Impact of human factors for student pilots in approved flight training organizations in Korea

236-49, Gomseom-ro, Nam-myun, Taean-gun, Chungcheongnam-do, Korea, 357-953
Phone : +82-41-671-6221 Fax : +82-41-671-6228

Kang-Seok, Lee*, Eun-Suk, Seol, Seth Young*****
***Professor, Dept. of Air transportation and Administration, Hanseo University, South Korea, E-mail : kasulee@hanseo.ac.kr**
**** Researher, Korea Transport Institute, South Korea**
***** Associate Professor, Director, Center for Aviation Studies, Ohio State University, USA**

Abstract

Statistics for aviation accidents in Korea show that the safety level of training flights is high. However, of the accidents that do occur, more than 80% occur due to human factors. Furthermore, because most causes of human factors-related accidents are "pilot error," it is important for student pilots who will transport passengers to develop knowledge of safety and skills associated with human factors risk management to mitigate the risk of such accidents.

To investigate the human factors that affect safety in training student pilots for flight, this study examined the correlation between events that are associated with accidents, differences according to the pilot's experience level of flight training, and differences between student pilots who received flight training at approved collegiate flight education centers and those who did not. The study was conducted on human factors, focusing on the SHELL model. Using the SPSS software (ver. 17.0), correlation analyses, analyses of variance (ANOVA), and t-tests were conducted to generate statistical results.

Briefly, the results of this study found that a student pilot's natural ability and equipment in the cockpit are the important factors for safety for pilot on training flights. Additionally, the analysis of the differences between human factors according to the characteristics of student pilots' groups shows that college student pilots are effected by immanent factors and organizational cultures.

To date, there have been no accidents with related human casualties when training at collegiate "Approved Training Organizations" (ATOs) in Korea. However, accidents can occur at anytime and anywhere. Especially human factors, which cause most aviation accidents, have a wide reach and are impossible to eliminate. Because ATO is the starting point to lead the aviation industry of Korea, awareness of risks and initiatives to improve education/training of human factors is essential.

Key words: ATO, human factors, SHELL model, training flight

1. Introduction

"Human factors" have become a significant issue in aviation safety because a high percentage of aviation accidents are caused by human factors. Training on human factors is regarded seriously for aviation personnel in Korea; thus, training programs, such as Crew Resource

management (CRM) and Line-Oriented Flight Training (LOFT), are often emphasized by airlines.
As seen in curricula related to human factors in traditional flight training centers in Korea, only designated prerequisite subjects are required to obtain a pilot's license. For the private pilot course, only 12 hours are assigned for human performance and limitation classes of the total 180 hours of courses, and for a commercial pilot's license, 20 hours out of 510 hours are assigned. Thus, these training centers dedicate less than 10% of total course duration for human performance and limitation classes.
This is far from sufficient in terms of recommended training hours in comparison with the recommendations of the International Civil Aviation Organization (IACO). It is also not sufficient to prevent student pilots' risks of having accidents or incidents due to human factors with the given curricula.
With the continuous growth of the Korean air transport industry and demands for air travel, demand for pilots has also increased rapidly. To meet the demand for pilots, the Korean government has approved the establishment of Approved Training Organizations (ATO). The first ATO was established at the Uljin Flight Training Center in July 2010, with facilities to train upwards of 200 pilots annually. This is one of the government's efforts to meet the increasing demand on civil aviation pilots who are generally foreign pilots or Koreans who trained at overseas training centers. With this effort, domestic training flight traffic is expected to increase continually.
The degree of safety on training flights by ATO is regarded as high. However, even at the ATOs, more than 80% of accidents in air transportation are caused by human factors, and, mostly, by pilot mistakes. Thus, it is important that student pilots have in-depth knowledge of safety and abilities in risk management.
This study consists of a survey based on the SHELL model which is designed to prevent human error. The survey subjects were student pilots so risk factors that can affect training flights by student pilots can be identified. The survey object was to eliminate risk factors during training flights, to prevent accidents or incidents. Furthermore, safety management for training flights can be maintained at a high level.

2. Literature review on human factors

Peterson (1988) developed causal models that classified the reasons for and causes of unsafe behavior specifically to reduce unsafe behavior by managers by providing practical items. This causal model can explain the connection between multiple contributing factors leading up to the event when an accident occurs and configures the process of the primary causal factor of the human error that lead to work overload, decision error, and traps. The "overload" component of this model may be defined as an inconsistency in the ability to work. Mental ability, low cognitive ability, and unconsciousness are the supplementary causes of what may be defined as "decision-making error." "Traps" can be created by the supplementary causes, such as workplace design and incompatibility of instruments and control devices.
Cooper (1998) claimed that there were mutual relationships between the organization's safety management system, perceptions, and attitudes about safety, and daily goal-oriented behavior. A reciprocal safety culture model is confirmed in organization experiences that have numerous different components relationships.
Reason (1990) explained how a human contributes to the cause of accidents or is involved in accidents in the complex and interconnected aviation industry. He emphasized that only one occurrence of negligence or unsafe behavior in the complex system does not lead to accidents.

