國立成功大學
交通管理科學系碩士班

碩士論文

# 航空器駕駛員及飛航管制員
# 溝通疏失與飛航事故之探討
# Pilot–Air Traffic Controller
# Communication Errors and Aviation Occurrences

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Pilot – Air Traffic Controller Communication Errors and Aviation Occurrences

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# Abstract

The demands for air transportation keep growing steadily and issues of flight safety are the most important. Human factors are the main reasons for air incidents and accidents, of which pilot-controller communication error is one of the noticeable issues.

Most studies addressed this issue with international statistical data, not personal experiences of pilots and controllers in Taiwan. From the subjective results of a questionnaire survey, this study first examined which factor may lead to which communication errors, and next found out which communication error may cause specific aviation occurrences. Third, comparing different results between pilots and controllers and finally this study provided practical implications and suggestions.

By Exploratory Factor Analysis, this study extracted five factors, including workload, linguistic factors, pilot anticipation, similar call sign, and frequency change. Besides, this study found two communication errors as readback and hearback error and no pilot readback, and two main aviation occurrences, including runway incursion and altitude/heading deviation. From pilots' viewpoints, the significant factors comprised workload, pilot anticipation, and frequency change, whereas controllers think those are linguistic factors, pilot anticipation and similar call sign. Furthermore, this study found the different relations between communication errors and aviation occurrences based on pilots and controllers' opinion. All results suggest pilots and controllers, airlines and government focus on the factors and improve to avoid communication errors and aviation occurrences.



**Key words: pilots, air traffic controllers, communication errors, aviation occurrences, Multiple regression analysis**

# 摘要

在航空運輸穩定成長之趨勢下，飛航安全是最要之課題。就飛航事故而言，人為因素是造成航空器意外事件以及失事之主要原因，其中有關航空器駕駛員以及飛航管制員之溝通疏失為顯著的議題。

對於航空器駕駛員與飛航管制員溝通之多數研究多為國際上之統計數據，而非以駕駛員及管制員之個人經歷與感受作為調查依據，同時此議題之研究於台灣地區亦較為缺乏。本研究以航空器駕駛員與飛航管制員之觀點透過問卷填答，探索特定原因造成特定溝通疏失，而進一步造成特定之飛航事故。並比較駕駛員以及管制員對於此原因、疏失以及事故關係結果之不同，最後針對研究發現提供結論與建議。

藉由探索性因素分析，本研究萃取五項駕駛員與管制員溝通疏失之常見原因，包含工作負荷、言語因素、駕駛員期望、相似呼號以及頻率轉換；兩項主要溝通疏失，包含覆誦與覆聽錯誤以及駕駛員無覆誦；兩項主要飛航事故，包含跑道入侵與高度/航向偏航。結果顯示駕駛員認為工作負荷、駕駛員期望以及頻率轉換顯著與溝通疏失有關聯；而管制員則認為言語因素、駕駛員期望以及相似呼號為顯著有關因素。接著本研究找出駕駛員與管制員溝通疏失與各種飛航事故之關係。依據研究結果，本研究提供航空器駕駛員、飛航管制員、航空公司以及政府機關減少駕駛員與管制員溝通疏失以及飛航事故之意見，以保障飛航安全。

**關鍵字：航空器駕駛員、飛航管制員、溝通疏失、飛航事故、多元迴歸分析**

# 誌謝

又到了六月，鳳凰花開滿街道的季節，碩二的我要畢業了，學生身分就要告一段落。時光飛快，彷彿踏入成大校園不過是昨日之事，如今即將離開，內心充滿著不捨與感恩。

首先，非常感謝我的指導教授張有恆教授，不僅交給我豐富的知識以及給予論文的各項協助，更時常關心我的生活以及教導我待人處事的道理。其中，老師常提到的「三千萬」：千萬要利他、千萬要感恩以及千萬要謙虛，是人生中所要不斷提醒自己的處事箴言。帶著老師的祝福以及提點，未來不論工作或生活上我都會付諸施行，越自己，造福他人。此外，感謝高星潢資副、賴明輝副總、李宏鳴督導、郁蓉學姐以及所有問卷填寫者的大力協助，使我的論文問卷設計與發放相當順利。也非常感謝楊慧華教授以及鄭永祥教授細心審閱我的論文並提出建議，讓內容更臻完備。

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翊暉 謹致於成大交管 62403 室

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# Chapter 1 Introduction

## 1.1 Research background and motivation

As aviation transportation has become an essential carrier for international travel, demands for air transport maintain a steady growth. International Air Transport Association (IATA) 20-year passenger forecast (2016a) predicted that air passengers would grow from 2016's 3.8 billion to 2035's 7.2 billion as nearly doubled. Crabtree et al. (2016) also forecasted in a Boeing's report that global air cargo traffic would increase from 223 billion RTKs in 2015 to 509 billion RTKs in 2035. This suggests the rising dependency on air transportation, leading to more intensive flow of air traffic in the sky. Flight safety at the same time is a foreseeably more noteworthy issue in this trend. It relies on the perfect communicative cooperation between pilots and air traffic controllers (abbreviated as "controller") to prevent from conflicts and accidents. Human factors are majority of incidents and accidents in civil aviation, and communication is one of this kind of factors which includes many phases of problems. Among these problems, communication error between the pilot and controller plays an important role (IATA, 2016b).

Because pilots and controllers are unable to talk face-to-face during flight time, communication can be done with voice messages exchanging via radiotelephones and controller-pilot data link communications (CPDLC) with texted words. As CPDLC is currently a supplement for some routine voice communication (FAA, 2016a), pilots and controllers still contact orally. This can be explained as voice is more temporal and often more salient than the visual modality (Sorkin, 1987). Also, voice clearance may draw a more immediate response (Lozito et al., 2003).

In line with continuous increase of air traffic volume nowadays, the oral transmitting channel may be congested on the same frequency to make effective pilot-controller communication more difficult, where is the hotbed for communication errors. What are more noticeable are that much research found other critical factors which also affects communication, included linguistic factors (accent, multiple instructions, and non-standard phraseology), workload, call sign confusion, pilot expectation, blocked transmission, frequency change, etc (Cardosi et al., 1998; Van Es, 2004; Wever et al., 2006; Geacar, 2010; Barshi & Farris, 2013; Cummings, 2013; Molesworth and Estival, 2015). Most of these studies followed the factor-error-occurrence framework to explore the causal relation that different factors can result in different communication errors and continue to cause undesired states as incidents, and finally, if worse, lead to accidents with fatalities. The incidents and accidents, according to International Civil Aviation Organization (ICAO) (2013), belong to "Aviation occurrence", this research thus adopts this phrase to stand for all the results of communication errors. A worldwide known aviation occurrence is Tenerife disaster, the deadliest accident in aviation history, which was a runway incursion from the miscommunication due to readback with non-standard phraseology, pilot expectation and high workload, finally leading to the collision of two heavy aircraft, taking 583 people lives away.

Many new technologies have been continuously innovated and tested to upgrade the efficiency and capability of global air traffic system, of which the reduction of communication errors of pilots and controllers is indispensably included. CPDLC DCL (Departure clearance) with texted messages exchanging decreases pilots and controllers' workload, frequency congestion, and provides visual transmission to prevent errors. The other example is an innovation now under tested named AcListant, with automatic speech recognition to follow pilot-controller communication and support arrival manager systems for any timely deviation of the instructions, lowering controllers' workload and ensuring the efficiency of communication (Hartmut et al., 2016). However, oral messages exchange is still the main way of pilot-controller communication, breakdown keeps inevitable and should definitely be faced squarely.

Although pilots and controllers share the responsibilities for upholding flight safety, they respectively have their own profession and errands. Global Aviation Information Network Working Group E (2004) pointed out that responsibilities and operational priorities of pilots and controllers are different. One of the reasons is that pilots are trained to act in order as "aviate, navigate, and communicate". However, controllers place their priority on "communication", which is the means for them to exercise their job responsibilities. Therefore, the experiences and memories of pilots and controllers are different and their perceptions of each other's workplace environment, motivations, responsibilities, or expectations are often inaccurate and incomplete. It can be inferred that pilots and controllers possess different viewpoints on communication error issues.

IATA Annual Review (2016c) indicated that aviation's center of gravity keeps shifting eastward. One of the evidence is that seven of the top ten increasing origin-destination passenger markets were located in Asia in 2015. Taiwan is an important local hub in East Asia, and main airlines in Taiwan have various route services directed around the world (Chang et al., 2015). The 2015 Annual Report of Taiwan Air Navigation and Weather Services (ANWS) (2016) pointed out that recently, total flights of air traffic control (including all area control, approach control, and aerodrome control) in Taiwan remain increasing, and Figure 1.1 shows this trend. In pace with the gradually denser air traffic, it can be inferred that the occurrences of communication errors between pilots and controllers may rise as well.

Many related aviation occurrences in Taiwan reported previously do show the potential threats to safety. An example is the case from TAiwan Confidential Aviation safety REporting system (TACARE), an altitude deviation occurred due to pilot expectation and the absent pilot’s readback. Another case is the Antonov-124 runway incursion (CAA, 2010) owing to controller’s workload, leading to the incapability of correcting the pilot’s problematic readback. These incidents in fact had big chances to develop to more severe situations, which should really be focused on and avoided. Therefore, as now the communication errors are predicted to increase, it’s imperative to explore the factor-error-occurrence relation on this urgent issue and develop strategies to improve the quality of pilot-controller communication for flight safety.

Here is still little research on pilot-controller communication errors in Taiwan, and many foreign studies on this topic often do statistical analysis with real data reported which are events from the same region. Objective result is the merit of this method, Nevertheless, evidences based on limited number of reports cannot embody the true feeling of pilots and controllers. Besides, statistical data were lacking in Taiwan and circumstances in foreign countries are not necessarily consistent with that in Taiwan. Hence, this study tries to conduct a survey of pilots and controllers having frequent duties in Taiwan to find out the factor-error-occurrence relationship according to their experiences and professional opinions, and furthermore, to see if there is any cognitive difference between pilots and controllers on this communicative issue, and finally, to check if there is any different result from past data and research.

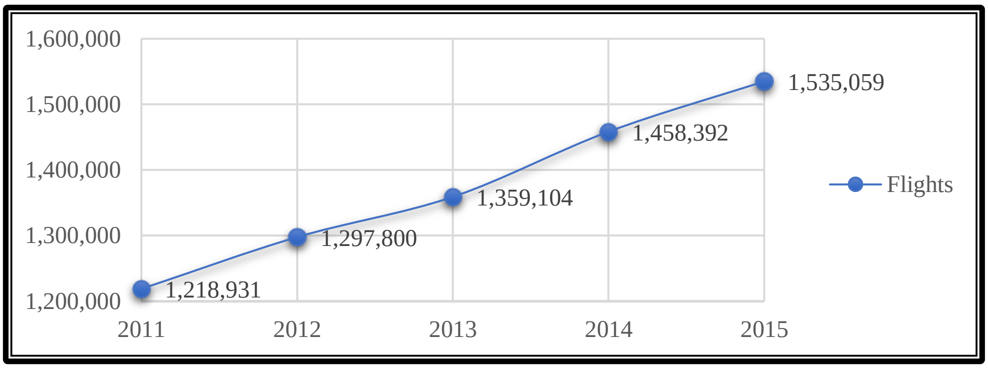


Figure 1.1 Total flights of air traffic control from 2011 to 2015
Source: ANWS, CAA, MOTC (2016)

## 1.2 Research purpose

Based on the background and motivation, this study mainly focuses on the relationship of the contributory factors and types of pilot-controller communication errors, and related aviation occurrences. The purposes of this research are listed as following:

(1) To explore the common contributing factors of pilot-controller communication errors, types of communication errors, and related aviation occurrences.

(2) To explore the significant difference between the cognition of pilots and controllers to the factors, communication errors, and occurrences.

(3) To verify the significant factor-error-occurrence relationship with line-operating pilots and controllers based on their experiences and professionally viewpoints through a questionnaire survey.

(4) Based on the results, understanding the current frequencies of the factors, communication errors, and aviation occurrences related to the errors to provide

suggestions for pilots, controllers, airline carriers, and government authorities, thereby to improve the flight safety.

## 1.3 Research scope and object

The sample population in this study is researched from air traffic controllers in Taiwan and pilots of Taiwan main airlines by the questionnaire method. The questionnaires are all done with papers. It is planned to distribute 100 questionnaires for pilots and 40 questionnaires for controllers. Sample population of pilots are divided into native and foreign, whereas all controllers are native in Taiwan and include area, approach, and tower control.

## 1.4 Research procedure

Based on the purpose of this study, the research procedure is constructed as shown in Figure 1.2.

Chapter 1 states the importance of exploring the factors-error-occurrence relationship of pilot-controller communication as the background and motivation, and defines scopes and objects. Chapter 2 introduces pilot-controller communication process and lists the factors, communication errors between two sides, and related occurrences of according to several related literature reviews, international aviation associations and authorities' suggestions. Besides, it provides some case studies and analyze the pilot-communication error in each incidents and accidents as a verification of the factors, errors, and occurrences listed in the previous section. Adopting the factors, errors and occurrences selected, the third stage is to establish the framework, hypothesis and methodology and at the same time design the questionnaire with experts' advices. After the completion of formal questionnaire, it is distributed to controllers and airlines' pilots. In Chapter 4, an empirical analysis is conducted to understand the results of the questionnaire. The final step includes the overall conclusions and contributions as well as some suggestions for improvement in the future.

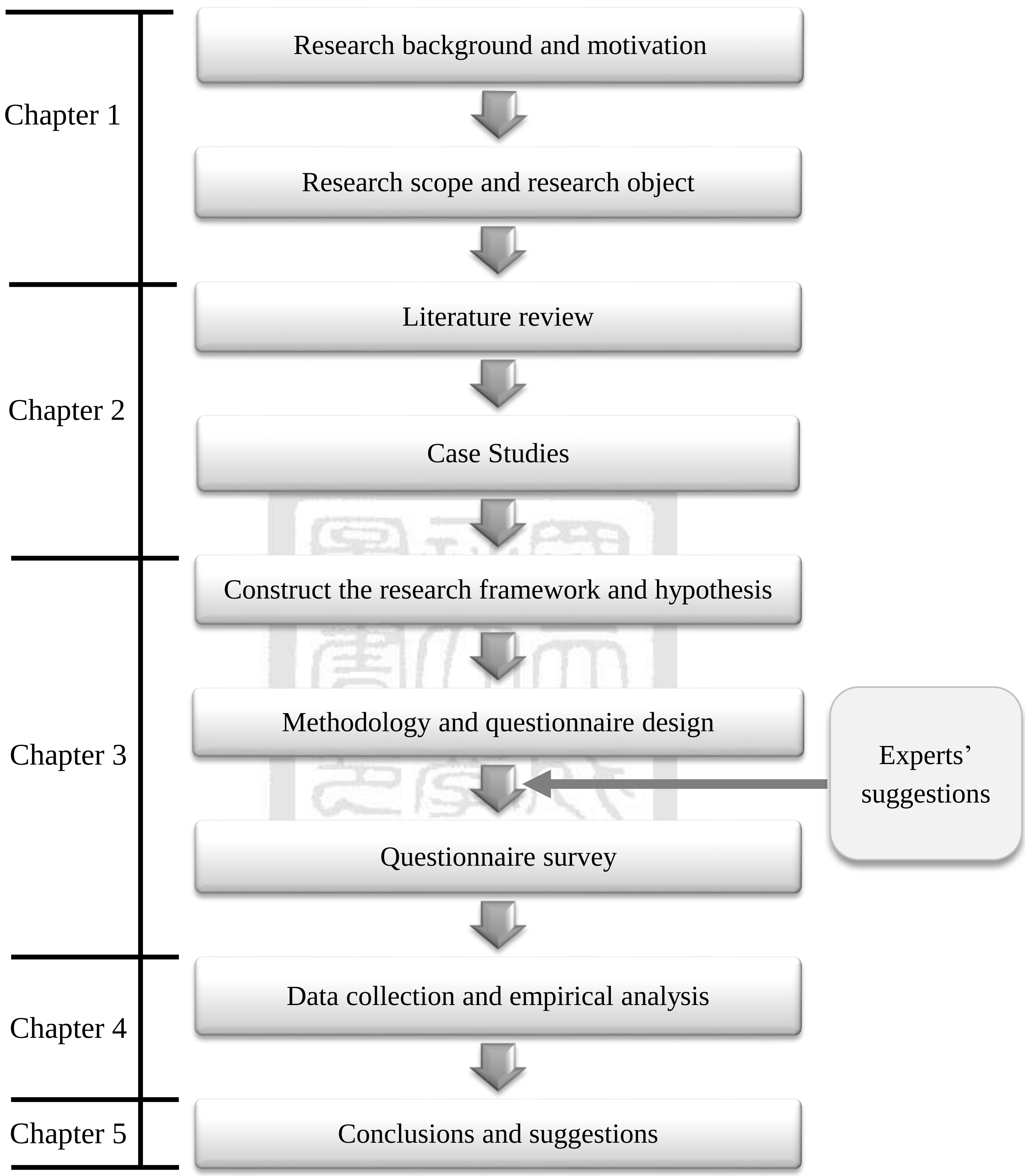


Figure 1.2 Research procedure

# Chapter 2 Literature Review

This study mainly focuses on the communication errors between pilots and air traffic controllers, and the related aviation occurrences result from the errors. Therefore, five sections are in this chapter. The first section introduces the definitions and job characteristics of a pilot and an air traffic controller respectively, and the relationship between two sides. The second section introduces the communication process and the communication errors, and then discusses the types of pilot-controller communication errors. The third section introduces the factors of pilot-controller communication errors and the related aviation occurrences. The fourth section summarizes the causal connection of the communication errors and the occurrences mentioned in the previous sections. Finally, the last section reviews several incidents and accidents cases and explores the factor-error-occurrence relation.

