the experiment, Tables 1 and 2 were measured by B737 aircraft, showing the level of active navigation performance (ANP) of 0.02 in the RNP 2.0 section (Choi et al., 2021). This shows that more precise system development and pilot training are required to satisfy the RNP 0.01 level of UAM-only routes designed by UBER (Bradford, 2020).[2)]

2.2 Analysis of UAM Control Environment using SMS

ICAO Annex 19 explains the definition, background, and concept of SMS (Safety Management System). The development of a complete system is impractical, but internalizing a safety-oriented philosophy can reduce predicted risks by identifying hazards ahead of time.

Table 1. RNAV2 Y722 route accuracy

구분	RNP / ANP	FMS	IRS L	IRS R	GPS L	GPS R	RA-DIO
MAKSA N3530.2E12654.4	2.0/ 0.02	N3530.2E12654.4	N3530.1E12654.3	N3530.2E12654.3	N3530.1E12654.3	N3530.1E12654.3	N3530.0E12654.3
ATASO N3553.7E12657.0	2.0/ 0.02	N3553.7E12657.0	N3553.7E12656.9	N3553.8E12656.9	N3553.7E12656.9	N3553.6E12656.9	N3553.6E12656.9
PEBRI N3623.2E12700.2	2.0/ 0.02	N3623.1E12700.2	N3623.0E12700.2	N3623.2E12700.1	N3623.0E12700.2	N3623.0E12700.2	N3622.6E12700.1
GUNKU N3634.2E12659.8	2.0/ 0.02	N3634.3E12659.8	N3634.3E12659.8	N3634.4E12659.7	N3634.2E12659.8	N3634.2E12659.8	N3634.1E12659.8

Table 2. RNAV GMP ILS 32L accuracy

구분	RNP / ANP	FMS	IRS L	IRS R	GPS L	GPS R	RA-DIO
WON-KO N3724.0E12659.1	0.3/ 0.02	N3724.2E12659.1	N3724.0E12659.4	N3724.1E12659.0	N3724.0E12659.2	N3724.0E12659.2	N3724.0E12659.2
SS371 N3726.6E12655.9	0.3/ 0.02	N3726.6E12655.9	N3726.6E12656.2	N3726.7E12655.7	N3726.6E12655.9	N3726.6E12655.9	N3726.6E12656.0
SS373 N3727.7E12654.5	0.3/ 0.02	N3727.7E12654.5	N3727.7E12654.5	N3727.8E12654.3	N3727.7E12654.6	N3727.7E12654.6	N3727.8E12654.6
WABAN N3728.7E12653.3	0.3/ 0.02	N3728.7E12653.4	N3728.6E12653.7	N3728.8E12653.2	N3728.7E12653.4	N3728.7E12653.4	N3728.5E12653.5

ICAO recommends the SMS model as a standard model by issuing ANNEX 19 through

2) The basic design of UAM in major foreign countries is conceptualized in Bradford, S. FAA NextGen Concept of Operation v1.0 (June 27, 2020), pp.16–20, Uber Operation inside corridor (June 10, 2020), EmbraerX Conops-Australia v1.0, and NASA Conventions.

four revisions from 2006 to 2018. SMS aims to promote operational safety by identifying Hazard in the operating environment, classifying them according to Safety Risk, and removing Hazard in advance. This methodology will be appropriate as a way to promote aviation safety by predicting the Hazard constituting the UAM ecosystem in advance. As a result of this study, pilots who are responsible for promoting UAM operation safety will be able to identify hazards before UAM design and then apply SMS concepts to their training and training pilots.[3)]

Ⅲ. DIRECTION OF UAM OPERATIONAL QUALIFICATIONS AND TRAINING

3.1 UAM Pilot Qualifications

3.1.1 UAM pilot candidate

The criteria for UAM aircraft are important challenges as they become the criteria for training and selecting UAM pilots. The current type of airplane can therefore accommodate pilot training.

Therefore, UAM trainees, fixed-wing airplanes, rotor wing airplanes, and drone pilots can be reviewed in the selection of pilot training.

There is usually no difference in the flying skills of aircraft control regardless of the type of aircraft. Especially in military education institutions, it is common to see that Skill for aircraft control has common skills, but there is a difference in technic used in the operating environment.

Therefore, considering the market environment in which UAM aircraft is being developed as a composite according to fixed wing, rotorcraft, or drone technology, the categories of selection targets required to train UAM pilots are those with basic understanding and control skills (Park et al., 2014).