Accidents are caused when each element occurs organically or there is already potential risk existing in the current system.
Reason hypothesized that accidents were caused by one or more of four levels of failure: organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts themselves. The defenses against these failures were modeled and when all the individual barriers weaknesses aligned, accidents or incidents occurred, as illustrated in Figure 1.

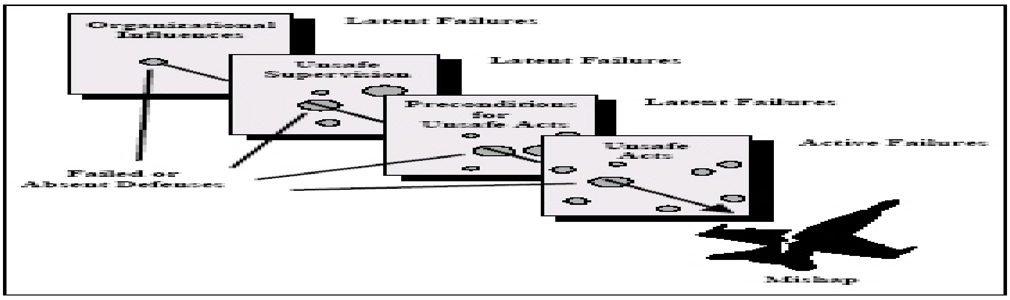

Figure 1. Reason's "Swiss Cheese" model

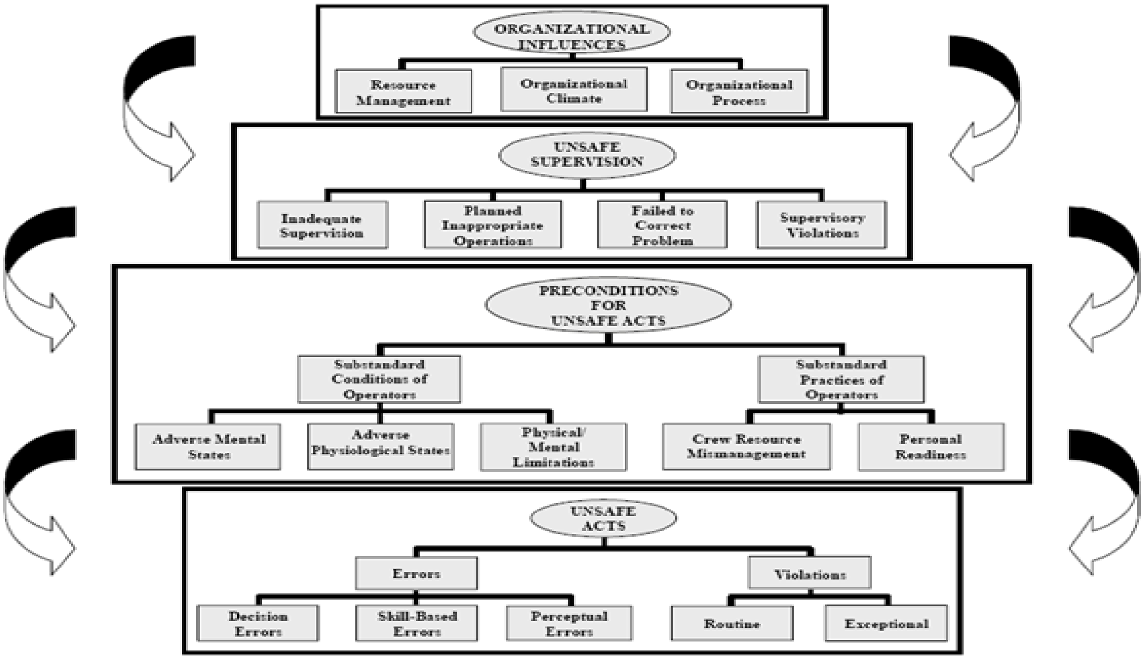

Figure 2. HFACS Model

Reason(1990) and Weigmann & Shappell (1997) introduced the Human Factors Analysis and Classification System (HFACS), which was used to analyze Navy and Marine Corps flight accidents. HFACS is a comprehensive human-error framework developed from the Swiss cheese model and it identifies the human causation of accidents, and provides tools to aid the investigation process, as illustrated in Figure 2.

O'Hare, Wiggins, Batt, and Morrison (1994) claimed that humans were the major cause of civil and military aviation accidents among human-machine interface, environment, and communication.

ICAO addressed in their Investigation of Human Factors of accidents and incidents document, adopting an investigation approach to human factors in aviation accidents and incidents that has not been effective even accepting that 'humans make errors'. Thus, investigating authorities and investigators have difficulties in investigating the human factor contribution to accidents.

The most basic approach to investigating human factors in accidents and incidents is Reason's Accident Causation model. ICAO recommends that aviation accident investigators investigating human factors must have in-depth knowledge in aviation and various elements that could affect pilots on flight duty.