## 2.1 Definitions, job characteristics and relationship

### 2.1.1 Definitions and job characteristics of pilot

(1) Definitions of pilot

According to ICAO Annex 1 (2011), the definition of Flight crew member “*is a licensed crew member charged with duties essential to the operation of an aircraft during a flight duty period.*” On the other hand, the annex defines pilot as “*To manipulate the flight controls of an aircraft during flight time.*”

Taiwan Civil Aeronautics Administration (CAA) Aircraft Flight Operation Regulations (2016) defined Single flight crew as “*A composition of flight crew during aircraft flight time no less than the required by the flight manual for that type of* *aircraft. It shall include a pilot in command, a co-pilot and a flight engineer if applicable.*" Besides, Aircraft pilot is defined by Taiwan CAA Regulations Governing Licences and Ratings for Airmen (2015) as "*The person conducting the flight operation of an aircraft, who is the holder of appropriate type rating and valid medical certificate. A licensed pilot includes pilot in command and co-pilot.*"

Flight crew members are often thought to be inclusive of pilots, flight engineers, and cabin crew members. To avoid confusion, this study therefore adopts "Pilot" to represent every civil air transport pilot, setting the subject accurately.

(2) Job characteristics of pilot

Pilot in command refers to "*The pilot designated by the operator, or in the case of general aviation, the owner, as being in command and charged with the safe conduct of a flight*" (ICAO, 2011). The Federal Aviation Regulations / Aeronautical Information Manual (FAR/AIM) (2017) defined pilot in command as "*The person who：(1) Has final authority and responsibility for the operation and of the flight. (2) Has been designated as pilot in command before or during the flight. (3) Holds the appropriate category, class, and type rating, if appropriate, for the conduct of the flight.*" Summarizing the references above, pilot in command is the leader of the flight crew members on an aircraft, and is given the highest authority and responsibility for the safe operation during the flight.

Jeppesen (2017), a Boeing Company, provided numerous and professional air transport pilot training courses, as communication and air traffic control (ATC) courses are two of them. Besides, English is currently the most wide-used language among air community. Therefore, apart from the courses, personnel trying to become an air transport pilot, has to meet ICAO Operational Level 4 in pronunciation, structure, vocabulary, fluency, comprehension and interactions (ICAO, 2009), and meanwhile be able to communicate effectively in voice-only with telephone or radiotelephone and in face-to-face situations (ICAO Annex 1, 2011).

Crew resource management (CRM) is a necessary process in contemporary pilot training around the world. Originated from the reflections of air accidents result from human factors, CRM is the effective utilization of all available resources to achieve safe and efficient operation. The goal is to strengthen the communication and management skills of the flight crew member concerned (EASA, 2014). Currently, one of the CRM definitions includes all groups routinely working with the cockpit crew involved in decisions required to operate a flight safely (FAA, 2008a). Obviously, the groups include air traffic controllers, whom pilots keep communicating with during the flight duty.

### 2.1.2 Definitions and job characteristics of air traffic controller

(1) Definitions of air traffic controller

FAR/AIM (2017) defined air traffic control (ATC) as "*A service operated by appropriate authority to promote the safe, orderly, and expeditious flow of air traffic.*" Taiwan CAA Regulations Governing Licences and Ratings for Airmen (2015) defined air traffic controller as "*Licenced public service personnel who holds on appropriate type rating and valid medical certificate authorized to perform a safe, orderly and expeditious control service to facilitate the pilot accomplishing a flight.*"

This study adopts "controllers" as representation for all the members involved in the ATC system communicating with pilots.

(2) Job characteristics of air traffic controller

ATC is responsible for the safe and efficient flow of air traffic in and out of airports that are served by control towers, and enroute between airports (Barshi & Farris, 2013). In order to accomplish the responsibilities mentioned above, according to Belobaba et al. (2015), ATC provides four basic services as Separation assurance, flight information (e.g., weather reports and renewed airports conditions), search and rescue, and finally, congestion management. Besides, ATC has generic elements which are surveillance, communication, and navigation system. The communication system is for controllers' issuances of instructions and clearances. Recently, "Air Traffic Management" (ATM) has been more widely used than "air traffic control." EUROCONTROL (2017) categorized three distinct activities in ATM which include air traffic control, and the other two activities are "Air Traffic Flow Management" and "Aeronautical Information Services."

The training of an air traffic controller based on EUROCONTROL (2008) is divided into four stages which are initio, unit, continuation, and development training. One of the basic initial training courses is communication, for ensuring that the ATC communication is effectiveness in all circumstances. Besides, same as pilots, a person has to meet ICAO Operation Level 4 English standard to be qualified as an air traffic controller.

Motivated by the CRM for pilots, Team resources management (TRM) emerged to be the strategies for the best use of all available resources to optimize the safety and efficiency of air traffic services. The resources include information, equipment and people. As "people" resources mentioned here, it represents the teamwork of the

ATM system, which not only includes the controllers' cooperation with each other but also that, an essential issue, between controllers and pilots (EUROCONTROL, 1996).

### 2.1.3 Relationship between pilot and controller

For the purpose of fulfilling the responsibility for keeping the safety and efficiency of air traffic, controllers use voice-over radio to communicate with pilots (and recently some vocal messages are replaced by Controller–pilot data link communications, as known as CPDLC). Controllers issue instructions or clearances to provide pilots the information such as altitudes, speeds, navigation directions, real-time and forecasted weather, and the air traffic flow. As pilots, especially the pilot in command, is responsible for the operation and the comprehensive safety of an aircraft, unless the instructions and clearances would have potential occurrences, putting the aircraft and its occupants in danger, pilots should follow the instructions and clearances issued by controllers (Barshi & Farris, 2013).

FAA Aeronautical Information Manual (2014) provided the procedures for controllers and pilots in the ATC Communication, and are listed below：

(1) Pilots

(i) Acknowledges receipt and understanding of an ATC clearance.
(ii) Reads back any hold short of runway instructions issued by ATC.
(iii) Requests clarification or amendment, as appropriate, any time a clearance is not fully understood or considered unacceptable from a safety standpoint.
(iv) Promptly complies with an air traffic clearance upon receipt except as necessary to cope with an emergency. Advises ATC as soon as possible and obtains an

amended clearance, if deviation is necessary.

(2) Controllers

(i) Issues appropriate clearances for the operation to be conducted, or being conducted, in accordance with established criteria.

(ii) Assigns altitudes in IFR clearances that are at or above the minimum IFR altitudes in controlled airspace.

(iii) Ensures acknowledgement by the pilot for issued information, clearances, or instructions.

(iv) Ensures that readbacks by the pilot of altitude, heading, or other items are correct. If incorrect, distorted, or incomplete, makes corrections as appropriate.

The careful coordination between pilots and controllers is critical to flight safety, the correctness, completeness and clearness of the information exchange between two sides therefore are the key points to achieve the good coordination.

## 2.2 Communication process and communication error

This section first presents the communication process model, and then introduces in what situation communication error would occur, and at last, discusses the types of pilot-controller communication error.

### 2.2.1 Communication process

Communication is "*An interaction, involving two or more participants, in which information is transmitted, with the sender having the intention to change the knowledge state of the receiver*" (Doherty-Sneddon, 1995). This communicative act can be said to have been accomplished when the relevant mental representations of the participants have been aligned. Individual, group, or organization are unable to exist without sharing meaning among its members (Robbins & Judge, 2012). As a result, we convey information and ideas.

David K. Berlo (1960) postulated a famous model of communication named Sender-Message-Channel-Receiver (SMCR) Model which is an extent of Shannon and Weaver's Model of Communication (1949). Figure 2.1 presents the communication process extracted from Berlo’s model. According to the figure, a communication process is from the sender encoding the message, then sends it through a channel (medium) to the receiver, and decoded by the receiver as final. The model presented a one-way information transmitting process, which was improved by many studies afterward.

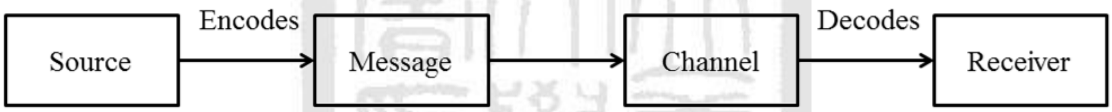


Figure 2.1 Berlo’s Communication Process
(Berlo, 1960)

Robbins and Judge (2012) indicated that communication is not merely unidirectional message imparting. The message must also be understood. Communication must include both the transfer and the understanding of meaning, making the communication effective. In other words, effective communication is a two-way process that requires effort and skill by both sender and receiver (Lunenburg, 2010). To verify that the receiver understands, believes and accepts the sender’s message, giving feedback to the sender plays an essential role, as the receiver transforms into the sender, encoding the message to response. Additionally, it is inevitable of noises and barriers obstructing the communication process, leading to the failure of information sharing. Thus, these negative elements should also be included in the communication model. Figure 2.2 shows the communication model constructed by Robbins and Judge (2012) in the study of organizational behaviors. Based on Berlo's model, they added issues of noise and feedback to the process, and it was referred by many study fields.

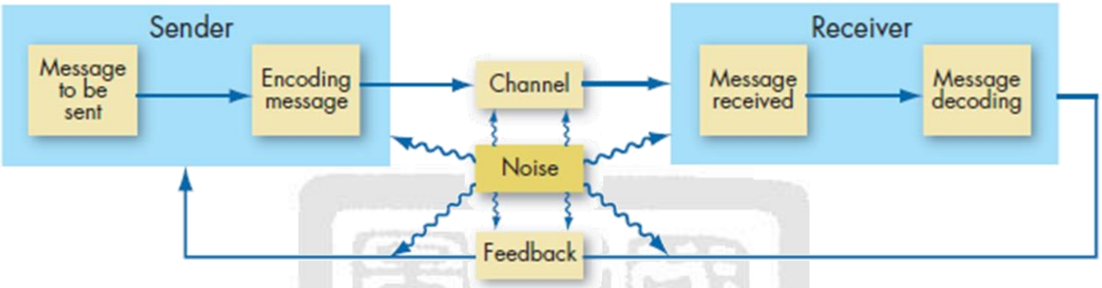


Figure 2.2 Robbins and Judges' Communication Process
(Robbins and Judge, 2012)

Sets pilots and controllers into the process：

(1) Sender and Receiver

Communication must involve two or more participants, the sender and the receiver is controller and pilot, while the sender-receiver role doesn't maintain but keep exchanging during the process.

(2) Encodes and Decodes

Instructions, clearances, weather or airport information, etc. which a controller intends to transmit to a pilot, would be encoded to symbols and words, then the pilot would realize the given message through decoding and translating it into controller's original intention. When effective communication is at work, what the pilot decodes is what the controller sends (Zastrow, 2001).

(3) Channel

A channel is a place through which the message is exactly sent to the receiver. Currently, voice with radio contact is the main channel for the communication between controllers and pilots, while sometimes texts with data link plays coefficient channel to support the congested frequency situation.

(4) Feedback

After receiving and understanding the messages from the controller, the pilot changes to the sender, conveying the responsive messages back to controller, as it is so-called “readback”, which is a procedure for the controller acknowledging the pilot’s comprehension of his or her own intention.

(5) Noise

Noise represents communication barriers that distort the clarity of the message, increasing the possibilities for pilot-controller communication error. The detail will be discussed in the next subsection.

An effective communication depends on pilots’ and controllers’ good operation of both encoding and decoding. That is the reason for global regulation of standard phraseology of pilot-controller radio contact to make coding methods as similar as possible. Apart from the coding issue, giving feedback to the sender is also an indispensable element to the success of communication. Once the controller confirms the pilot’s understanding the instruction or corrects pilots’ misunderstanding through the readback, the corresponding action of the pilot can be foreseen as meeting flight safety. Figure 2.3 shows a pilot-communication loop that embodies the communication process.

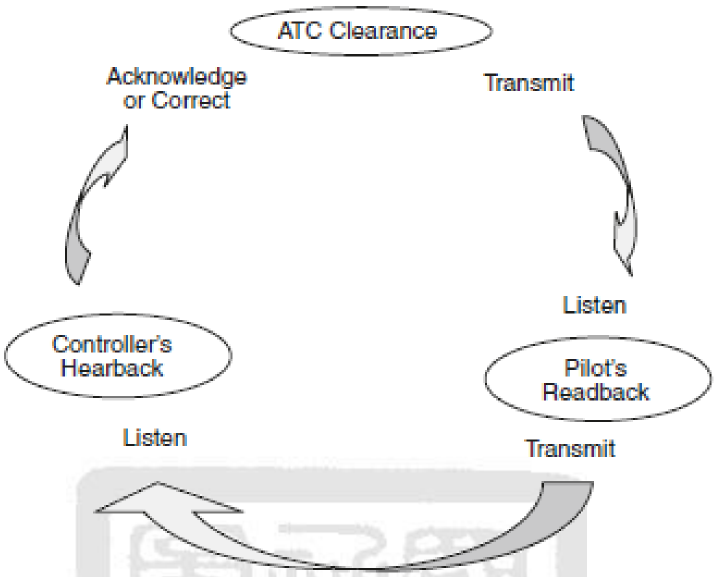


Figure 2.3 Pilot-controller communication loop
(Flight Safety Foundation, 2000)

### 2.2.2 Communication Error

A breakdown in the communication process may occur if the intended message was not encoded or decoded properly (Baron, 2010). Communication error takes place and contributes to miscommunication if there are discrepancies between the mode of encoding and decoding, showing a distorted and ineffective communication result. However, problems not merely at the coding-involved steps but at every link can be related to communication error. This is attributed to barriers interfering with the communication process, and collectively known as “noise” in Robbins and Judges’ model. Every step in the model is likely to be the place where barriers exist, and the six common barriers are classified by Robbins and Judge (2012) as filtering, selective perception, information overload, emotions, language, and silence.

Because pilots and controllers are not visible to one another, they are unable to rely on visual cues to facilitate communication (Uplinger, 1997). Flight Safety Foundation (FSF) states that until data link comes into widespread use, pilot-controller contact will depend on voice communications (FSF, 2000a). It is inevitable that communication error takes place in the oral-only communication situation (Wang, 2007).

ICAO Threat and Error Management (TEM) in Air Traffic Control (2005) presented a threat-error-undesired states framework. The framework indicates that threats would lead to errors and would continue to create undesired states and finally bring about air accidents, while the bad consequence can be prevented with efficient management to every link in the framework. Communication error is one of the three basic error categories under the framework, identifying the situation that controller incorrectly interacts with people such as pilot. Set into the framework, pilot-controller communication error is often generated from threats such as high traffic flow or severe weather and it may be followed by undesired states, also known as flight occurrences, that can cause air incidents and accidents. Integrating partial TEM framework and the communication process built up by Tseng (2007) in a study of the cockpit-cabin communication, the occurrence and management of pilot-controller communication error is designed and shown in Figure 2.4. Based on the concept of Figure 2.4, a principal factor-error-occurrence relation of communication error between pilots and controllers is displayed in Figure 2.5.