3.1.2 Requirement of UAM pilot

The UAM operating environment is accompanied by the flight methods of visual flight rules (VFR), instrument flight rules (IFR), and essentially performance-based navigation (PBN). Pilots who have UAM capabilities must also have PBN capabilities.

First, UAM pilots must be equipped with control techniques that skillfully handle UAM aircraft. Second, UAM pilots must have the ability to VFR and IFR. Third, UAM pilots must have an understanding and operational capability for PBN navigation. Fourth, UAM pilots must have the ability to overcome crises in abnormal situations.

3.1.3 UAM flight operation verification

As part of UAM, fixed-wing aircraft, rotor wings, and drones will be developed. As a result of these development trends, UAM aircraft are classified into airplane types and designated with Type Ratings. Overseas, there is a tendency to classify airplanes by complexity, but this method might confuse when training early UAM pilots. To reduce confusion and train efficient pilots, it is appropriate to maintain Article 34 and Article 35 of Aviation Safety Act Chapter 4 and to classify and grant UAM aircraft as type certification. Furthermore, it is necessary to strengthen the minimum qualifications for people who are capable of overcoming crises in abnormal situations, such as advanced navigation equipment, the volume of airplanes, and crisis-resilient skills. According to Table 3, a verification system is set up for each step of the UAM roadmap once the concept of the UAM pilot qualification criteria is defined.

3) Choi (2021) proposed Preliminary Safety Management (PSM) that implements an environment in which Hazard cannot occur in the system by pre-blocking the occurrence factors of Hazard by internalizing safety-based philosophy in the SMS conceptualization stage.

Table 3. Flight operation verification system phase

System	Phase
Aircraft technology certification system	Piloted
Safe flight operation management system	Piloted
Pilot training and certification system	Piloted
Flight operation management system for non-experts in the pilot field	Transition
Autonomous flight operation certification system	Autonomous

3.2 UAM Pilot Training

The characteristic of the UAM system is that it is exposed to a low altitude, urban-dense operating environment. To address this, it is necessary to develop an education and training system. Several factors limit maneuvering and navigation in the UAM environment, such as obstacles, navigation equipment, TCAS (Traffic alert and Collision Avoidance System), and low visibility weather conditions. According to the 2013 helicopter crash analysis results of LG Electronics, the accident occurred due to low altitude strong gusts, and low visibility even though the accident aircraft was equipped with a TCAS and autopilot control devices. Therefore, pilot training should be conducted by setting a systematic UAM flight operation environment and effective program, and curriculum (KBS News, 2015).

3.2.1 Training PIC (pilot in command)

It is important to establish UAM pilot qualification criteria based on the operating environment and the pilot's essential requirements. The exact literature for UAM pilot eligibility criteria is the PIC definition of FAA UAM Conops.[4] When applying this, UAM aviation personnel shall apply to the Aviation Safety Act, Chapter 4, Aviation personnel, etc., Article 34 (Certificate of qualification for aviation personnel, etc.), and Article 35 (Type of qualification). In particular, concerning PIC concept presented in FAA Conops and the definition of a pilot given in Article 63 of the Aviation Safety Act, the minimum qualification criteria for early UAM operators should be considered as transport pilots and qualified equivalent to PIC. In addition, it is necessary to review the minimum qualifications as a person with performance-based navigation experience and sub-functional abnormal situations. A person with performance-based navigation experience and subfunctional abnormal situations must also review the minimum qualifications.

Therefore, according to Table 4, training and certifying UAM pilots as qualified persons for Commercial License PICs of small air transport operators or aircraft users is effective.

3.2.2 Transition training

The UAM operator will select the aircraft to be used in the transportation business. In the UAM transportation business, as part of UAM's transportation business, aircraft qualifications are granted based on aircraft selected by operators. Hanwha System and Hyundai Motor Group are developing the UAM aircraft as a VTOL, but research and development are underway as a fixed-wing aircraft as well. In summary, in accordance with Table 5, the pilot

Table 4. Operation cerificatate of UAM

Classification	Certification
Fix wing	Commercial License or ATP
Rotor wing	

4) Bradford, S. FAA NextGen Concept of Operation v1.0 (2020. 6. 26), p.14, 4.3.3 Pilot in Command (PIC): The PIC is the person aboard the UAM aircraft who is ultimately responsible for the operation and safety during flight.

Table 5. Transition cerificate of UAM

Classification	Certification
Fix wing	Type rating
Rotor wing	

can obtain a type rating for the model selected by each UAM operator with the fixed wing and rotor blade certificate as a joint qualification.