Weigmann & Shappell (2001) claims that if the current aviation accidents rate was not going to decrease further, given how aviation traffic is expected to grow in the next 10 years, there would be a major accident occurring every week.
Taneja (2002) found that human error had been implicated in almost 70-80% of civil and military aviation accidents. He proposed a holistic approach to minimize aircraft accidents and aimed to provide a composite and macroscopic view of the activities within the aviation environment that can be targeted to produce the desired result. He also emphasized that the influence of safety culture in integrating the diverse components of an accident prevention program is important.

3. Theoretical Background of the study

3.1 Study on Human Factors

3.1.1 Definition of Human Factors

Human factors can be defined as the discipline of study that deals with any factor that can affect human behavior, physically or psychologically. Human factors not only focuses on pilot performance, but can also be applied to all aviation personnel, such as air traffic controllers, maintenance personnel, and dispatchers. Human factors has also been referred to as ergonomics. Murrell (1965) used the term 'ergonomics,' and it became generalized due to his book title. He defined ergonomics as 'the scientific study of the relationship between man and his working environment.'
Human factors, in a broad sense, deals with the user and the system the user is in, such as the human-machine interface, human-human interface, human procedures, and human environments. 'Human factors' is widely used in US and 'ergonomics' is used more generally internationally.

3.1.2 Introduction of the Study of Human Factors in Aviation

After World War II, human factors studies were initiated due to the need to improve productivity of nations and industries through hiring appropriate employees who could conduct duties efficiently while at the same time providing systematic training.
In the UK, the Ergonomics Research Society (ERS) in 1949 and the International Ergonomics Association (IEA) in 1959, and in the US, Human Factor Society (HFS) in 1957 were established to study systemically ergonomic issues including human factors and those studies began to be applied to industry sectors.

In the aviation sector, through investigation results of major and minor accidents and incidents, human factors became a key factor in flight safety, and some countries developed human factors courses for aviation personnel in various forms. NASA and the US FAA collected extensive human error data through the Aviation Safety Reporting System (ASRS) to investigate human factors as a research project. Similarly, through the Confidential Human Factors Reporting Programme (CHRIP) in the UK, the Confidential Aviation Safety Reporting Program (CASRP) in Canada, and the Confidential Aviation Incident Report (CAIR) in Australia, research on human factors was executed.

In March 1977, due to a breakdown of coordination between cockpit crew and air traffic controllers, KLM B-747 and Pan Am B-747 collided on the runway at Los Rodoes airport, Tenerife, and of 637 passengers, 583 people died.

In December 1978, a United Airlines aircraft en route to Portland, Oregon, crashed due to breakdowns in cockpit management and teamwork. Ten passengers died and 28 passengers were seriously injured.

According to analyses of various aircraft accidents, including these two major accidents, it was found that accidents were caused by lack of coordination between the cockpit crew and air traffic controllers. Thus, the importance of close cooperation and coordination between associated personnel during flights became apparent, and various international organizations including ICAO and regional organizations such as NASA and the FAA started to study human factors for the effectiveness and safety of crew work during flights.

3.1.3 Theory of SHELL model

Various industries including the aviation sector have realized the need for understanding human factors and the utilization and application of this understanding to protect humans and properties and enhance to productivity through maximizing efficiency in the workplace.

To this end, Elwyn Edward developed the SHEL (software, hardware, environment, liveware) model that visualizes the interrelationships among the crew and the aircraft system components systematically.

Edward argued that human factors theory is more problem solving-oriented rather than theory-oriented. He also argued that it is essential that human performance and its limitations must be perceived together to resolve the discrepancies between of humans and their surrounding environments.

Frank H. Hawkins, a former captain at KLM, modified Edwards' SHEL model into a 'building block' structure as can be seen below figure 3. The SHELL model adopted a system perspective that suggests the human is rarely the *sole* cause of an accident.

The components of the SHELL model are also software, hardware, environment, and liveware. These components represent the building blocks of human factors as they pertain to the human's interaction with each component. The human element, the most critical component, is at the center of the SHELL model.

In the center of the model, "L" represents liveware, which means humans in the workplace; for example, cockpit crew, air traffic controllers, management, administration personnel, and maintenance personnel. The other system component must be carefully adapted and matched to this central component to accommodate human limitation.

The "L" on the right side of the model stands for those persons at the front line of operation who conduct duties, and thus represents the human-to-human interaction in aviation operations.

"H" is hardware, which is any physical element of the aviation system, such as aircraft, operator equipment, tools, computers, and even buildings.

"S" is software and represents the non-physical and intangible aspects of the aviation system that govern how the aviation system operates, including rules, instructions, regulations, laws, checklists, operating procedures, symbology, computer programs, and procedural checklists.
"E" represents the environment, which includes physical factors like cabin temperature, air pressure, humidity, noise, ambient light levels, and physical environment within an aircraft, as well as factors outside the work area, such as weather, terrain, and physical facilities.