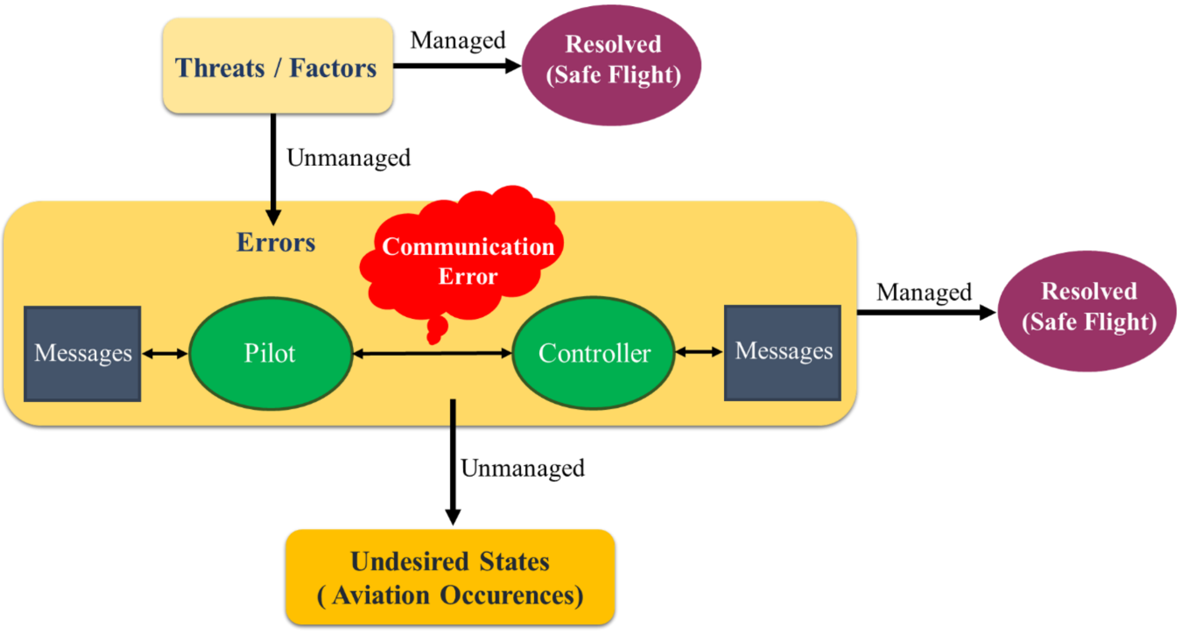


Figure 2.4 Occurrence and management of pilot-controller communication error

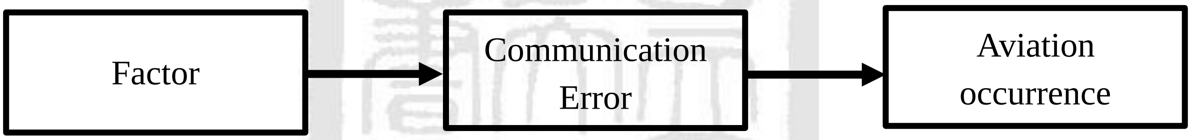


Figure 2.5 Principal factor-error-occurrence relation

An analysis of Aviation Safety Reporting System (ASRS) reports (Cardosi et al., 1998) sponsored by FAA Office of the Chief Scientific and Technical Advisor for Human Factors and two EUROCONTROL air-ground communication safety studies (Van Es, 2004; Wever et al., 2006) collecting data from an occurrence reporting campaign addressing European airlines and Air Navigation Service Providers (ANSP) found common factors of communication errors, the error types, and the related flight occurrences. This study mainly refers to these three materials along with other supplement studies, then integrates and introduces them in the following section of this chapter.

### 2.2.3 Types of pilot-controller communication error

Figure 2.6 displays the distribution of communication error types sorted out in Cardosi et al. (1998) study; Figure 2.7 and Figure 2.8 displays reported communication problems in two EUROCONTROL studies (Van Es, 2004; Wever et al., 2006) of which readback/hearback error, no pilot readback, and hearback error are concentrated on. The summation of main items are not 100 percent in the three figures since three studies all have the "other" category which does not belong any type or which could not be classified due to a lack of information.

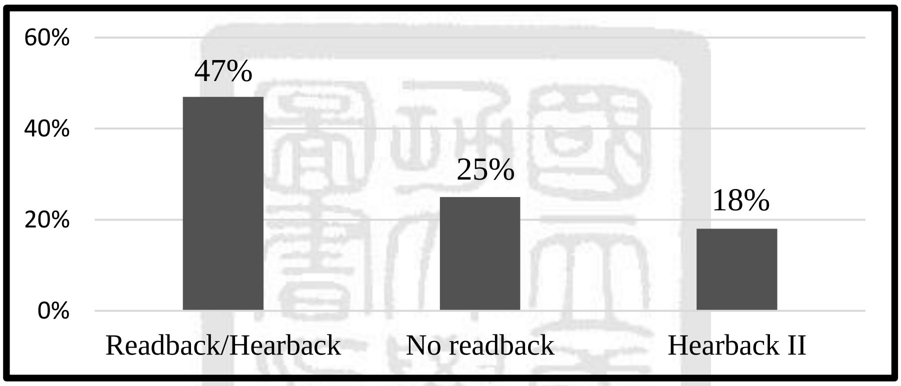


Figure 2.6 Types of communication errors
Source: Cardosi et al. (1998)

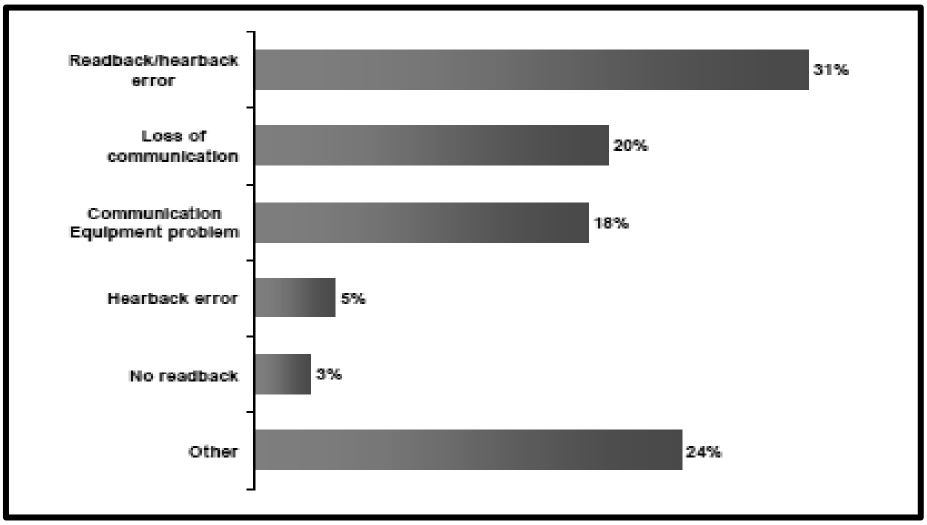


Figure 2.7 Distribution of generic communication problems
Source: Van Es (2004)

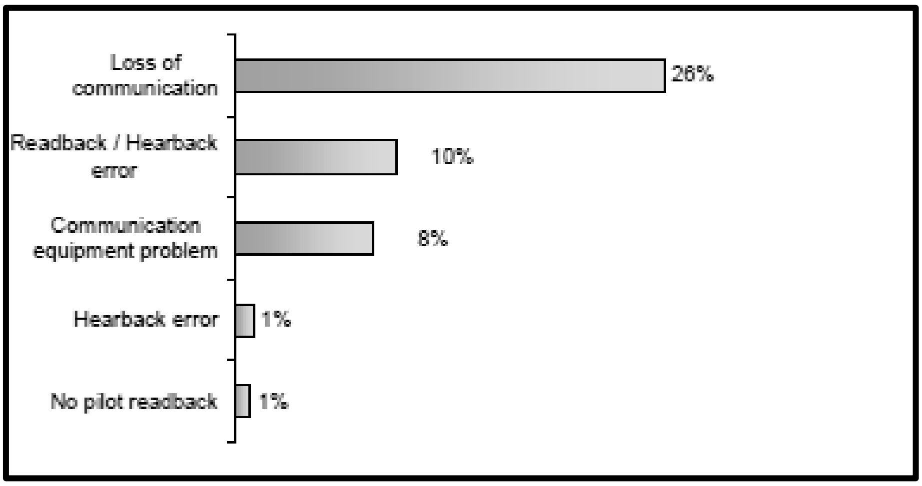


Figure 2.8 Reported communication problem
Source: Wever et al. (2006)

(1) Readback/Hearback error

*The pilot reads back the clearance incorrectly and the controller fails to correct the error* (Cardosi et al., 1998). Following is an example:

The controller said: "XXX 321, climb and maintain one one thousand," then the pilot read back "Roger, climb and maintain one *zero* thousand, XXX321." This is an readback error at first because the pilot should have responded as 11000 for altitude. If the controller did not notice and correct the error, the second error as hearback error would be formed. Consequently, the errors in two steps combine into the readback/hearback error. It is more prone to happen on a congested frequency, for the controller has no chance to correct the pilot's wrong response (EUROCONTROL SKYbrary, 2013). As the figures present, this is the most common pilot-communication errors, and it would result in various flight hazards.

(2) No pilot readback

*A lack of a pilot readback. The pilot does not indicate to the controller that he/she understands the clearance by repeating (reading back) the message* (Wever et al., 2006). This error also includes the situation that pilots responds with partial (i.e. only with "ROGER" or "WILCO") instead of the full safety-related parts of ATC clearances and instructions which must be always read back (ICAO, 2007a). The safety-related parts include runway in use, heading and speed, clearance and instruction to enter land and take-off on, hold short of, cross or backtrack on a runway, etc (Airbus, 2004). Congested frequency, in which is hard to break in the continuous transmission exchange and pilot's complacency can lead to this error (Cardosi et al., 1998).

(3) Hearback error

*The controller fails to notice his or her own error in the pilot's correct readback or fails to correct critical erroneous information in a pilot's statement of intent* (Van Es, 2004). Hearback II in Figure 2.5 stands for the same meaning as hearback error. An instance is provided as a controller issued a left turn instruction while a right turn is intended, and the pilot read back "turn left" correctly, but the controller failed to notice and revise. This highlights the importance of controller listening readbacks or statements of intend cautiously to prevent from a series of erroneous results afterward.

## 2.3 Factor and related aviation occurrence of pilot-controller communication error

This subsection first introduces the contributory factors of pilot-controller communication errors, including six common factors and next, it introduces the aviation occurrences related to the errors, including four common occurrences mentioned in literatures.

### 2.3.1 Factor

(1) Similar call sign

An aircraft call-sign is a group of alphanumeric characters used to identify an aircraft in air-ground communications (ICAO, 2013). Most of airline call signs follow one of the rules laid down in ICAO Annex 10 (2001), consisting of the telephony designator of the aircraft operating agency, followed by the flight identification with no condition for permission to be abbreviated. ICAO (2016a) Doc 4444 stated that in radiotelephony, the telephony designator (e.g. KLM511, NIGERIA213) contained in ICAO (2016b) Doc 8585 is used instead of the three-letter designator (UAE, CAL).

Because most aircraft call signs use numeric flight identification, on the same frequency that multiple aircraft call signs with identical airline designators and/or the same or similar numbers can result in call sign confusion (Cardosi et al., 1998). It was the single most contributing factor to communication error in Cardosi et al. (1998), Van Es (2004), and Wever et al. (2006) which can easily lead to readback/hearback error. Several airlines adopt alpha-numeric call sign (e.g. UAE59CG) to prevent call sign confusion, but it is now only prevailing in European Region. A controller is responsible for notifying each pilot concerned when communicating with aircraft having similar identifications (FAA, 2010); on the other hand, pilot shouldn’t be reluctant to correct a call sign discrepancy caused by the controller (Cardosi, 2010) to avoid the occurrence of communication errors.

(2) Workload

*Workload is based on the difference between the amount of resources demanded by the task situation and the amount of resources available by the operator to perform* *in the task situation.* It can be changed by altering the demands of the task on the operator and/or the amount of resources available within the operator (Watson et al., 1996).

Gawron et al. (1989) defined pilot workload with two elements. First, it is “what the pilot is required to accomplish with the aircraft,” which indicates that pilot workload increases with difficulty and the number of tasks. Secondly, “the conditions or circumstances under which the required operation is to be conducted,” suggesting that adverse conditions such as fatigue, severe weather, equipment malfunction, etc. (EUROCONTROL SKYbrary, 2016a). On a congested frequency, it is often hard to communicate with the controller due to the blocked transmission, where pilot workload is thought to be strong because of the necessity to resolve the confusion, and this can also increase controller workload (EUROCONTROL SKYbrary, 2013).

Next, for controller workload, it in response to those task loads will be a function of what he/she brings with him/her to the situation (knowledge, abilities, and skills) and what he/she must do in order to maintain a safe and expeditious traffic flow (Stein, 1985). Air traffic and sector characteristics, i.e. ATC complexity can generate controller workload (Majumdar & Ochieng, 2002). ATC complexity, as the primary factor of controller workload, can be measured by the physical aspects of the sector (e.g., size), or factors relating to the movement of air traffic through the airspace (e.g., the number of climbing and descending flights), or the combination of above two (Mogford et al., 1994). The procedures required in the sector, flight plans of the aircraft, traffic load, weather, and other variables form the basis for the “tasks” the controller must complete (Mogford et al., 1995). ATC complexity increases the workload of the controllers (Majumdar & Ochieng, 2002) because of the inferred result of increased numbers and difficulty of tasks. In addition, severe weather, fatigue, frequency congestion, and equipment malfunction can also strengthen controller workload. (Brooker, 2003; Song et al., 2009; EUROCONTROL SKYbrary, 2013; EUROCONTROL SKYbrary, 2016a).

Increasing the pilots' workload adversely affected their ability to communicate effectively during flight (Molesworth & Estival, 2015). On the other hand, Skaltsas et al. (2013) pointed out that an increase in traffic volume and exchanged messages increases controller workload and fatigue, and thus reduces their capability to respond on-time. According to Cardosi et al. (1998), pilot workload and controller workload inclines to cause readback/hearback error, and controller workload is also the main reason for hearback error, resulting in various flight safety hazards such as altitude deviation, loss of separation, operational errors, etc.

(3) Pilot expectation

Pilot Expectation reflects the expectation bias in ATC. This bias is defined as *Having a strong belief or mindset towards a particular outcome* (EUROCONTROL SKYbrary, 2016b). Pilot expectation is the situation that a pilot hears what he or she expects to hear rather than the actual instruction or clearance issued by the controller (Cardosi et al., 1998).

Pilot expectation can be the result of pilot's over-familiarity with the same route schedules (EUROCONTROL SKYbrary, 2010) When the instructions are different from what is expected, pilots may unintentionally revert to habit in their actions (FAA, 2008b). This situation is reflected by pilots reading back what they thought they might have heard, which can cause readback/hearback error next. Besides, the familiarity with the routine works may engender complacency and pilots therefore do not read back as an acknowledgement to confirm the transmission from the controller, as known as the no readbacks error (Cardosi et al., 1998). Since the expectation may lead to communication errors and further pilot deviation, it's important for pilots to read back the instruction or clearance precisely and be willing to query the controller if there is any difference from what they anticipate (FAA, 2012).

(4) Frequency change

There are many possibilities for errors appearing in pilot-controller communication when a flight changes frequency. These include events such as pilot tuning in the wrong frequency of the receiver on the plane, controller's negligence of handing off the flight to the next controller, and pilot missing a call from the controller (FSF, 2006). The main related communication error due to frequency change was readback/hearback error that it was one of the key factors in both Wever et al. (2006) and Cardosi et al. (1996) studies. An example of the events is that pilot misunderstood correct frequency and read back wrongly, and the controller failed to amend it.

(5) Blocked transmission

Blocked transmission plays an important role in pilot-controller communication error and set the air traffic in jeopardy as well. Appendix 4 of European Action Plan for Air Ground Communications Safety (AGC) published by EUROCONTROL (2006) gave a clear and integral introduction. Blocked transmission can be result from simultaneous transmission or radio interference. Simultaneous transmission is two stations results in one of the two (or both) transmissions being blocked and unheard by the other stations (or being heard as a buzzing sound or as a squeal). Transmissions by two aircraft or an aircraft and ATC at the same time results in a blocked transmission that one or both transmissions will be blocked and not heard. Radio interference includes the events such as unauthorized transmissions or breakthrough from commercial stations leading to reception difficulties or the loss of all or part of a message.

Readback/Hearback error is one of the error type due to blocked transmission. It can make a controller assume that a message received is from a different flight and issues inappropriate instructions (Wever et al., 2006), leading to the conflict of flights. The other error type is no pilot readback as EUROCONTROL (2006) stated that the absence of a readback from the pilot should be treated as a blocked transmission and prompt a request to the pilot to repeat or confirm the message. What's more, increasing amount of air traffic and frequency congestion would enhance the occurrence of blocked transmission to flight safety (Rodgers, 2017).

(6) Linguistic factors

Linguistic problems can also breakdown pilot-controller communication. Barshi and Farris (2013) indicated that these kinds of factors include English proficiency, message length, message composition, rate of speech, accent, etc. Though from the statistical data in Cardosi et al. (1998), Van Es (2004) and Wever et al. (2006), these elements are not the top contributing factors of communication errors (readback/hearback errors are the most obviously related), their significance still manifest as many pilots and controllers in formal surveys emphasized the big issue of linguistic-related events from their experiences (IATA, 2011; Wever et al., 2006).

English proficiency such as using standard phraseology, aids significantly by reducing any ambiguities of spoken language and hence promotes a common understanding among people of different native languages, or of the same native language but using or understanding words differently (IATA, 2011). There would be obstacles to pilot-controller communication if non-standard phrases are used. As a result, ICAO Doc 9432 (2007) as Manual of Radiotelephony provided the standard phraseologies which should be followed in global aviation community. Table 2.1 shows some commonly-used phrases extracted from ICAO Doc 9432.