3.2.3 Navigation training

Pilots who have UAM capabilities must also have VFR, IFR, and PBN capabilities. For UAM aircraft to operate at low altitudes, an environment based on performance-based navigation, communications, navigation surveillance, and information (CNSi), and required navigation performance (RNP) must be provided. A concept that secures navigation safety by applying the concept of maritime airspace communication performance and performance-based navigation to aircraft capable of long-distance operations between continents.

Additionally, UAM airspace takes into account the operating environment and restrictions. Considering weather, airmass, and obstacle restrictions, routes should be built using existing performance-based navigation systems like the Global Navigation Satellite System (GNSS), RNP, and IMU. The initial stage of development is likely to be GNSS-based. In the civil aviation sector, the "Differential Global Positioning System (DGPS)" is used to improve the accuracy of GNSS. Therefore, the supply and demand of prepared personnel to use these advanced navigation and information systems are essential for the safe flight of UAM. Urban Air Traffic Management (UATM) is operated based on data communication, so it is expected that required communication performance (RCP) and required surveillance performance (RSP) technologies will be applied. The concepts of the two technologies are shown in Figs. 1 and 2.

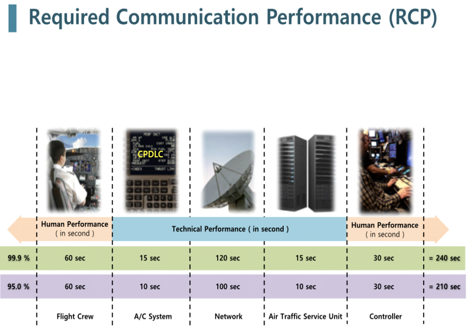

Fig. 1. RCP concept

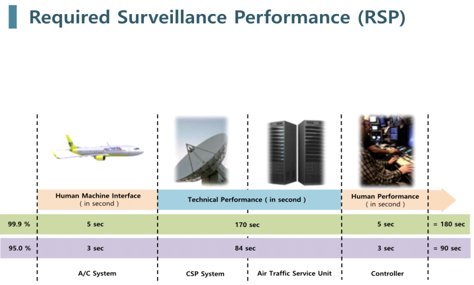

Fig. 2. RSP concept

3.2.4 Non-normal training

The direction of training should be to develop crisis management training for weather consideration and obstacle avoidance and to ensure safety by organizing training, regular training, and evaluation. The training of UAM experts should be conducted through essential training, non-essential training, evaluation system development, and training certification based on the operating environment. In particular, the establishment of contingency procedures should be subdivided into weather condition analysis and emergencies. During the early stages of development, the UAM airspace will be operated as a satellite navigation system. A skillful use of advanced navigation equipment is therefore necessary.

Early stages of development require examining whether it can be applied to low altitude airspace for UAS Traffic Management (UTM). In civil aviation operations, NON-normal situations are frequent due to receiver autonomous integrity monitoring (RAIM) problems. Solving this problem requires the development of situational action training at the same time.

3.2.5 Evaluation

As well as evaluating skill and competency, UAM pilots are extremely important. UAM pilots should always ensure operational safety and maintain the skills and capabilities to protect human life. Therefore, the evaluation system for this should consist of regular examination, simulation training, and SMS training.

Ⅳ. CONCLUSION

A pilot will be responsible for controlling the flight of the UAM in the initial phase of UAM technology development. The act of flying is directly related to human life as well as a priority for safety. In order to prevent flight accidents, safety factors must be considered in detail.

The UAM environment is a human challenge against nature and the courage to confront dangerous environments with technology. Civil aviation continues to experience safety accidents despite the latest technology, and UAM development will face greater safety challenges. The current act can serve as a lesson for preventing this in the future. As a crystal of perfect high-tech, UAM will operate in the human realm until a perfect gas, AI, and navigation technology are developed.

Training UAM pilots as qualified personnel for Commercial License PIC of an aircraft operator or small air carrier would be effective. The pilot must also obtain a Type Rating for the model selected by each UAM operator and a fixed wing and rotor blade certificate. Navigation training for low altitude flight, which is characteristic of UAM, and gastric functional training should be included in education and training. Legal evaluation for flight competency maintenance and development is continued.

Lastly, we emphasize the establishment of a risk-based safety system for successful UAM system construction and look forward to the development of pilot training, normal operation procedures, and operation capability of performance-based navigation.

Review

This study is to inform you that the thesis (Choi et al., 2021) published at the 2021 Spring Conference of the Korean Society for Aeronautical and Space Sciences has been revised and supplemented.

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