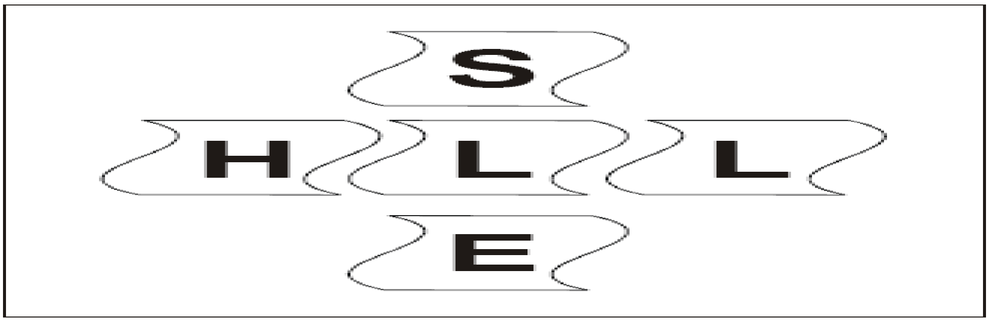

Figure 3. SHELL model

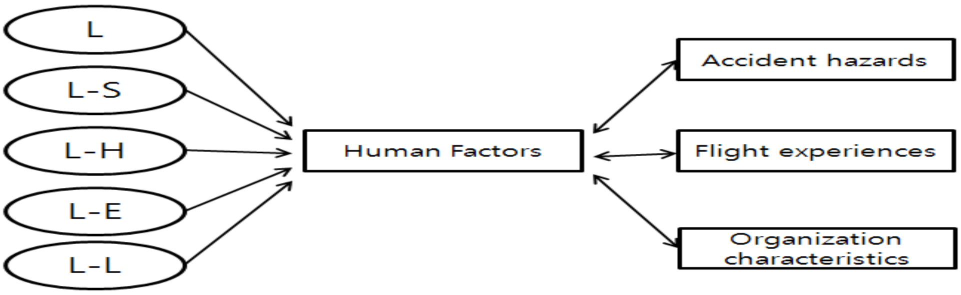

Figure 4. Failures of the SHELL model contribute to human factor-related

The SHELL model indicates relationships between people and other system components and therefore provides a framework for optimizing the relationship between people and their activities within the aviation system. As any component that surrounds liveware can directly affect aircraft operations. The interaction and interface of those components should be kept at an optimum level to maintain efficiency and ensure safety. A mismatch of the interface of people and other system components, such as Liveware-Software (L-S), Liveware-Hardware (L-H), Liveware-Environment (L-E), Liveware-Liveware (L-L), and Liveware(L), can be a major source of human error (Fig. 4).

3.1.4 Current state of Human Factors Training

Training on human factors is meant to influence an aviation professional's attitudes and behavior; thus, training should be conducted over the long term, systemically and periodically, rather than for a short period in the aviation professional's career. Furthermore, such positive attitude and behavioral changes should be habituated through constant management and supervision.
ICAO encourages human factors training by setting standards for human factors education for aviation personnel to be aware at human factors, such as human performance and its limitations, and to foster basic human factors knowledge. However, standardized program development for technical training on human factors is not part of many aviation education

programs. This is because implementation methods and program contents may vary widely due to the unique circumstances of training environments. Thus, regional seminars on human factors are held periodically to realize the rational procedures of the program. A description of ICAO's recommended Human factors training for aviation personnel is provided in Table 1.

Table 1. Human Factors Curriculum

Subject	Curriculum	Percentage (%)	Hours (HH:MM)
1	Introduction of Human Factors	5	1:45
2	Physiology	20	7:00
3	Psychology	30	10:30
4	Fitness for Duty	5	1:45
5	Liveware-Hardware	5	1:45
6	Liveware-Software	10	3:30
7	Liveware-Liveware	15	5:15
8	Liveware-Environment	10	3;30
Total	**8 Subjects**	**100**	**35:00**

Source : ICAO, Doc 9683 - Human Factors Training Manual, 2013

3.2 Theoretical review on training flight

3.2.1 Definition of training flight

A training flight can be defined as instruction received from a flight school to accumulate flight experiences to obtain a flight certificate.
In Korea, according to the Aviation Act, Article 35, a training flight is explained as a practice flight performed by a person holding a certificate of flight and a medical examination for the aircrew on board an aircraft (limited to aircraft of limited categories) other than that of a limited class or type, under the supervision of a person holding a certificate of qualification and a medical examination for the aircrew by which he/she is allowed to pilot the aircraft, including those who are designated by the Minister of Land, Transport, and Maritime Affairs. Practice flights have to be performed under the supervision of a person holding a flight instruction certification after obtaining permission from the Minister of Land, Transport, and Maritime Affairs. When any person who has received written permission for practice flights, he or she has to carry the written permission and certificate of medical examination for the crew. In case of US, the FAA does not permit practice flight but issue student pilot certificates for solo flight.