However, even phraseologies are used correctly, there are still some reasons for communication errors. First, native English speakers in different regions or non-native English speakers have various accents. This increases the difficulty for pilots and controllers to understand each other (IATA, 2011). Second, controllers may increase their speech rate and produce long messages with multiple items to reduce the total number of transmissions (Morrow et al., 1993), but these strategies induce a high potential to pilots' incorrect readbacks (Rantanen & Kokayeff, 2002). Molesworth and Estival (2015) found higher occurrences of communication errors due to four or more items per transmission from the controller. Finally, it was also discovered by Molesworth and Estival (2015) that prosodic features such as transmission without pauses have higher possibilities for communication errors.

Table 2.1 Examples of standard words and phrases

| Word/Phrase | Meaning |
|---|---|
| CLEARED | Authorized to proceed under the conditions specified. |
| ROGER | I have received all of your last transmission |
| READ BACK | Repeat all, or the specified part, of this message back to me exactly as received. |
| STANDBY | Wait and I will call you. |
| WILCO | (Abbreviation for "will comply".) |

Source: ICAO Manual of Radiotelephony (2007)

It is important to pay attention on the frequency congestion problem. It often appears to be associated with many factors leading to communication error such as workload and blocked transmission and increases their effects, Therefore, the threat of this supporter cannot be ignored.

### 2.3.2 Related aviation occurrence

Following is the introduction of aviation occurrences related to communication errors, which are at the last step before the occurrence of an air accident.

(1) Altitude and heading deviation

It comprises pilot actions that deviate from assigned altitudes and headings (FAA, 2013), whereas FSF (2000b) provided more detailed explanation of altitude deviation as a deviation from the assigned altitude (or flight level) equal to or greater than 300 feet. This is the top common flight safety hazard which can be resulted from all three communication errors.

A kind of phenomenon has high relation with altitude or/and heading deviation (Cardosi et al., 1998). That is loss of separation, which occurs when there has not been a clear application of a separation standard (Airservices Australia, 2015) made by pilots, and it often happens right after the altitude or/and heading deviation. ICAO Doc9689 (1998) points out that separation between flights can be applied horizontally and vertically, and most countries follow the standard set by ICAO.

(2) Wrong aircraft

This is about the negative phenomena between instructions and aircraft which can be dichotomized as two groups of circumstances. One is the pilot takes the clearance or instruction that was for another aircraft (FSF, 2000a), which most are caused by readback/hearback error; the other is the controller issues a clearance or an instruction to the wrong aircraft (Cardosi et al.,1998), which may be the results of readback/hearback and hearback error.

(3) Runway incursion

Its definition is "*Any occurrence at an airport involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and take-off of aircraft*" (ICAO, 2007b). FAA Pilot's Handbook of Aeronautical Knowledge (2016) also indicated that runway incursion may be caused by an aircraft during its takeoff and landing as well as crossing a runway hold marking. Most references use "Runway transgression" to identify the runway hazards caused by communication errors (Cardosi et al.,1998; Van Es, 2004; Wever et al., 2006), while its definition by NASA ASRS (2003) is included in runway incursion. Effective pilot-controller communication is paramount to safe airport surface operations (FAA, 2016b), but all three communication errors can beat the effectiveness and increase the possibilities for runway incursion.

(4) Operational error

An Operational error occurs whenever there is a violation of aircraft separation minima resulted from an element within the air traffic system. A violation may involve, two or more aircraft, an aircraft and terrain or obstacles, or an aircraft landing or departing on a closed runway after receiving air traffic authorization to do so (FAA, 2010). This aviation occurrence may be brought about by readback/hearback error and hearback error.

## 2.4 Summary of the factor, error, and occurrence

Based on the literature reviewed, the factor-error-occurrence relationship is summarized as following.

The common contributory factors of pilot-controller communication errors include similar call sign, workload, pilot expectation, frequency change, blocked transmission, and linguistic factors. Next, the common communication errors between pilots and controllers are readback/hearback error, no pilot readback, and hearback error. Lastly, the related aviation occurrences contain altitude/heading deviation, wrong aircraft accepted the instruction or instruction issued to wrong aircraft, runway incursion, and operational error. Table 2.2 shows the inferred factor-error-occurrence relationship according to the literature reviews in this chapter.

Table 2.2 The Factor-Error-Occurrence relationship

| Factor of the error | Error | Aviation occurrence |
|---|---|---|
| Similar call sign | Readback/Hearback error | Altitude/Heading deviation |
| Pilot expectation | | Wrong aircraft |
| Blocked transmission | | Runway incursion |
| Linguistic factors | | Operational error |
| Pilot expectation | No pilot readback | Altitude/Heading deviation |
| | | Runway incursion |
| Workload | Hearback error | Altitude/Heading deviation |
| | | Wrong aircraft |
| | | Runway incursion |
| | | Operational error |

## 2.5 Case studies

This section focuses on case studies of incidents and accidents caused by pilot-controller communication errors from both Taiwan (as domestic cases) and international. Two incidents in Taiwan are discussed. One is from Taiwan Civil Aeronautical Authority's investigation and the other is from TAiwan Confidential Aviation safety REporting system (TACARE) instituted by Aviation Safety Council (ASC). International cases include two accidents of which one occurred in Tenerife and the other was in Alaska. After the description of each cases is a factor-error-occurrence model analysis to indicate how the unfortunate result broke out as a way to explore the connected relation.

### 2.5.1 Case studies in Taiwan

(1) On December 6th 2009, an anonymous pilot reported to TACARE that they made an altitude deviation during the process from TPE Approach to TPE Control.

The air traffic controller instructed the pilots to climb and maintain FL320 and they requested FL380 after a correct readback. The controller first said “standby” and after three minutes, saying” your final level is 340.” The pilots thought it meant that they could continue to climb to FL340 and they did so without any readback or question to the controller. An altitude deviation was found as the controller inform the pilots of FL320, the real clearance given (TACARE, 2009).

The factor-error-occurrence relation of this case is shown in Figure 2.9. In this case, a no pilot readback took place. While the controller had not used modifiers as “expect” or “will be”, the pilots were supposed to check the real instruction and did the right action rather than followed their expectation.

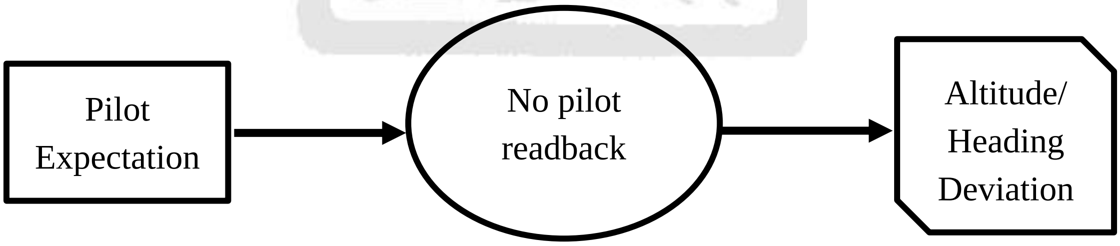


Figure 2.9 The factor-error-occurrence relation of an altitude deviation in TACARE

(2) In the afternoon on July 15th 2010, a runway incursion caused by an Ukrainian Airline (Antonov Design Bureau), an Antonov124, and almost had a collision with a Singapore Airlines, an Airbus A330-300, in Taiwan Taoyuan International Airport, as shown in Figure 2.10.

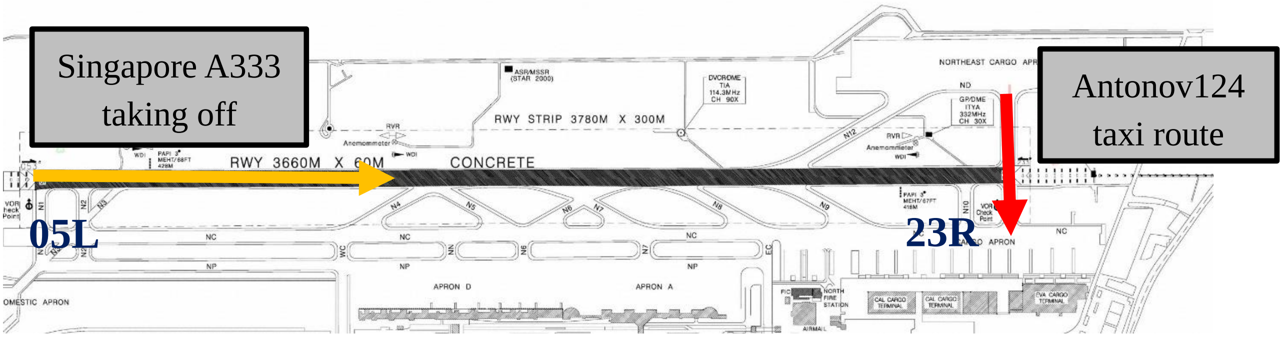


Figure 2.10 Runway incursion caused by Antonov124
Graphic source: AVH/EAIP Taiwan

The pilot of the Antonov124 incorrectly read back as “cleared to cross the runway” instead of the real clearance as “hold short of the runway” issued by the ground controller. The controller did not notice and correct the error in time, and therefore the Antonov124 continued moving on taxiway N13 and crossed at the end of runway 05L. However, at the mean time a Singapore Airlines had cleared its take-off and started rolling. The tower controller noticing the conflict and required ground control to immediately have the Antonov124 keep speed to vacate the runway. Fortunately, when the Singapore Airlines was off the ground at the two thirds down the runway, the Antonov124 had reached the opposite hold short line, escaping from a horrifying collision (CAA, 2010).

This event was a readback/hearback error caused by the incorrect readback of pilots which was not discovered and amended in time by the controller. The investigation states that it may due to the distraction of the controller. It can occur during high workload that controllers appear to reduce attention paid to certain aircraft and variables (Endsley and Rodgers, 1998). Therefore factor-error-occurrence relation of this case can be inferred as presented in Figure 2.11.

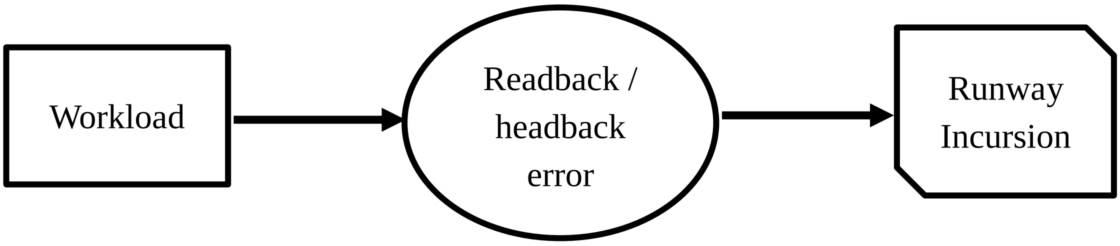


Figure 2.11 The factor-error-occurrence relation of Antonov124's Runway incursion

### 2.5.2 International Case studies

(1) KLM 4805 and PanAm 1736, two Boeing 747 passenger aircrafts, collided in the runway of Tenerife North Airport on March 27th 1977. This catastrophe took away 583 people's lives and now it is still the deadliest accident in aviation history. The process of the collision is displayed in Figure 2.12 where the green line represents Pan Am taxi route, and the orange is for KLM.

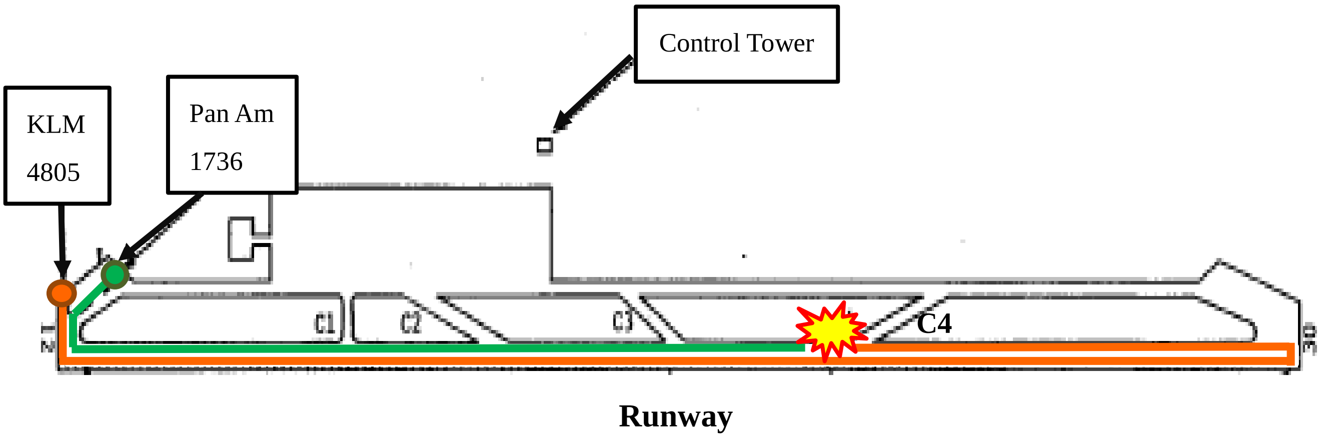


Figure 2.12 Tenerife airport disaster
Source: Air Line Pilots Association (1977)

Because of a bomb explosion at Las Palmas airport, many flights to Las Palmas were diverted to Tenerife Los Rodeos airport. The air traffic at Los Rodeos on that day was unusually congested. After obtaining the news of Las Palmas airport's reopening, all the aircrafts immediately began to depart for their scheduled destination. KLM was first instructed to taxi to the end of the runway and take off on runway 30, and few minutes later Pam Am was instructed to taxi along the quite same route as KLM while it was required to exit runway by “the third taxiway to their left (i.e. C3)” and move on to the take off point via a parallel taxiway. The visibility turned very low during the two aircrafts taxied because of dense fog that neither the two aircrafts could see each other nor the controller was able to see the two aircrafts. The angle of C3 taxiway was too hard for a Boeing 747 to turn, pilots of Pan Am therefore thought “the third” was C4 taxiway since they got the instruction when they are at C1 and felt C4 was much easier. However, the main factor of this disaster was not wrongly using the assigned taxiway, which is stated in next paragraph.

When Pan Am still taxied on the runway, KLM had turned 180 degree, and was asking the clearance for takeoff at Runway 30. The controller gave the clearance of routes after takeoff, but the KLM crew misunderstood that was a permission to go. The first officer therefore readback “…We are now at takeoff.” and released the brake to speed up rolling right after the readback. The controller did not notice the error and considered that readback the report of “at the takeoff position”, and responded “O.K., stand by for takeoff. I will call you.” However, just the standby clearance was given, the crew of Pam Am at the same time declared that they were still taxiing on the runway. The two simultaneous messages intertwined to produce a whistle in KLM’s cockpit, making KLM’s crew not aware of the desperate situation. Even the flight engineer had reminded the captain of the possible conflict, the captain still continued the takeoff, giving no readback with a stable accelerating rolling speed. It was too late when crew on both aircrafts discovered the conflict, leading to a runway incursion and a catastrophic collision in the foggy airport with no eyewitness (ICAO, 1978; Roitsch et al., 1977).

Investigation showed many contributory factors of this serious accident, while the main factors are discussed here. First is the workload. Because of the delay caused by diverting to Tenerife, the captain of KLM was in tension due to the KLM's duty-time regulations, being anxious to takeoff. Besides, the unusually congested traffic volume increased the controller's workload as well as the bad weather degraded the visibility, which made it difficult for the operation of the controller and the crew of both aircrafts. Second, the KLM captain was eager to take off. This made his expectation has bias with the controller's non-takeoff clearance, believing that it was the takeoff clearance itself. Finally, crew of KLM failed to use standard phrases to indicate their intention to go, so the controller mistakenly thought that they were just waiting at the position and did not notice and correct the wrong readback. All the factors above resulted in the main pilot-controller communication error of this accident as a readback/hearback error.

In addition, there was another error: no pilot readback. The blocked transmission resulted from the Pam Am crew's speaking overlapping of the controller's transmission for standby lowering the clarity of signal for KLM crew. The result was KLM crew could not be aware of their unclear takeoff as well as the unclear runway. With absence of the readback, they lost the last chance to give up their deadly action followed by an inevitably fatal runway incursion.

The factor-error-occurrences relation can be divided into two models in this accident as shown in Figure 2.13.