3.2.2 Flight training center status

In Korea, flight training centers are authorized to conduct training flights; hence, they are also called Authorized Training Organizations (ATOs). The government designates ATOs to train pilots. Excluding the Air Force, Army, and Navy, there are three ATOs: the Flight Training Center of Korea Aerospace University, Hanseo University Flight Training Center, and Uljin Flight Training Center.
A flight training center can be categorized as a training center for the airlines to train their own staff, and specialized educational institutions that are designated by the Ministry of Land,

Transport, and Maritime Affairs under the Aviation Act, Article 29-3, and the Ministerial Regulation of Aviation Act, Article 93.

There are no specific requirements to establish an airline flight training center in Korea but government approval is required for certification of education regulations, training subjects and methods (including the training program), training equipments and tools, and status of the inspectors.

A designated ATO is required to set an education plan containing education subjects and education methods, as well as a training discipline for the purpose of training qualified pilots and carrying out designated duties effectively. Korea Aerospace University, Hanseo University, the Air Force, Army, and Navy are designated to operate such programs.

Designated ATOs can be categorized as military training institutions and civil training institution (Table 2). In this study, we surveyed students who trained at civil training institutions. For civil training institutions, there are Korea Aerospace University and Hanseo University, and the Uljin Flight Training Center that was co-opened by Korea Aerospace University and Hanseo University. The status of flight training centers is shown in the table.

Table 2. Current state of Korea's Approved Training Organizations

	Course	**Training Period**	**Available Trainee number (Annually)**
Korea Aerospace University (12 Aircraft)	Private pilot	3 Months	150
	Commercial pilot	9 Months	90
	Instrument flight certificate	3 Months	30
	Certified flight instructor	3 Months	30
Hanseo University (12 ircraft)	Private pilot	6 Months	20
	Commercial pilot	12 Months	40
	Certified flight instructor	3 Months	20
Air force (160 Aircraft)	Commercial pilot	17 Months(82 Weeks)	120
	Commercial pilot(Ⅰ)	72 Weeks	50
	Commercial pilot (Ⅱ)	3.5 Months(15 Weeks)	50
	Certified flight instructor	1 Week	90
Army (65 Aircraft)	Commercial pilot	27 Weeks	80
	Commercial pilot	13 Weeks	50
	Instrument flight certificate	8 Weeks	30
Navy (59 Aircraft)	Private pilot	22 Weeks	30
	Commercial pilot	-104 Weeks (Fixed) -160Weeks (Rotational)	30
	Instrument flight certificate	10 Weeks	50
	Certified flight instructor	8 Weeks	25
	Private/Commercial	14 Weeks	25
Total	-	-	**1,100 Annually**

Source: Ministry of Land, Transport, The Office of Aviation, 2013.

4. Study Design

4.1 Study Model

The study model was created based on the SHELL model of Hawkins (1975). The SHELL model is generally used to understand human factors, and it helps to understand the interaction between human, software, equipment, and environmental factors.
In the study, it was presumed that human factors, based on the SHELL model, will have an effect on the safety of training flights, and we also hypothesized that human factors will vary by flight experiences and characteristics of the organization. The model for the study was designed based on those assumptions.

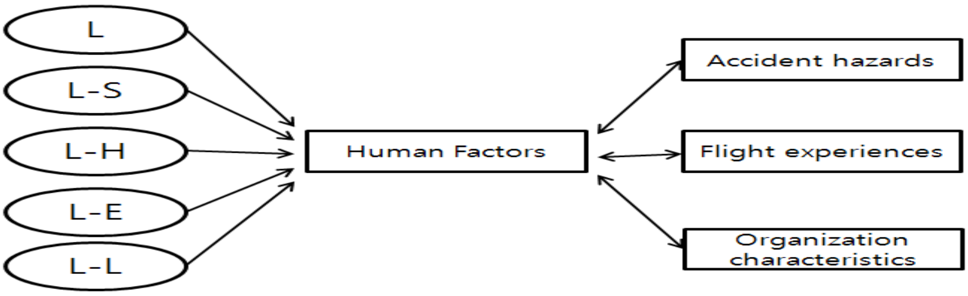

Figure 5-1. Study Model

4.2 Sample Composition

The study subjects were 3rd- and 4th-year university student pilots from flying courses and helicopter flying courses, and members of the general public who were certified pilots. In total, 121 surveys were distributed between the October 10 and 20, 2010; one faulty survey was eliminated. Thus, in total, 120 surveys were analyzed and the description of the sample composition is provided in the table. Table 3 provides the demographic characteristics of the sample.

Table 3 provides the demographic characteristics of the sample.

Division		Frequency	Percentage
Total		120	100%
Gender	**Male**	118	98.3%
	Female	2	1.7%
Affiliation	**Flying course**	61	50.8%
	Flying Helicopter course	21	17.5%
	General Trainee	38	31.7%
Grade	**3rd Year**	41	34.2%
	4th Year	41	34.2%
	General Trainee	38	31.7%
Flying training course	**Private pilot course**	93	77.5%
	Instrument flight course	4	3.3%
	Commercial pilot course	23	19.2%
Flying Hours	**1-50**	61	50.8%
	51-100	31	25.8%
	Over 101	28	23.3%

4.3 Hypothesis of the study

In the study, we attempted to assess how variables such as accident hazards, flight experiences, and organizational culture could affect human factors, as described in the SHELL model. In the study, thus, the hypotheses set out below were assessed in terms of how three variables, accident hazards, flight experiences, and organization characteristics, can affect the on interaction between liveware and other system components; that is, how each interaction is perceived to have a human factors effect on safe aircraft operations.

Hypothesis 1
Hypothesis 1-1. Accident hazards and Liveware are interrelated.
Hypothesis 1-2. Accident hazards and Liveware-Software are interrelated.
Hypothesis 1-3. Accident hazards and Liveware-Hardware are interrelated.
Hypothesis 1-4. Accident hazards and Liveware-Environment are interrelated.
Hypothesis 1-5. Accident hazards and Liveware-Liveware are interrelated.

Hypothesis 2
Hypothesis 2-1. With a lower amount of flight experience, the impact of Liveware that affects safety will be greater.
Hypothesis 2-2. With a lower amount of flight experience, the impact of Liveware-Software that affects safety will be greater.
Hypothesis 2-3. With a lower amount of flight experience, the impact of Liveware-Hardware that affects safety will be greater.
Hypothesis 2-4. With a lower amount of flight experience, the impact of Liveware-Environment that affects safety will be greater.
Hypothesis 2-5. With a lower amount of flight experience, the impact of Liveware-Liveware that affects safety will be greater.

Hypothesis 3
Hypothesis 3-1. The impact of Liveware that affects safety will differ by pilot organization characteristics.
Hypothesis 3-2. The impact of Liveware-Software that affects safety will differ by pilot organization characteristics.
Hypothesis 3-3. The impact of Liveware-Hardware that affects safety will differ by pilot organization characteristics.
Hypothesis 3-4. The impact of Liveware-Environment that affects safety will differ by pilot organization characteristics
Hypothesis 3-5. The impact of Liveware-Liveware that affects safety will differ by pilot organization characteristics,

5. Empirical Analysis

5.1 Reliability Analysis

First, a reliability analysis was conducted for each survey item under SHELL model's human factors variables. The Liveware, Liveware-Software, Liveware-Hardware, Liveware-Liveware factors' reliability analysis results were all used without elimination because the α value was greater than 0.6, the 'standard' reliability value.
The result of the reliability analysis for Liveware-Environment was an α value of 0.586, less than the 0.6 standard reliability value. To increase the overall reliability of the Liveware–Environment factor, item 18 was removed, which was regarded as the least reliable item. When this item was removed, Cronbach's α value was 0.605. Thus, without item 18, the Liveware-Environment factor can be used as a reliable measuring factor.

Table 4. Reliability Analysis

Factor	Measuring Item	Eliminated Item Cronbach's α	Cronbach's α
Liveware	1	.725	**.714**
	2	.631	
	3	.683	
	4	.687	
	5	.631	
	6	.718	
	7	.677	
Liveware-Software	8	.481	**.601**
	9	.545	
	10	.686	
	11	.463	
	12	.545	
Liveware-Hardware	13	.708	**.774**
	14	.690	
	15	.759	
	16	.745	
	17	.756	
Liveware-Environment	**18**	**.605**	**.586**
	19	.485	
	20	.549	
	21	.498	
	22	.491	
Liveware-Liveware	23	.766	**.714**
	24	.718	
	25	.592	
	26	.619	
	27	.599	

5.2 Factor Analysis

Factor analysis was conducted with those factors that passed reliability verification. The number of factor was determined when the eigenvalue was greater than 1, and the common factor was set with a standard factor loading of 0.5. Principal component analysis was used as the extraction model, and the varimax rotation among orthogonal rotation was used for the analysis. Result of the factor analysis of the liveware variables are listed in Table 5 and two factors were derived. Factor 1 was 'Pilots' internal factor' and factor 2 is 'Pilot's capability.'

Table 5. Results of factor analysis of liveware

Question Number	Factor 1	Factor 2
3	**.869**	-.145
2	**.772**	.279
7	**.580**	.298
1	**.521**	.030
4	.134	**.788**

6	-.084	**.767**
5	.468	**.690**
Eigenvalue	**2.702**	**1.376**
Variance Ratio	**38.6%**	**19.7%**
Cumulative Ratio	**38.6%**	**58.3%**

The second human factor was the interaction of Liveware-Software. The results of the factor analysis on variables are provided in Table 6, and two factors are derived, "Adequacy of Flight log book" as factor 1 and "Skipping Checklist" as factor 2.

Table 6. Results of factor analysis of Liveware-Software

Question Number	Factor 1	Factor 2
8	**.787**	.073
12	**.743**	-.110
9	**.668**	.081
11	**.650**	.400
10	.018	**.963**
Eigenvalue	**2.133**	**1.019**
Variance Ratio	**42.7%**	**20.4%**
Cumulative Ratio	**42.7%**	**63.1%**

The interaction of Liveware-Hardware variable's factor analysis result can be found in Table 7. One factor was derived, "Equipments in cockpit."