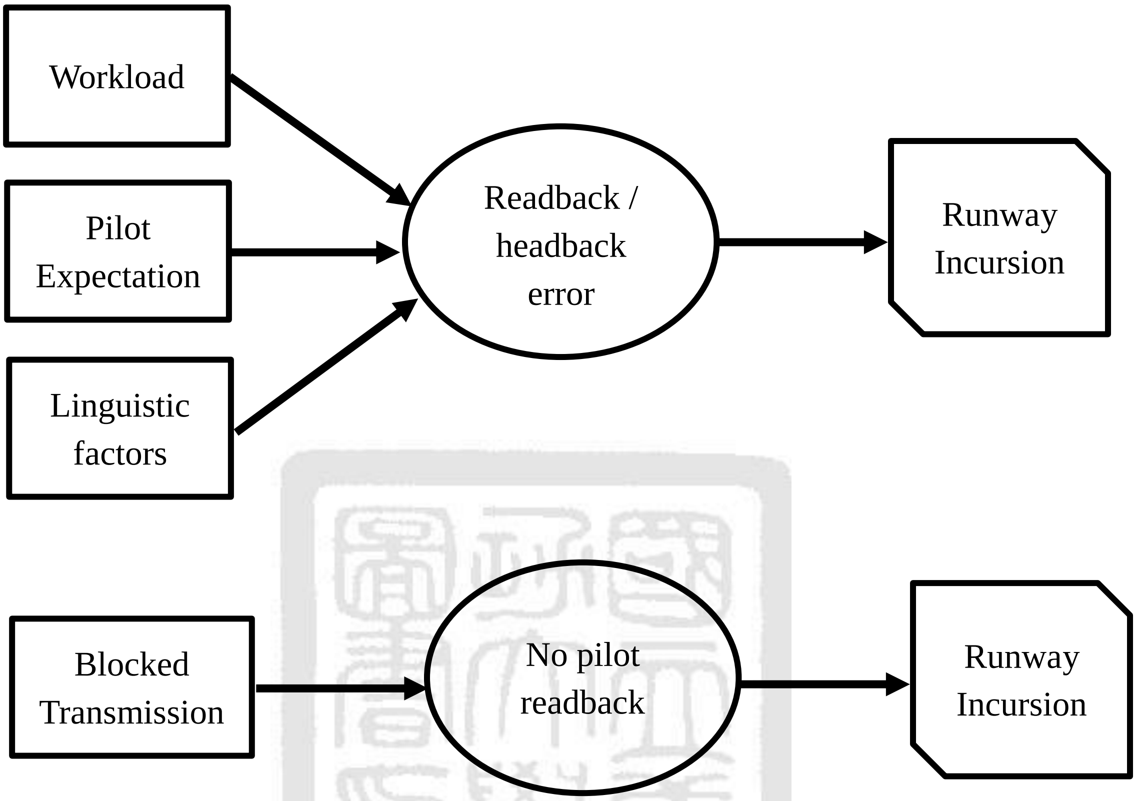


Figure 2.13 The factor-error-occurrence relation of Tenerife airport disaster

(2) On March 8th 2013, a fatal Beechcraft B1900C operated by Alaska Central Express had a controlled flight into terrain (CFIT) accident in instrument meteorological conditions at Aleknagik, Alaska.

From the investigation of National Transportation Safety Board (NTSB), as the aircraft approached the destination, the controller cleared the airplane to fly directly to the IAF followed by the ZEDAG transition and the RNAV/GPS runway 19 approach as the pilots requested. The controller said” maintain at or above 2,000 feet until established on a published segment of the approach,” which should have been stated as “enter the terminal arrival area at or above 5,400 feet.” The ambiguous instruction confused the pilots and they responded incorrectly as “maintain 2,000 feet until established.” Afterward, the descent began, and the controller did not catch the erroneous readback at that time. Flying at 2,200, the crews requested a hold to check the runway situation of destination on another frequency. The controller just replied” as published”, and in fact that location’s published minimum altitude for a hold is 4,300 feet msl, greater than the B1900C’s 2,200 feet. Finally, a collision occurred as the aircraft hit the rising terrain at 2,000 feet msl (NTSB, 2014).

The factor-error-occurrence relation in this case is presented in Figure 2.14. This tragedy was resulted from several phases and here is the discussion of communicative term. It was a readback/hearback error first caused by the controller’s wrong phraseology of the clearance that he should followed FAA’s regulation. This belonged to linguistic factors. The ambiguous clearance mislead the pilots and induced an incorrect read back, while the controller failed to notice and corrected it. The occurrences due to this error was a deviation from the assigned altitude and unfortunately it indeed brought out the calamity.

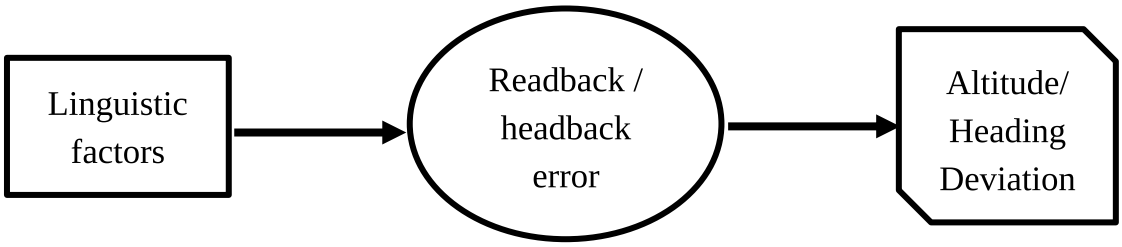


Figure 2.14 The factor-error-occurrence relation of a B1900C’s CFIT accident

### 2.5.3 Case studies conclusion

Based on the cases discussed above, human error factors present large percentage of causal elements in pilot-controller communication errors wherever in Taiwan or other countries. Despite the fact that no accident has occurred mainly associated with this kind of error, the incidents in Taiwan still gave a lesson to focus on this relevant issue. This chapter primarily verifies the factor-error-occurrence relations found in literature review which are summarized in Table 2.3.

Table 2.3 Summary of case studies

<table>
<tr><th></th><th>DATE</th><th>FLIGHT</th><th>LOCATION</th><th colspan="2">FACTOR-ERROR-OCCURRENCE</th></tr>
<tr><td rowspan="6">Taiwan Case Studies</td><td rowspan="3">6 Dec 2009</td><td rowspan="3">Unknown</td><td rowspan="3">Taipei Approach</td><td>Factor</td><td>Pilot expectation</td></tr>
<tr><td>Error</td><td>No pilot readback</td></tr>
<tr><td>Occurrence</td><td>Altitude/Heading Deviation</td></tr>
<tr><td rowspan="3">15 Jul 2010</td><td rowspan="3">Antonov Design Bureau</td><td rowspan="3">Taoyuan Intl Airport</td><td>Factor</td><td>Workload</td></tr>
<tr><td>Error</td><td>Readback/hearback error</td></tr>
<tr><td>Occurrence</td><td>Runway incursion</td></tr>
<tr><td rowspan="10">International Case Studies</td><td rowspan="7">27 Mar 1977</td><td rowspan="7">KLM4805 & Pan Am1736</td><td rowspan="7">Tenerife Airport</td><td rowspan="4">Factor</td><td>Workload</td></tr>
<tr><td>Pilot expectation</td></tr>
<tr><td>Linguistic factors</td></tr>
<tr><td>Blocked transmission</td></tr>
<tr><td rowspan="2">Error</td><td>Readback/hearback error</td></tr>
<tr><td>No pilot readback</td></tr>
<tr><td>Occurrence</td><td>Runway incursion</td></tr>
<tr><td rowspan="3">8 Mar 2013</td><td rowspan="3">Ace Air51</td><td rowspan="3">Aleknagik, Alaska</td><td>Factor</td><td>Linguistic factors</td></tr>
<tr><td>Error</td><td>Readback/hearback error</td></tr>
<tr><td>Occurrence</td><td>Altitude/Heading Deviation</td></tr>
</table>

# Chapter 3 Methodology

According to the literature review, case studies, and the purpose of this study, there are five sections to be presented. The first section is the overall procedure of the methodology. The second section introduces the research framework. The third section is about the development of the research hypotheses and the fourth section introduced the operational definitions and questionnaire items. The final section states the data analysis.

## 3.1 Procedure of methodology

This research analyzed the opinions of pilots and controllers on the communication error issue with questionnaire survey. First, the preliminary research framework was constructed based on the common factors, errors, and aviation occurrences collected in literature review and the questionnaire was also designed based on literature reviews and was amended by experts. After the delivery and collection of the questionnaires, exploratory factor analysis and reliability analysis were used to establish the representative factors, errors, and aviation occurrences components for the formal research framework. Next, exploring the different cognition of pilots and controllers and different groups among them with T-test and one-way ANOVA. Finally, examining the factor-error-occurrence relation respectively with simple and multiple regression. Figure 3.1 displays the procedure of the methodology in this research.

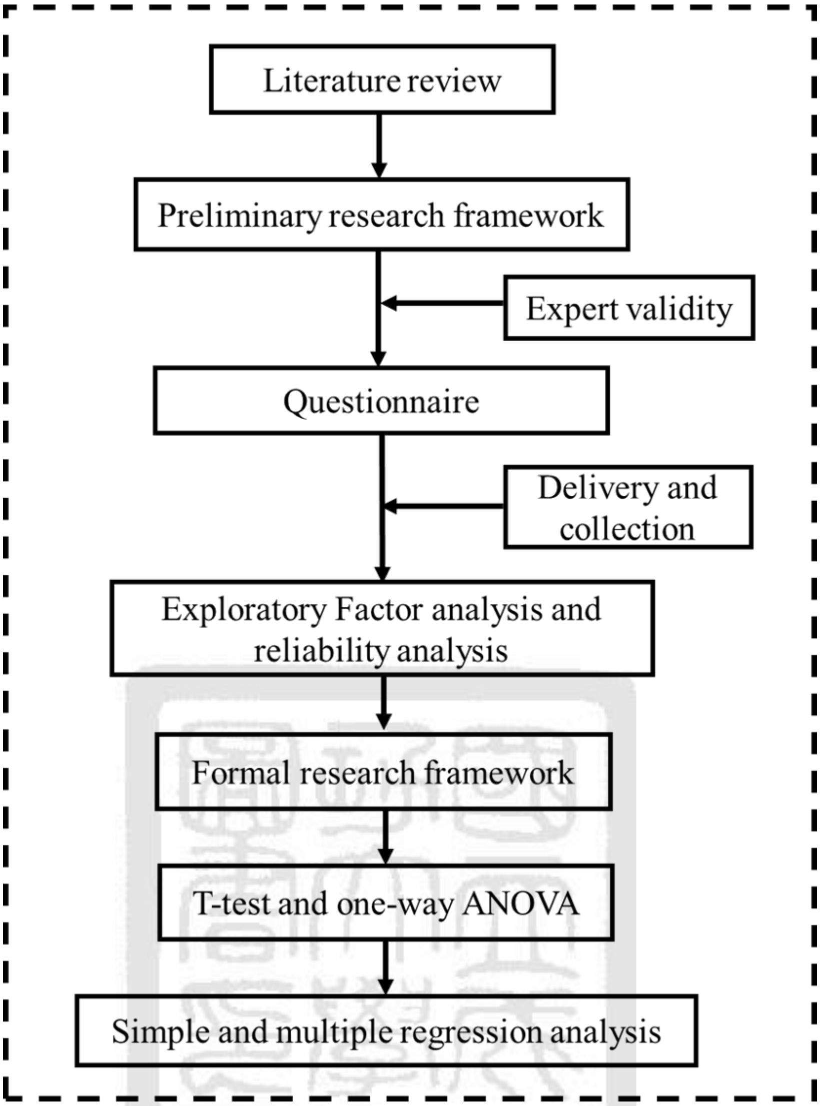


Figure 3.1 The procedure of the methodology

## 3.2 Research framework

This research first developed a preliminary research framework shown in Figure 3.2. Its construction was based on the purpose of this study and elements introduced by the literature reviews in Chapter 2. Factors, errors, and related aviation occurrences of pilot-controller communication were respectively three dimensions in the framework.

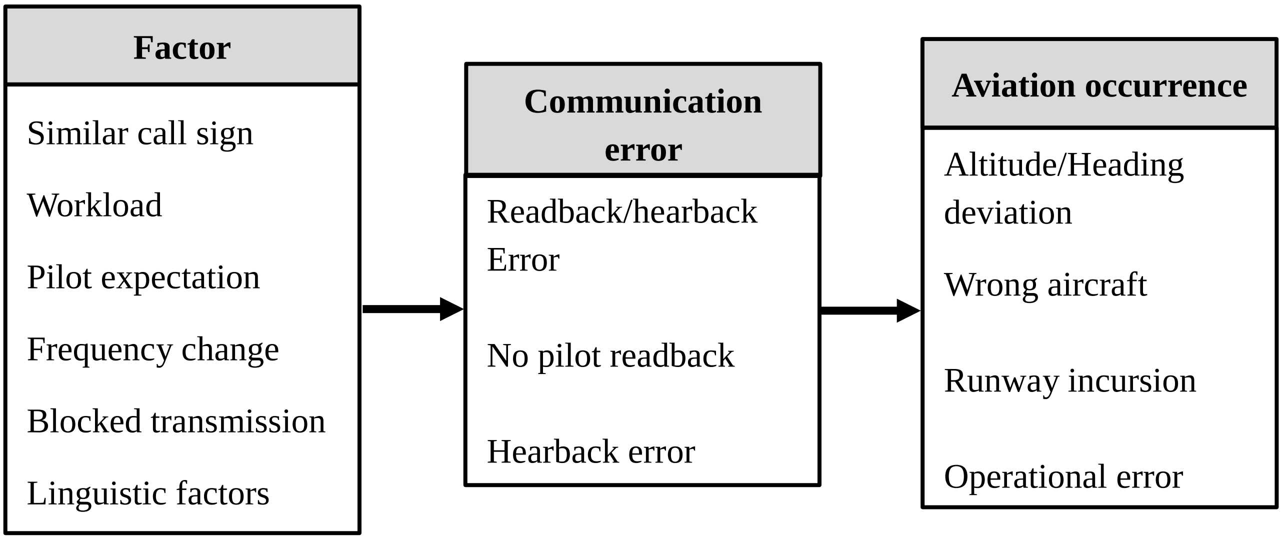


Figure 3.2 The preliminary research framework

After the deletion and amendment of the questions to conduct the formal questionnaire survey and the exploratory factor analysis and reliability analysis for all the valid responses, Figure 3.3 displays the final research framework for this study, embodying specific pattern of respondent in Taiwan. With the three dimensions, same as the preliminary one, it is to test the overall factor-error-occurrence relation, and further explore the detail that which specific factors have relations with specific errors as well as relation between specific errors and aviation occurrences. Besides, the significant difference between pilots and controllers' cognitions to each dimension is also examined.

The dimension of factors included components as workload, linguistic factors, pilot expectation, similar call sign, and frequency change. There are mainly two errors in the communication error dimension, including two components as readback and hearback error and no pilot readback. Finally, the aviation occurrences dimension includes altitude/heading deviation and runway incursion.

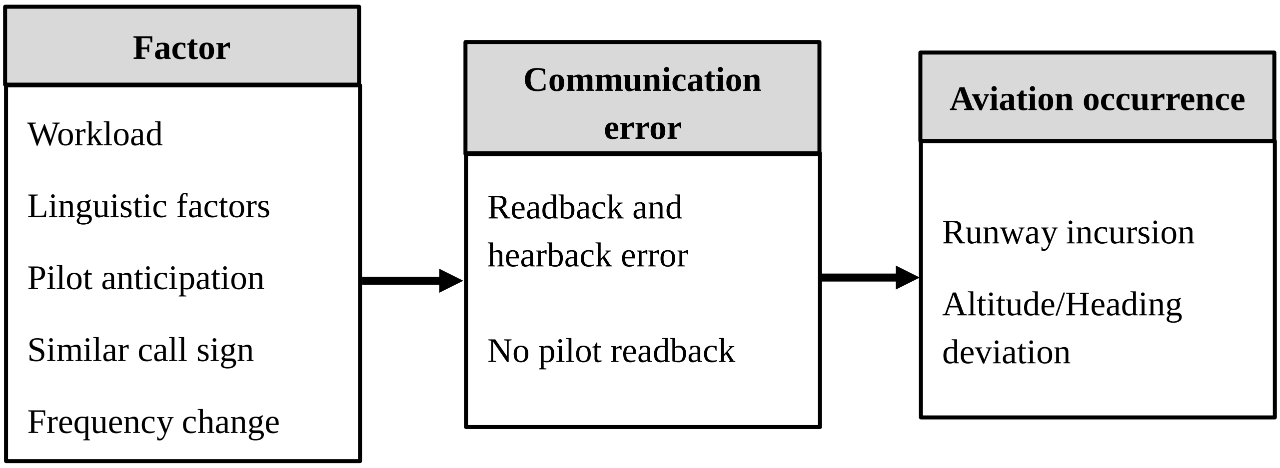


Figure 3.3 The research framework

## 3.3 Research hypothesis development

According to literature review and the research framework, the hypotheses of this study were developed and described as following of which some of the hypotheses are depicted in Figure 3.4.