Table 7. Results of factor analysis of Liveware-Hardware

Question Number	Factor 1
14	**.831**
13	**.794**
17	**.686**
16	**.675**
15	**.657**
Eigen value	**2.679**
Variance Ratio	**53.6%**
Cumulative Ratio	**53.6%**

From the fourth human factor, Liveware-Environment variable, two factors were derived through the reliability analysis. The analysis results are listed in Table 8: factor 1 was "Organizational culture" and factor 2 was "Weather/obstacle."

Table 8. Results of factor analysis of Liveware-Environment

Question Number	Factor 1	Factor 2
21	**.864**	.061
22	**.795**	.187
20	.039	**.872**
19	.219	**.791**
Eigenvalue	**1.836**	**1.018**
Variance Ratio	**45.9%**	**25.4%**
Cumulative Ratio	**45.9%**	**71.3%**

From the factor analysis of the interaction of Liveware-Liveware, two factors were derived and the results are given in Table 9.
Factor 1 was "Human relationship outside aircraft" and factor 2 was "Human relationship inside aircraft."

Table 9. Results of factor analysis of Liveware-Liveware

Question Number	Factor 1	Factor 2
26	**.904**	.011
27	**.882**	.117
25	**.847**	.188
23	-.023	**.836**
24	.230	**.756**
Eigenvalue	**2.517**	**1.168**
Variance Ratio	**50.3%**	**23.4%**
Cumulative Ratio	**50.3%**	**73.7%**

The values of factors derived from the factor analysis were converted to provide new values that could be used for the analysis of hypothesis verification.

5.3 Hypothesis Verification and Analysis

5.3.1 Hypothesis 1 Verification

The most correlated factors among human factors were Liveware, especially 'pilot's capability,' followed by Liveware-Hardware from the analysis of Hypothesis 1 verification. That can be explained as a student pilots' flight capability, and knowledge of academics and regulations, are critical for training flight safety. 'Equipment in cockpit' is concluded to be associated with an accident hazard; this is presumably the result of students using different aircraft each time. Thus, adaptability and judgment in operate equipment will be significantly related to flight safety.
Finally, the "Weather/obstacle" factor has a correlation of 0.42 with accident hazard because weather and obstacles can be issues with pilots in the case of visual flights. This matter is considered to actually involve in-training flight safety.

Table 10. Hypothesis 1 verification summary

Hypothesis	Measuring Factor	Coefficient correlation	Reference
1-1. Accident hazards and Liveware are interrelated.	**Pilot's internal Factor**	**.494****	**Adopt Hypothesis**
	Pilot's capability	**.513****	
1-2. Accident hazards and Liveware-Software are interrelated.	Flight log data Adequacy	.227*	Reject Hypothesis
	Skipping checklist	.223*	
1-3. Accident hazard and Liveware-Hardware are interrelated.	**Equipment in cockpit**	**.487****	**Adopt Hypothesis**
1-4. Accident hazard and Liveware-Environment are interrelated.	**Organization culture**	.271**	**Adopt some**
	Weather/ Terrain	**.422****	
1-5. Accident hazard and Liveware-Liveware are interrelated.	**Human relationship inside aircraft**	.037	Reject Hypothesis

	Human relationship outside aircraft	-.257**	

** correlation coefficient's level of significance is 0.01.
* correlation coefficient's level of significance is 0.05.

5.3.2 Hypothesis 2 verification

The hypothesis analysis results showed significant differences in "Pilot's internal factor" and "Pilot capability." However, according to average tendency, 'Pilot's capability' is affected more when 'Pilot's capability' is less, due to lower flight experience. However, as "Pilot's internal factor" is larger, it is affected more. This may be explained as more experienced student pilots having difficulties during flights due to lack of management of their own condition.
In pilots having lower levels of flight experience, it is considered that they have difficulties in using flight information and handling equipment appropriately. The "Human relationship outside the aircraft" of the Liveware-Liveware factor showed significant differences; however, looking at the average, there was no tendency as the level of flight experience was lower, so this hypothesis was rejected.

Table 11. Hypothesis 2 verification summary

Hypothesis	Measuring Factor	p-value	Average tendency	Reference
2-1. As flight experience is lower, value of Liveware that affects safety will be greater.	**Pilot's internal Factor**	0.044	Getting smaller	**Adopt some**
	Pilot's capability	**0.005**	Getting bigger	
2-2. As flight experience is lower, value of Liveware-Software that affects safety will be greater.	Flight log data Adequacy	**0.000**	Getting bigger	**Adopt some**
	Skipping checklist	0.175	Getting smaller	
2-3. As flight experience is lower, value of Liveware-Hardware that affects safety will be greater.	**Equipments in cockpit**	**0.039**	Getting bigger	**Adopt Hypothesis**
2-4. As flight experience is lower, value of Liveware-Environment that affects safety will be greater.	**Organization culture**	0.179	No tendency	Reject Hypothesis
	Weather/ Terrain	0.963	No tendency	
2-5. As flight experience is lower, value of Liveware-Liveware that affects safety will be greater.	**Human relationship outside aircraft**	0.367	No tendency	Reject Hypothesis
	Human relationship inside aircraft	0.016	No tendency	

Level of significance is $P < 0.05$.