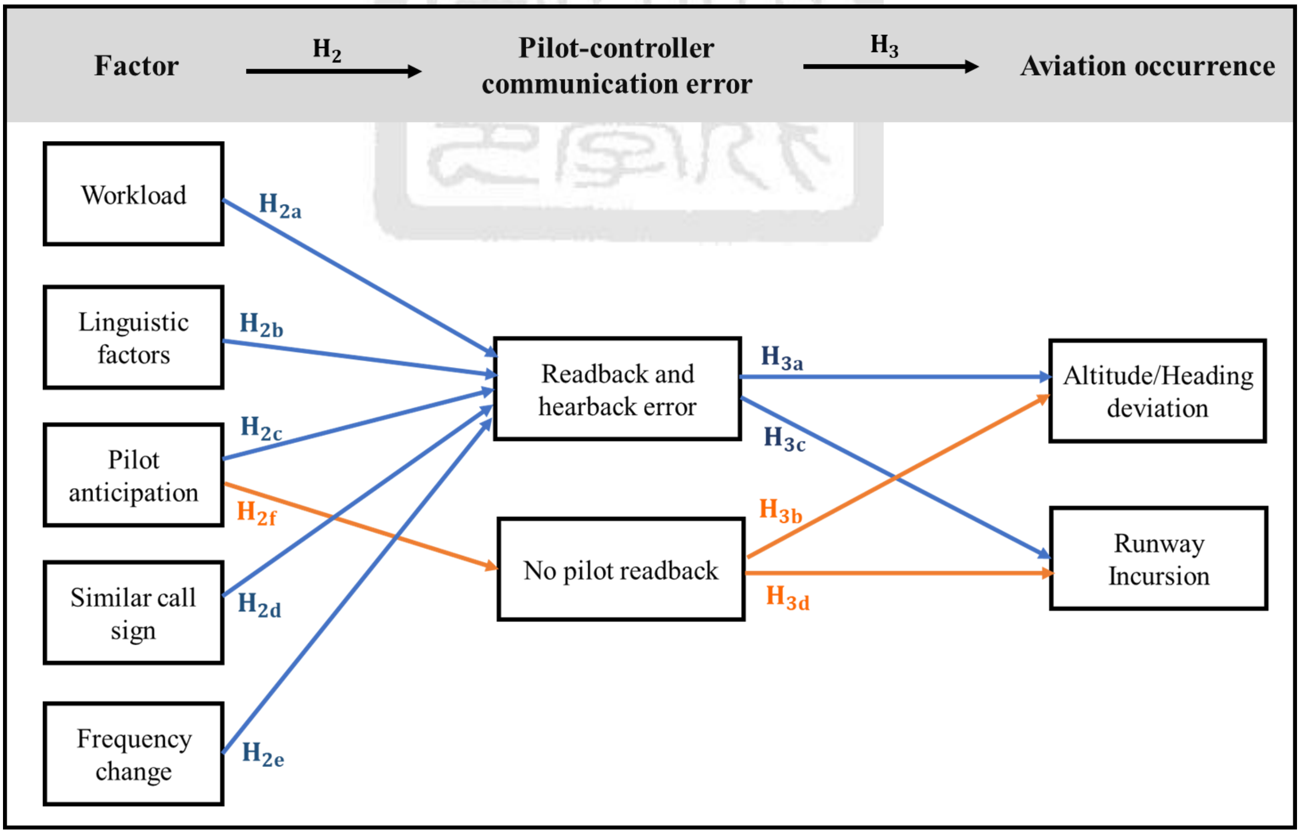


Figure 3.4 The hypotheses figure

### 3.3.1 The cognitive difference among pilot and controller

The collaborative goal of pilots and controllers is to keep the air traffic safe, while as described in Section 2.1, the definition and job characteristic shows the difference between pilots and controllers whatever in training, work place, and tasks (ICAO, 2011; FAA/AIM, 2017; Barshi & Farris, 2013). This can affect their perspectives on the same issue. Therefore, this study proposed a hypothesis as below:

**H1:** Pilots and controllers have significantly different cognitions to the dimensions of factors, errors, and related aviation occurrences.

### 3.3.2 The relation between factors and communication error

The hypotheses were based on the research framework of which the relation of factors and pilot-controller communication errors were mainly according to literatures (Cardosi et al., 1998; Van Es, 2004; Wever et al., 2006). A readback and hearback error may be caused by workload, linguistic factors, pilot anticipation, similar call sign, and frequency change. Next, the probable contributory factors to no pilot readback is pilot anticipation. From the statement above, this study proposed the following hypotheses:

**H2:** Factor has significantly positive relation with communication error.

**H2a:** Workload has significantly positive relation with readback and hearback error.

**H2b:** Linguistic factors has significantly positive relation with readback and hearback error.

**H2c:** Pilot anticipation has significantly positive relation with readback and hearback error.

**H2d:** Similar call sign has significantly positive relation with readback and hearback error.

**H2e:** Frequency change has significantly positive relation with readback and hearback error.

**H2f:** Pilot anticipation has significantly positive relation with no pilot readback.

### 3.3.3 The relation between communication error and aviation occurrence

The final step in the research framework is to examine the relation between pilot-controller communication errors and aviation occurrences. Same as mainly based on studies of Cardosi et al. (1998), Van Es (2004), and Wever et al. (2006). A readback and hearback error may cause aviation occurrences including altitude/heading deviation, runway incursion. Similarly, aviation occurrences related to no pilot readback are also composed of altitude/heading deviation and runway incursion. Thus, this study at the last proposed the following hypotheses:

**H3:** Communication error has significantly positive relation with aviation occurrence.

**H3a:** Readback and hearback error has significantly positive relation with runway incursion.

**H3b:** No pilot readback has significantly positive relation with runway incursion.

**H3c:** Readback and hearback error has significantly positive relation with altitude/heading deviation.

**H3d:** No pilot readback has significantly positive relation with altitude/heading deviation.

## 3.4 Questionnaire design

The questionnaire is separated into two parts. The first is the design procedure, and the second part shows the questions of the preliminarily designed questionnaire.

### 3.4.1 Design procedure

This study first adopted the resources from literatures, articles, survey questionnaires, international air association reports and regulations to draft the questions. Afterward, it will be transformed into expert questionnaire and handed in to the experienced experts of pilot-controller communication, which is for the expert validity. With the amendment, deletion and advices given by experts and professors, the formal questionnaire will be established, of which questions will be presented in both Chinese and English. Finally, the formal questionnaire will be given to line-operating airline pilots and controllers in Taiwan.

The design procedure is shown in Figure 3.5.

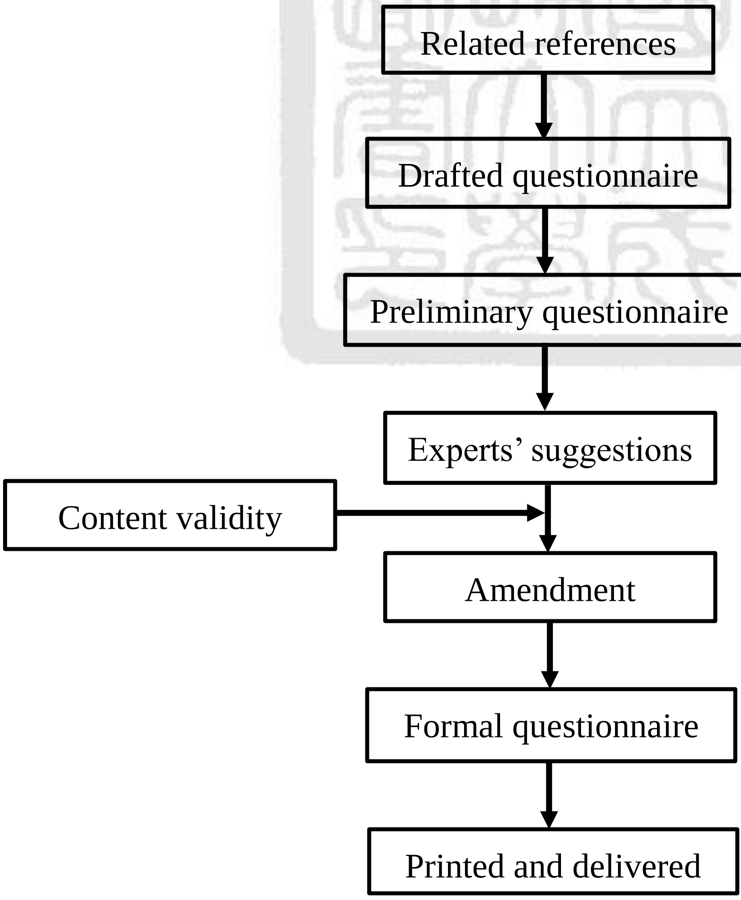


Figure 3.5 Questionnaire design procedure

### 3.4.2 Expert Validity

After the completion of the drafted questionnaire with 86 questions, of which 43 questions were for pilots and air traffic controllers respectively, the questionnaires were first checked by the advisor, and then delivered to and received from aviation experts or seniors all through email for the expert validity. Each question is with three kinds of suggestions, which are “preserve”, “amend”, and “delete”. The drafted questionnaire is presented at Appendix. Based on experts’ perspectives, most questions were preserved and seven questions were amended with words, grammatic, and narrative correction. The most significant change was that question No.10 and No.11 for both pilots and controllers of which “Pilot expectation” was changed to “pilot anticipation”. There was no question cancelled but one was suggested to be added as question No.25 by an expert, a senior air traffic controller.

Finally, the formal questionnaires were constructed with 44 consistent and representative questions for pilots and air traffic controllers. Table 3.1 shows the background information of the experts.

Table 3.1 Experts Background Information

| No | Position | Years | Institution / Company |
|---|---|---|---|
| 1 | Professor | 30 | University |
| 2 | Senior Vice General Manager | 32 | Airline in Taiwan |
| 3 | Supervisor | 16 | ANWS Taipei Approach |
| 4 | Tower Controller | 10 | ANWS Taipei Tower |

### 3.4.3 Formal questionnaire

The questionnaire was designed for both pilots and controllers. As a result, the meaning and contents of each question in each group's questionnaire was similar, with some narrative differences of the subject and object. It was divided into three parts. The first contained questions for contributory factors of pilot-controller communication errors. The second part was for the communication errors, and the questions within aviation occurrence dimensions. The last part was for respondents' background information.

Likert scale was used to score all questions, while the meanings of scale were different among three parts. The first part tried to understand the viewpoints on whether the specific factor would contribute to pilot-controller communication errors. Therefore, it took the degree for agreement as "Strongly agree" for 5 points; "Agree" for 4 points; "Neutral" for 3 points; "Disagree" for 2 points, and "Strongly disagree" for 1 point. The second and third part intended to understand the frequency of the specific errors and the further aviation occurrences due to the factors. Consequently, the second and third part took "Always" for 5 points; "Often" for 4 points; "Sometimes" for 3 points; "Few" for 2 points, and "Never" for 1 point. From Table 3.2 to Table 3.4 are the questions of the formal questionnaire and the sources. The integral questionnaire is shown in Appendix. "ATC" appearing in all questions represented for "controller", and "communication error" specifically represented for "pilot-controller communication error."

Table 3.2 Factor of pilot-controller communication error

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| A-1 | Confusion would occur if there are aircraft with the same number in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | Confusion would occur if there are aircraft with the same numbers in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | Cardosi et al. (1998) |
| A-2 | Confusion would occur if there are aircraft's call signs with the same numbers but in different orders on the same frequency (e.g. 432 and 342). | Confusion would occur if there are aircraft's call signs with the same numbers but in different orders on the same frequency (e.g. 432 and 342). | Cardosi et al. (1998) |
| A-3 | Confusion would occur if there are aircraft's call signs with the same airline designators and similar numbers on the same frequency (e.g. Dynasty254 and Dynasty255). | Confusion would occur if there are aircraft's call signs with the same airline designators and similar numbers on the same frequency (e.g. Dynast254 and Dynasty255). | Cardosi et al. (1998) |
| A-4 | I do not correct the ATC actively when he/she calls me with the wrong call sign. | Pilots do not correct me actively when I call his/her flight with the wrong call sign. | Cardosi (2010) |
| A-5 | ATC does not remind me when there is an aircraft with similar call sign on the same frequency. | I do not remind pilots when there is an aircraft with similar call sign on the same frequency. | FAA (2010) |

Table 3.2 Factor of pilot-controller communication error (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| A-6 | Amount and difficulty of tasks increase my workload. | Amount and difficulty of tasks increase my workload. | Watson (1996) |
| A-7 | Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | EUROCONTROL SKYbrary (2016) |
| A-8 | Frequency congestion increases my workload. | Frequency congestion increases my workload. | EUROCONTROL SKYbrary (2013) |
| A-9 | Increased workload affects communication. | Increased workload affects communication. | Molesworth & Estival (2015); Skaltsas et al. (2013) |
| A-10 | If I'm familiar with the route, I will have anticipation to ATC instructions. | If Pilots are familiar with the route, they have their own anticipation to my instructions. | EUROCONTROL SKYbrary (2010) |
| A-11 | I hear what I anticipate to hear, not the ATC's actual clearance. | Pilots hear what they anticipate to hear, not my actual clearance. | Cardosi et al. (1998) |

Table 3.2 Factor of pilot-controller communication error (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| A-12 | I do not request the ATC for clarifications, even a clearance or an instruction is not clear. | Pilots do not request for clarifications, even a clearance or an instruction I gave was not clear. | FAA (2012) |
| A-13 | I'm complacent when communicating with ATC. | Pilots are complacent when communicating with me. | Cardosi et al. (1998) |
| A-14 | Communication errors occur when I tune in the wrong frequency. | Communication errors occur when they tune in the wrong frequency. | FSF (2006) |
| A-15 | Communication errors occur when ATC neglects to hand me off to the next controller. | Communication errors occur when I neglect to hand the flight off to the next controller. | FSF (2006) |
| A-16 | Communication errors occur when I miss a call from ATC. | Communication errors occur when Pilots miss a call from me. | FSF (2006) |
| A-17 | Simultaneous transmission would cause communication errors. | Simultaneous transmission would cause communication errors. | EUROCONTROL (2006) |

Table 3.2 Factor of pilot-controller communication error (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| A-18 | Simultaneous transmission easily occurs due to congested frequency. | Simultaneous transmission easily occurs due to congested frequency. | EUROCONTROL (2006) |
| A-19 | Radio interference would cause communication errors. | Radio interference would cause communication errors. | EUROCONTROL (2006) |
| A-20 | Different accents would result in communication errors. | Different accents would result in communication errors. | Barshi & Farris (2013) |
| A-21 | Using non-standard phraseology would result in communication errors. | Using non-standard phraseology would result in communication errors. | IATA (2011) |
| A-22 | ATC issuing instructions without pause would result in communication errors. | When I issue instructions without pause, it would result in communication errors. | Molesworth & Estival (2015) |

Table 3.2 Factor of pilot-controller communication error (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| A-23 | ATC issuing instructions with high speech rate would result in communication errors. | When I issue instructions with high speech rate, it would result in communication errors. | Rantanen & Kokayeff (2002) |
| A-24 | ATC issuing more than four instructions at one time would result in communication errors. | When I issue more than four instructions at one time, it would result in communication errors. | Molesworth & Estival (2015) |
| A-25 | ATC frequently modifying the instructions during a short time would result in communication errors. | My frequent modification of the instructions during a short time would result in communication errors. | Experts' Sugestions |

Table 3.3 Pilot-controller error

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| B-1 | I read back ATC's clearances or instructions incorrectly. | Pilots read back my clearances or instructions incorrectly. | Cardosi et al. (1998) |
| B-2 | ATC neither notice nor correct my readback error. | I didn't notice nor correct Pilots' readback errors. | Cardosi et al. (1998) |
| B-3 | My wrong readbacks are difficult to be corrected by ATC when frequency is congested. | It's difficult for me to correct Pilots' wrong readbacks when frequency is congested. | EUROCONTROL SKYbrary (2013) |
| B-4 | I do not read back ATC's clearances or instructions. | Pilots do not read back my clearances or instructions. | Wever et al. (2006) |
| B-5 | I do not read back ATC's safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | Pilots do not read back my safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | ICAO (2007a) Airbus (2004) |
| B-6 | I do not read back ATC's clearances or instructions because of my complacency. | Pilots do not read back ATC's clearances or instructions because of their complacency. | Cardosi et al. (1998) |

Table 3.3 Pilot-controller error (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| B-7 | I cannot read back ATC's clearances or instructions because of the frequency congestion. | Pilots cannot read back my clearances or instructions because of the frequency congestion. | Cardosi et al. (1998) |
| B-8 | I read back correctly but ATC fails to notice that the clearances or instructions are not those he/she intended to issue. | Pilots read back correctly, but I fail to notice that the clearance or instruction are not what I intended to issue. | Cardosi et al. (1998)<br>Van Es (2004) |
| B-9 | ATC fails to notice that I make a request that might contain potential occurrence. | I fail to notice that pilot makes a request that might contain potential occurrence. | Cardosi et al. (1998)<br>Van Es (2004) |

Table 3.4 Aviation occurrence

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| C-1 | I deviated from ATC assigned altitude due to communication errors. | Pilots deviated from the altitude assigned by me due to communication errors. | FAA (2013) |
| C-2 | I deviated from ATC assigned heading due to communication errors. | Pilots deviated from the heading assigned by me due to communication errors. | FAA (2013) |
| C-3 | I deviated from ATC assigned altitude or heading and lost standard separation with other aircraft due to communication errors. | Pilots deviated from the altitude or heading assigned by me and lost standard separation with other aircrafts due to communication errors. | Cardosi et al. (1998) |
| C-4 | I took the ATC's clearance or instruction that was for another aircraft due to communication errors. | Pilots took the clearance or instruction that was for another aircraft due to communication errors. | FSF (2000a) |
| C-5 | ATC issued a clearance or an instruction to the wrong aircraft due to communication errors. | I issued a clearance or an instruction to the wrong aircraft due to communication errors. | Cardosi et al. (1998) |
| C-6 | An aircraft made a runway incursion during its takeoff due to communication errors. | An aircraft made a runway incursion during its takeoff due to communication errors. | ICAO (2007b)<br>FAA (2016b) |

Table 3.4 Aviation occurrence (continued)

| No. | Question for pilot | Question for controller | Source |
|---|---|---|---|
| C-7 | An aircraft made a runway incursion during its landing due to communication errors. | An aircraft made a runway incursion during its landing due to communication errors. | ICAO (2007b)<br>FAA (2016b) |
| C-8 | An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | FAA (2016b) |
| C-9 | ATC failed to provide required minimum separation between aircraft (in flight or during takeoff/landing with other aircraft on adjacent runways). | I failed to provide required minimum separation between aircraft (in flight or during takeoff/landing with other aircraft on adjacent runways). | FAA (2010) |
| C-10 | ATC failed to provide required minimum separation between aircraft and ground obstacle/terrain due to communication errors. | I failed to provide required minimum separation between aircraft and ground obstacle/terrain due to communication errors. | FAA (2010) |

## 3.5 Data analysis

Following are the steps for analyzing the data of questionnaires collected from pilots and air traffic controllers.

### 3.5.1 Analysis technique

Based on the purpose of this study and to examine the hypotheses, this research uses SPSS and adopted methods as below:

(1) Descriptive statistical analysis

Using descriptive statistical analysis to analyze pilots and controllers' background and responses to the elements in each dimension. With this method, the characteristics of factor means, standard deviation, and percentage of pilots and controllers can be clearly observed.

(2) Factor analysis

Factor analysis is an independence technique, whose primary purpose is to define the underlying structure among the variables in the analysis (Hair et al.,2010). Factor analysis operates on the notion that measurable and observable variables can be reduced to fewer latent variables that share a common variance and are unobservable, which is known as reducing dimensionality (Bartholomew et al., 2011). This study used exploratory factor analysis (EFA) to find the representative components in three dimensions. EFA is used when a researcher wants to discover the number of factors influencing variables and to analyze which variables 'go together' (DeCoster, 1998). Its goal is to find the smallest number of common factors that will account for the correlations (McDonald, 1985). The rules for retaining the number of factors are listed as following:

(i) Kaiser's criterion

It suggests retaining all factors that are above the eigenvalue of 1 (Kaiser, 1960)

(ii) Scree test

It is the number of factors to be retained is the data points that are above the point of inflexion (Yong & Pearce, 2013).

(iii) The cumulative percentage of variance

It is extracted after each factor is removed from the matrix, and this cycle continues until approximately 75-85% of the variance is accounted for (Gorsuch, 1983).

(iv) Eigenvalues

As the latent root, it represents the amount of variance accounted for by a factor (Hair et al., 2010)

(3) Reliability analysis

Reliability is concerned with the ability of an instrument to measure consistently (Tavakol et al., 2008). The concept of reliability assumes that unidimensionality exists in a sample of test items (Miller, et al., 1995). This study adopted Cronbach's alpha to test the consistency within questions in each dimension. The acceptable values of alpha are ranging from 0.70 to 0.95 (Tavakol & Dennick, 2011). However, a 0.60 level can be used in exploratory research (Hair, 2010).

(4) T-Test for difference between means

T-test is a test of statistical significance, often of the difference between two group means, which can test both independent and paired samples. Samples in this study, as pilots and controllers, are independent groups (Vogt & Johnson, 2011). Therefore, this study used independent samples t-test to see if there are differences between pilots and controllers' cognitions on three dimensions as factor, error, and occurrence.

(5) One-way Analysis of variance (One-way ANOVA)

This is used when having one nominal variable and one measurement variable; the nominal variable divides the measurements into two or more groups. It tests whether the means of the measurement variable are the same for the different groups. (McDonald, 2009). This study uses ANOVA to see whether there are differences in factors of each dimension due to the different characteristics among pilots group and controllers group.

(6) Regression analysis

Regression analysis is for predicting a single dependent variable from the knowledge of one or more independent variables. Simple regression is used when the problem involves a single independent variable, while when there are two or more independent variables, multiple regression would be adopted (Hair et al., 2010). Next, factor score is the composite measure created for each observation on each factor extracted in the factor analysis. The factor weights are used in conjunction with the original variable values (Hair et al., 2010). This study used exploratory factor analysis to extract factors representing each dimension and computed every factor score, then used the factor scores for two-staged multiple regression analysis to examine factor-error-occurrence relation of pilot-controller communication.

Generally, there are some values to indicate independent variables' influence on dependent variables which are listed below.

(i) $R^2$

It must be bounded by 0 and 1.0 The higher , the greater exploratory power of the regression equation; thus, the better prediction of the dependent variable (Hair et al., 2010). An unattractive property of the $R^2$ coefficient comes from the fact that cannot decrease when explanatory variables are added to the model, even if these have no relevance. Consequently, choosing to maximize can be misleading, penalizing models that contain too many variables. Therefore, when the dependent variable (y) is the same, adjusting degrees of freedom and maximize the adjusted $R^2$ is equivalent to minimizing the standard error of the regression (Dufour, 2011).

(ii) Significance level (p-value)

The probability the researcher is willing to accept that the estimated coefficient is classified as different from zero when it actually is not (Hair, 2010). A p-value helps to determine the significance of the statistical results (Rumsey, 2016). The levels of significance range from 0.01 to 0.10 (Hair, 2010).

(iii) Durbin Watson (DW) Test

It is a diagnostic test for autocorrelation (also called serial correlation) in residuals from regression analysis. The larger the autocorrelation, the less reliable the results of the regression analysis. Values between 1.5 to 2.5 are usually acceptable. Values outside of this range could be cause for concern (Vogt & Johnson, 2011).

(iv) Variance Inflation Factor (VIF)

It is the indicator of the effect that the other independent variables have on the standard error of a regression coefficient. Large VIF values also implies a high degree of collinearity of multicollinearity among the independent variables (Hair et al., 2010). VIF greater than 10 is thought to signal harmful collinearity (Marquardt, 1970).

### 3.5.2 Hypothetical regression formula

Below is a basic multiple regression formulation, where Y and each X are metric.

$$Y_i = a_0 + a_1X_{1i} + a_2X_{2i} + \cdots + a_nX_{ni} + \varepsilon_i \quad (i = 1 \ldots n)$$

With the basic formulation, four regression formulas were used to examine H2a to H2f and H3a to H3d in this study listed as following.

(1) For H2a to H2f **(Factor-error relationship)**

(i) $Y_{1i} = a_0 + a_1X_{1i} + a_2X_{2i} + a_3X_{3i} + a_4X_{4i} + a_5X_{5i} + \varepsilon_{1i} \quad (i = 1 \ldots n)$

i.e. $Y_{1i}$ as Readback and hearback error; $X_{1i}$ as Workload; $X_{2i}$ as Linguistic factors; $X_{3i}$ as Pilot anticipation; $X_{4i}$ as Similar call sign; $X_{5i}$ as Frequency change.

(ii) $Y_{2i} = b_0 + b_1X_{3i} + \varepsilon_{2i} \quad (i = 1 \ldots n)$

i.e. $Y_{2i}$ as No pilot readback; $X_{3i}$ as Pilot anticipation.

(2) For H3a to H3d **(Error-occurrence relationship)**

(iii) $Y_{3i} = c_0 + c_1X_{6i} + c_2X_{7i} + \varepsilon_{3i} \quad (i = 1 \ldots n)$

i.e. $Y_{3i}$ as Runway incursion; $X_{6i}$ as Readback and hearback error (previously as $Y_{1i}$); $X_{7i}$ as No pilot readback (previously as $Y_{2i}$).

(iv) $Y_{4i} = d_0 + d_1X_{6i} + d_2X_{7i} + \varepsilon_{4i} \quad (i = 1 \ldots n)$

i.e. $Y_{4i}$ as Altitude/Heading deviation; $X_{6i}$ as Readback and hearback error; $X_{7i}$ as No pilot readback.

# Chapter 4 Analysis and Results

According to the purpose, literature reviews and the methodology of previous chapters, this chapter analyzes the data collected from the responses of pilots and air traffic controllers and presents the results. There were six sections in this chapter. First is the descriptive statistical analysis, observing the pattern of responses. Second, by means of exploratory factor analysis and reliability analysis, extracting the components for each dimension. Third, using T-Test for difference between means to see if there are significant differences between pilots and controllers' cognition. Fourth, with T-Test for difference between means and one-way ANOVA to examine the significant differences among different groups of pilots or controllers. Fifth, to discuss and explain the significant relation between specific factors, communication errors, and aviation occurrences by regression analysis. Last, the final part was the summary of the results found in this chapter.

## 4.1 Descriptive statistical analysis

This section was divided to five parts. First is the analysis of questionnaires collection. Next was to present the sample characteristics, which are the descriptive statistical data of pilots and controllers' demographic profile. The third part to fifth part are the analysis of pilots and controllers' agreement level on each question.

### 4.1.1 Questionnaires collection

The survey was from May, 2017 to August, 2017. The questionnaires for pilots were first sent to the Flight Operation Division of an airline and the vice general manager of this department helped distribute the questionnaire to pilots classified with different types of aircraft. The collection of questionnaires is likewise through the Flight Operation Division. At all 300 questionnaires were delivered to pilots and 245 were collected, of which 173 were valid and 72 were invalid. The overall response rate was 81.7% and the effective response rate was 57.7%. The controller questionnaires were distributed to the approach and tower control in Kaohsiung and Taipei and the managers or supervisors aided to deliver and collect the questionnaire. Finally, 152 questionnaires were delivered and 132 were collected, of which 112 were valid and 20 were invalid. The overall response rate was 86.8% and the effective response rate was 73.7%. Questionnaires determined as invalid were either with incomplete responses or all same answers within one dimension. Table 4.1 displays the questionnaire collection profile.

Table 4.1 Questionnaire collection profile

| Research Objects | Numbers Issued | Numbers Collected | Valid | Invalid | Overall Response Rate | Effective Response Rate |
|---|---|---|---|---|---|---|
| **Pilots** | 300 | 245 | 173 | 72 | 81.7% | 57.7% |
| **Air traffic Controllers** | 152 | 132 | 112 | 20 | 86.8% | 73.7% |
| **Entire** | 452 | 377 | 285 | 92 | 83.4% | 63.1% |

### 4.1.2 Demographic Profile

The demographic profile of pilots encompassed six items. First is gender, with the traditional job characteristics, consisted with male (96%) much more than female (4%). Aged from 21 to more than 61, 31-35 (20.8%) accounting for the largest percent, followed by 41-45 (19.1%) and 36-40 (17.3%), the majority was from 31 to 55, accounting for 85.5%. As for nationality, because the questionnaire survey was conducted in a Taiwanese airline, Taiwanese pilots (94.8%) are much more than pilots from other country. Professional status includes five categories which were from first officer to management, and among all respondents, captain (34.7%) and first officers (27.7%) accounts for the majority. With regard to flight training background, company training (52%) had the largest numbers, followed by Commercial Pilot License (CPL)/Airline Transport Pilot License (ATPL) (27.2%). Lastly, though 5-10 years (26.6%) accounted for the highest percentage of years experiences, all categories in this demographic profile almost had equal percentages. Figure 4.2 presents the demographic profile of pilots.

There were five items in the demographic profile of controllers. First, on the contrary to pilot respondents, female controllers (52.7%) had more percentages than male (47.3%), but the gap was pretty smaller than pilots. The age was from 21 to more than 60, of which 41-45 (25%) had the largest percentage, followed by 31-35 (21.4%), and most respondents were aged from 26-50, accounting for total 84.8%. As for professional status, almost 70% of the respondents were tower (30.4%) or radar controllers (39.4%), which are the initial levels of air traffic controller career. This therefore explained why the “less than 10 years” (38.4%) group accounted for the largest percentages in years experiences. Finally, the numbers of respondents in Taipei (Northern Taiwan, 58%) and Kaohsiung (Southern, 42%) had no significant difference. Table 4.3 shows the demographic profile of air traffic controllers.

Table 4.2 Demographic profile of pilots

| Demographic Profile | Response Category | Frequency | Percentage of total (%) |
|---|---|---|---|
| Gender | Male | 166 | 96 |
| | Female | 7 | 4 |
| Age | 21-25 | 0 | 0 |
| | 26-30 | 12 | 6.9 |
| | 31-35 | 36 | 20.8 |
| | 36-40 | 30 | 17.3 |
| | 41-45 | 33 | 19.1 |
| | 46-50 | 23 | 13.3 |
| | 51-55 | 26 | 15 |
| | 56-60 | 10 | 5.8 |
| | >61 | 3 | 1.7 |
| Nationality | Taiwan, R.O.C. | 164 | 94.8 |
| | Others | 9 | 5.2 |
| Professional Status | Management | 9 | 5.2 |
| | Check Pilot (CP)/ Instructor Pilot (IP) | 25 | 14.5 |
| | Captain | 60 | 34.7 |
| | Relief Pilot | 31 | 17.9 |
| | First officer | 48 | 27.7 |
| Flight Training Background | Military | 33 | 19.1 |
| | Commercial Pilot License (CPL)/ Airline Transport Pilot License (ATPL) | 47 | 27.2 |
| | Company Training | 90 | 52 |
| | Others | 3 | 1.7 |
| Years Experiences | <5 years | 34 | 19.7 |
| | 5-10 years | 46 | 26.6 |
| | 11-15 years | 35 | 20.2 |
| | 16-20 years | 23 | 13.3 |
| | >20 years | 35 | 20.2 |

Table 4.3 Demographic profile of air traffic controllers

| **Demographic Profile** | **Response Category** | **Frequency** | **Percentage of total (%)** |
|---|---|---|---|
| Gender | Male | 53 | 47.3 |
| | Female | 59 | 52.7 |
| Age | 21-25 | 5 | 4.5 |
| | 26-30 | 14 | 12.5 |
| | 31-35 | 24 | 21.4 |
| | 36-40 | 12 | 10.7 |
| | 41-45 | 28 | 25 |
| | 46-50 | 17 | 15.2 |
| | 51-55 | 9 | 8 |
| | 56-60 | 3 | 2.7 |
| | >61 | 0 | 0 |
| Professional Status | Tower | 34 | 30.4 |
| | Radar | 44 | 39.3 |
| | Supervisor | 25 | 22.3 |
| | Manager | 9 | 8 |
| Years Experiences | <10 years | 43 | 38.4 |
| | 10-15 years | 17 | 15.2 |
| | 16-20 years | 20 | 17.9 |
| | >20 years | 32 | 28.6 |
| Area | Northern | 65 | 58 |
| | Southern | 47 | 42 |

### 4.1.3 Agreement level on contributing factors of communication errors

Here are the means, standard deviation of the questions about pilots and controllers' agreement levels on the factors which may cause communication errors between both sides. The ranks based on the mean of each question was discussed, as shown in Table 4.4. Table 4.5 showed the questions with top and bottom three means.

(1) Pilots' agreement level on factors

The top three mean scores were A-7 as "Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload", A-1 as "Confusion would occur if there are aircraft with the same number in the call signs on the same frequency (e.g. Dynasty123 and EVA123)", and A-18 as "Simultaneous transmission easily occurs due to congested frequency". The results denoted that pilots were very agree with these three conditions existing during their work time, including workload, similar call sign problem and same-time transmission.

The last three mean scores are A-12 as "I do not request the ATC for clarifications, even a clearance or an instruction is not clear", A-4 as "I do not correct the ATC actively when he/she calls me with the wrong call sign", and A-11 as "I hear what I anticipate to hear, not the ATC's actual clearance". These questions were related to pilots' mistake and the results showed that pilots did not tend to think these would occur when in flight.

(2) Air traffic controllers' agreement level on factors

According to controllers' responses, the top three mean scores are A-7 as "Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload", A-8 as "Frequency congestion increases my workload", and A-18 as "Simultaneous transmission easily occurs due to congested frequency". It could be inferred with the results that controllers were really aware of workload and the same -time transmission during their duty, and these had great relation with frequency congestion.

The last three mean scores were A-5 as "I do not remind pilots when there is an aircraft with similar call sign on the same frequency", A-12 as "Pilots do not request for clarifications, even a clearance or an instruction I gave was not clear", and A-11 as "Pilots hear what they anticipate to hear, not my actual clearance". Most of controllers thought they would remind pilots of similar call sign, and thus incline to disagree with A-5. Additionally, neither did controllers think pilots had their anticipation and lack for obtaining clarifications.

(3) Total agreement level on factors

At the total aspect, the top three mean scores were A-7 as "Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload", A-18 as "Simultaneous transmission easily occurs due to congested frequency", and A-8 as "Frequency congestion increases my workload". This indicated that among all the questions, those involved in workload and transmitting interference related to frequency congestion were the most common situation both pilots and air traffic controllers were aware of.