5.3.3 Hypothesis 3 verification

Hypothesis 3 was analyzed to compare the difference of human factors depending on the characteristics of the student pilots. Only Liveware-Software factor was rejected and others were adopted or adopted partially.

“Pilot’s internal factor” among the Liveware factors showed a statistically significant analysis, indicating that in a group of student pilots, internal factors have great impacts. This is because by student pilots are mentally burdened because their flying is evaluated every time and reflected in their grades.
The analysis also showed that “Cockpit equipment” had an enormous influence on general public student pilots. This may be explained as the general public student pilots fly infrequently; consequently, they relatively rarely use cockpit equipment, compared with other students pilots who are more familiar with cockpit equipment and operation principles. Therefore there are differences between the two types of student pilots.
“Organization culture” in the Liveware-Environment factors showed a statistically significant difference. It was compared according to the characteristic of pilot groups; differences can be seen in the ‘Organization culture.’ Organization culture of the current students was shown to have a greater effect on flights because the relationships between senior and junior, power distances between instructors and students, and military organization are involved in the formation of the organization culture and even affect the actual flights.
It was also seen that there was a significant difference in the “Human relationship inside aircraft” factor. Humans inside the aircraft are instructors and students, and the actual flight performance can vary a lot depending on the students and instructors, as students are affected by the instructor and the relationship can affect training flight safety.

Table 12. Hypothesis 1 verification summary

Hypothesis	Measuring Factor	p-value	Reference
3-1. Value of Liveware that affects safety will differ by pilot organization characteristics.	**Pilot’s internal Factor**	**0.022**	**Adopt some**
	Pilot’s capability	0.536	
3-2. Value of Liveware-Software that affects safety will differ by pilot organization characteristics.	Flight log data Adequacy	0.700	Reject Hypothesis
	Skipping Checklist	0.880	
3-3. Value of Liveware-Hardware that affects safety will differ by pilot organization characteristics.	**Equipments in cockpit**	**0.016**	**Adopt Hypothesis**
3-4. Value of Liveware-Environment that affects safety will differ by pilot organization characteristics.	**Organization culture**	**0.009**	**Adopt some**
	Weather/ Terrain	0.429	
3-5. Value of Liveware-Liveware that affects safety will differ by pilot organization characteristics.	**Human relationship inside aircraft**	**0.036**	**Adopt some**
	Human relationship outside aircraft	0.564	

Level of significance is $P < 0.05$.

6. Conclusions

Human factors in aviation generally have been studied extensively; however, human factors in student pilots have not been studied before. As can be seen in previous studies, there were very strong relationships between accident hazards and human factors. Especially, relationships among Liveware and Liveware-Hardware were strongly related to flight safety. Organization Culture strongly affects humans; even though there was not direct effect on accident hazard, it can, however, be regarded as a potential risk factor for accidents. To improve overall safety in aviation, the aviation industry needs to take human factors seriously as a priority for safety. Thus, airlines in Korea continually strive to prevent any accidents or incidents from human factors through human factor training, such as CRM and LOFT.

However, human factors training in flight training centers currently is far from sufficient to effectively educate students, and student pilots do not recognize human factors as potential risk factors that can lead to accidents in flights. Flight training centers must recognize this issue and must improve and develop further human factors training and education.

To study the effects of human factors on flight safety, it is critical to analyze the degree of human factors influence in actual accidents. Limitations of this study include the lack of training flight accident statistics; accident hazard variables were derived from only the sample subjects' own accidents experiences. Thus, critical factors that can lead to actual accidents could not be included in the analysis. In particular, although skipping checklists can lead to accidents directly, checklist skipping was not significant in the accident hazard analysis in this study. Thus, it is recommended to address this limitation through constantly collecting data on actual aviation incidents and aviation safety barriers that can create accurate accident analyses.

The most critical factor in flight *training* is the interaction between students and instructor. The interaction with an instructor significantly influences student performance. However, an in-depth examination on the interaction between students and instructor was not conducted in this study; thus, it needs to be examined thoroughly in the future to improve training flight safety.

Human factors that can lead to accidents have a significant potential risk that has not been revealed yet. Consequently, a detailed human factors study has limitations. It is clear that the risks related to human factors are greater than the values from this analysis because accidents cannot be predicted. Despite this limitation, a human factors study on training flights was conducted in this study with the intention of improving training flight safety and increasing safety awareness of student pilots. Clearly, further research is required to analyze human factors not only with student pilots, but also flight instructors and other related personnel. Such research can help to enhance overall safety of training flights while meeting the increased training flights demand.

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