The last three mean scores for the entire were A-12 as "Pilots do not request for clarifications, even a clearance or an instruction ATC gave was not clear", A-11 as "Pilots hear what they anticipate to hear, not ATC actual clearance", and A-4 as

"Pilots do not correct ATC actively when ATC call his/her flight with the wrong call sign". The results showed that both pilots and air traffic controllers did not really perceive the situation that pilots negatively not to follow or correct instructions or clearance issued by ATC.

Table 4.4 Agreement level on the factors of communication errors

| Question | Pilots | | | Air Traffic Controllers | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank |
| A-1 | 4.38 | 0.63 | 2 | 4.41 | 0.70 | 5 | 4.39 | 0.66 | 4 |
| A-2 | 3.90 | 0.86 | 17 | 3.86 | 0.93 | 16 | 3.88 | 0.89 | 17 |
| A-3 | 4.08 | 0.75 | 15 | 4.21 | 0.82 | 9 | 4.13 | 0.78 | 10 |
| A-4 | 1.92 | 0.87 | 24 | 2.98 | 0.99 | 22 | 2.34 | 1.05 | 23 |
| A-5 | 2.82 | 0.99 | 22 | 2.14 | 0.93 | 25 | 2.55 | 1.02 | 22 |
| A-6 | 4.01 | 0.79 | 16 | 4.37 | 0.77 | 6 | 4.15 | 0.80 | 9 |
| A-7 | 4.57 | 0.55 | 1 | 4.82 | 0.38 | 1 | 4.67 | 0.51 | 1 |
| A-8 | 4.28 | 0.62 | 5 | 4.57 | 0.65 | 2 | 4.39 | 0.65 | 3 |
| A-9 | 4.25 | 0.61 | 6 | 4.53 | 0.61 | 4 | 4.36 | 0.63 | 5 |
| A-10 | 4.12 | 0.71 | 11 | 4.12 | 0.72 | 10 | 4.12 | 0.71 | 11 |
| A-11 | 2.05 | 0.94 | 23 | 2.77 | 0.90 | 23 | 2.33 | 0.98 | 24 |
| A-12 | 1.61 | 0.80 | 25 | 2.30 | 0.76 | 24 | 1.88 | 0.86 | 25 |
| A-13 | 3.85 | 0.88 | 19 | 3.79 | 0.62 | 17 | 3.83 | 0.79 | 18 |
| A-14 | 3.77 | 0.98 | 21 | 3.57 | 0.97 | 21 | 3.69 | 0.98 | 21 |
| A-15 | 3.84 | 0.85 | 20 | 3.71 | 0.85 | 18 | 3.79 | 0.85 | 19 |
| A-16 | 4.09 | 0.66 | 14 | 4.11 | 0.70 | 11 | 4.10 | 0.67 | 12 |
| A-17 | 4.18 | 0.69 | 9 | 4.27 | 0.77 | 8 | 4.21 | 0.72 | 7 |
| A-18 | 4.36 | 0.55 | 3 | 4.54 | 0.61 | 3 | 4.43 | 0.58 | 2 |
| A-19 | 4.25 | 0.53 | 7 | 4.28 | 0.65 | 7 | 4.26 | 0.58 | 6 |
| A-20 | 4.28 | 0.59 | 4 | 4.01 | 0.65 | 13 | 4.18 | 0.63 | 8 |
| A-21 | 4.20 | 0.66 | 8 | 3.68 | 0.85 | 19 | 3.99 | 0.78 | 16 |
| A-22 | 3.86 | 0.76 | 18 | 3.66 | 0.75 | 20 | 3.78 | 0.76 | 20 |
| A-23 | 4.10 | 0.63 | 13 | 4.10 | 0.60 | 12 | 4.10 | 0.61 | 13 |
| A-24 | 4.18 | 0.68 | 10 | 3.87 | 0.85 | 15 | 4.06 | 0.77 | 14 |
| A-25 | 4.12 | 0.71 | 12 | 3.92 | 0.86 | 14 | 4.04 | 0.78 | 15 |

*Note: The gray grids indicated the top three mean scores. The number and corresponding questions was in Table 3.2.

Table 4.5 Top and bottom three agreement levels of factors of communication errors

| Question for pilot | | | Mean | Rank |
|---|---|---|---|---|
| Top three | A-7 | Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | 4.57 | 1 |
| | A-1 | Confusion would occur if there are aircraft with the same number in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | 4.38 | 2 |
| | A-18 | Simultaneous transmission easily occurs due to congested frequency. | 4.36 | 3 |
| Bottom three | A-11 | I hear what I anticipate to hear, not the ATC's actual clearance. | 2.05 | 23 |
| | A-4 | I do not correct the ATC actively when he/she calls me with the wrong call sign. | 1.92 | 24 |
| | A-12 | I do not request the ATC for clarifications, even a clearance or an instruction is not clear. | 1.61 | 25 |
| **Question for controller** | | | **Mean** | **Rank** |
| Top three | A-7 | Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | 4.82 | 1 |
| | A-8 | Frequency congestion increases my workload. | 4.57 | 2 |
| | A-18 | Simultaneous transmission easily occurs due to congested frequency. | 4.54 | 3 |
| Bottom three | A-11 | Pilots hear what they anticipate to hear, not my actual clearance. | 2.77 | 23 |
| | A-12 | Pilots do not request for clarifications, even a clearance or an instruction I gave was not clear. | 2.30 | 24 |
| | A-5 | I do not remind pilots when there is an aircraft with similar call sign on the same frequency. | 2.14 | 25 |

### 4.1.4 Frequencies of communication errors

Following are the means, standard deviation of pilots and controllers' perception of the frequencies of their communication errors, along with the rank of means, as shown in Table 4.6. The questions for pilots and controllers with top and bottom three means were displayed in Table 4.7.

(1) Pilots' perception of communication errors' frequencies

The top three mean scores were B-3 as "My wrong readbacks are difficult to be corrected by ATC when frequency is congested", B-2 as "ATC neither notice nor correct my readback error", and B-7 as "I cannot read back ATC's clearances or instructions because of the frequency congestion". The results pointed out that pilots thought their readback errors, no readback, and ATC's hearback errors, especially because of congested frequency, occurred more often than other circumstances.

Three mean scores at the last were B-6 as "I do not read back ATC's clearances or instructions because of my complacency", B-5 as "I do not read back ATC's safety-related clearances (take off or landings) or instructions (Altitude, speed or heading)", and B-4 as "I do not read back ATC's clearances or instructions". This showed that pilots were inclined to disagree with their negligence of responding ATC's instructions or clearances.

(2) Air traffic controllers' perception of communication errors' frequencies

For air traffic controllers, the top three mean scores were B-1 as "Pilots read back my clearances or instructions incorrectly", B-3 as "It's difficult for me to correct Pilots' wrong readbacks when frequency is congested", and B-4 as "Pilots do not read back my clearances or instructions". Air traffic controllers also considered pilots' readback and their hearback errors with frequency congestion the more frequent phenomenon. However, opposed to pilots' perception, they thought pilots would neglect to respond their instructions or clearance. This could also be proved that air traffic controllers' mean scores on both B-5 and B-6 were higher than those of pilots.

The lowest three mean scores were B-9 as "I fail to notice that Pilot makes a request that might contain potential occurrence”, B-6 as “Pilots do not read back ATC’s clearances or instructions because of their complacency”, and B-8 as “Pilots read back correctly, but I fail to notice that the clearance or instruction are not what I intended to issue”. B-9 and B-8 mainly described controllers’ oversight, and controllers tended to disagree with these mistakes happening. On the other hand, they did not feel pilots’ complacent attitude during their communication.

(3) Total perception of communication errors’ frequency

Entirely, the three scores at the top were B-3 as “Pilots’ wrong readbacks are difficult to be corrected by ATC when frequency is congested”, B-1 as “Pilots read back ATC’s clearances or instructions incorrectly”, and B-2 as “ATC neither notice nor correct pilots readback error”. This revealed that both pilots and controllers considered readback/hearback errors, based on the literature review, to be more frequent situations than others. The last three were the same with those of pilots, which may because of the more collected samples of pilots than air traffic controllers.

Table 4.6 Perception of frequencies of communication errors

| Question | Pilots | | | Air Traffic Controllers | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank |
| B-1 | 2.39 | 0.61 | 4 | 2.90 | 0.72 | 1 | 2.59 | 0.70 | 2 |
| B-2 | 2.60 | 0.71 | 2 | 2.17 | 0.54 | 5 | 2.43 | 0.68 | 3 |
| B-3 | 2.94 | 0.80 | 1 | 2.50 | 0.88 | 2 | 2.76 | 0.86 | 1 |
| B-4 | 1.53 | 0.67 | 7 | 2.45 | 0.72 | 3 | 1.89 | 0.82 | 7 |
| B-5 | 1.31 | 0.61 | 8 | 2.15 | 0.77 | 6 | 1.64 | 0.79 | 8 |
| B-6 | 1.30 | 0.66 | 9 | 2.02 | 0.89 | 8 | 1.58 | 0.83 | 9 |
| B-7 | 2.42 | 0.77 | 3 | 2.41 | 0.88 | 4 | 2.42 | 0.81 | 4 |
| B-8 | 2.28 | 0.64 | 5 | 2.03 | 0.68 | 7 | 2.18 | 0.67 | 5 |
| B-9 | 2.17 | 0.82 | 6 | 1.85 | 0.60 | 9 | 2.04 | 0.76 | 6 |

*Note: The gray grids indicated the top three mean scores. The number and corresponding questions was in Table 3.3.

Table 4.7 Top and bottom three perception of frequencies of communication errors

| Question for pilot | | | Mean | Rank |
|---|---|---|---|---|
| Top three | B-3 | My wrong readbacks are difficult to be corrected by ATC when frequency is congested. | 2.94 | 1 |
| | B-2 | ATC neither notice nor correct my readback error. | 2.60 | 2 |
| | B-7 | I cannot read back ATC's clearances or instructions because of the frequency congestion. | 2.42 | 3 |
| Bottom three | B-4 | I do not read back ATC's clearances or instructions. | 1.53 | 7 |
| | B-5 | I do not read back ATC's safety-related clearances (takeoff or landings) or instructions (Altitude, speed or heading). | 1.31 | 8 |
| | B-6 | I do not read back ATC's clearances or instructions because of my complacency. | 1.30 | 9 |
| **Question for controller** | | | **Mean** | **Rank** |
| Top three | B-1 | Pilots read back my clearances or instructions incorrectly. | 2.90 | 1 |
| | B-3 | It's difficult for me to correct Pilots' wrong readbacks when frequency is congested. | 2.50 | 2 |
| | B-4 | Pilots do not read back my clearances or instructions. | 2.45 | 3 |
| Bottom three | B-8 | Pilots read back correctly, but I fail to notice that the clearance or instruction are not what I intended to issue. | 2.03 | 7 |
| | B-6 | Pilots do not read back ATC's clearances or instructions because of their complacency. | 2.02 | 8 |
| | B-9 | I fail to notice that Pilot makes a request that might contain potential risk. | 1.85 | 9 |

### 4.1.5 Frequencies of aviation occurrences due to communication errors

Following are the means, standard deviation and the ranks of pilots and controllers' perception of frequencies of aviation occurrences, which were possibly the negative results of communication errors.

As Figure 4.8 presents, for both pilots and controllers, or entire, C-4 as "Pilots took the ATC's clearance or instruction that was for another aircraft due to communication errors", and C-5 as "ATC issued a clearance or an instruction to the wrong aircraft due to communication errors" had relatively higher mean scores than other occurrences. This can be inferred that these two situations seemed to happen more easily. Other occurrences' mean scores were all between 1 and 2, indicating that pilots and air traffic controllers encountered these occurrences not that frequently. Table 4.9 presented the questions for pilots and controllers with top two frequencies.

Table 4.8 Perception of frequencies of aviation occurrences

| **Question** | **Pilots** | | | **Air Traffic Controllers** | | | **Total** | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank | Mean | Std. Deviation | Rank |
| C-1 | 1.42 | 0.70 | 6 | 1.76 | 0.63 | 4 | 1.55 | 0.69 | 4 |
| C-2 | 1.49 | 0.65 | 4 | 1.78 | 0.67 | 3 | 1.60 | 0.67 | 3 |
| C-3 | 1.36 | 0.63 | 9 | 1.34 | 0.53 | 5 | 1.35 | 0.59 | 6 |
| C-4 | 1.90 | 0.61 | 2 | 2.35 | 0.69 | 1 | 2.07 | 0.68 | 1 |
| C-5 | 2.14 | 0.62 | 1 | 1.92 | 0.63 | 2 | 2.06 | 0.63 | 2 |
| C-6 | 1.37 | 0.66 | 7 | 1.29 | 0.55 | 6 | 1.34 | 0.62 | 7 |
| C-7 | 1.37 | 0.70 | 8 | 1.21 | 0.45 | 9 | 1.31 | 0.62 | 9 |
| C-8 | 1.35 | 0.69 | 10 | 1.27 | 0.48 | 7 | 1.32 | 0.62 | 8 |
| C-9 | 1.59 | 0.74 | 3 | 1.22 | 0.42 | 8 | 1.45 | 0.66 | 5 |

*Note: The gray grids indicated the higher mean scores. The number and corresponding questions was in Table 3.4.

Table 4.9 Top two perception of frequencies of aviation occurrences

| **Question for pilot** | | | **Mean** | **Rank** |
|---|---|---|---|---|
| Top two | C-5 | ATC issued a clearance or an instruction to the wrong aircraft due to communication errors. | 2.14 | 1 |
| | C-4 | I took the ATC's clearance or instruction that was for another aircraft due to communication errors. | 1.90 | 2 |
| **Question for controller** | | | **Mean** | **Rank** |
| Top two | C-4 | I took the ATC's clearance or instruction that was for another aircraft due to communication errors. | 2.35 | 1 |
| | C-5 | ATC issued a clearance or an instruction to the wrong aircraft due to communication errors. | 1.92 | 2 |

## 4.2 Factor and reliability analysis

This section extracted the components among all the questions for the three dimensions as factors, errors and aviation occurrences with factor analysis and reliability analysis.

### 4.2.1 Factor and reliability analysis for communication errors' factors

(1) Factor analysis

This study adopted Exploratory factor analysis (EFA) to categorized and decreased the questions for communication errors' factors. Prior to the EFA, Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to determine the appropriateness of the EFA. A value of 0.60 or above from the KMO test suggested the adequacy for EFA (Tabachnick & Fidell, 1989). Besides, Bartlett's test of sphericity was required to be significant.

The value from KMO test was 0.796 and the Bartlett's test of sphericity, of which Chi-square value was 1543.163 and it reached the level of significance (< 0.05), indicating that questions for communication errors' factors were suitable for EFA. There were 25 questions in the factors dimension, and with factor analysis, deleting questions of which factor loads were below 0.5, including A-10, A-17, and A-19. Further, with Kaiser's criterion, keeping all questions of which components' eigenvalues were >1. Finally, it extracted five components and the total variance explained was 59.337%.

The five components were given name based on the final EFA results and are shown in Table 4.10., and the name were listed orderly as following.

(i) Component 1: Workload

This component comprised five questions, including A-8 as “Frequency congestion increases my workload”, A-7 as “Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload”, A-9 as “Increased workload affects communication”, A-6 as “Amount and difficulty of tasks increase my workload”, and A-18 as “Simultaneous transmission easily occurs due to congested frequency”. Among these questions, A-8, A-7, A-9, and A-6 were obviously related to workload. As for A-18, SKYbrary (2013) pointed out that frequency congestion may lead to simultaneous transmission from another aircraft which is trying to communicate is lost or misheard, generating the confusion between pilots and controllers, which would increase the workload for both sides to resolve the confusion. The circumstance described in A-18 was an important factor for pilot and controller workload. Therefore, with all these five questions, this component was named “Workload”.

A-18, A-17 as “Simultaneous transmission would cause communication errors”, and A-19 as “Radio interference would cause communication errors” all described the situations as blocked transmission. However, the latter two questions were deleted because of the factor analysis. This again indicated that in Taiwan, blocked transmission could be included as the causal elements of workload.

(ii) Component 2: Linguistic factors

There were six questions, which were A-23 as “ATC issuing instructions with high speech rate would result in communication errors”, A-22 as “ATC issuing instructions without pause would result in communication errors”, A-25 as “ ATC frequently modifying the instructions during a short time would result in communication errors”, A-24 as “ATC issuing more than four instructions at one time would result in communication errors”, A-21 as “Using non-standard phraseology would result in communication errors”, and A-20 as ” Different accents would result in communication errors”. All these questions regarded the form of speaking, thus this component was named “Linguistic factors”.

(iii) Component 3: Pilot anticipation

In this component, the questions were A-12 as “Pilots do not request the ATC for clarifications, even a clearance or an instruction is not clear”, A-11 as “Pilots hear what they anticipate to hear, not the ATC’s actual clearance”, and A-4 as “Pilots do not correct the ATC actively when he/she calls the wrong call sign”. These questions described that pilots had their own anticipation and did not follow ATC’s instruction or challenge ATC’s mistakes. In most literature, these situations were synthesized as “Pilot expectation”. However, since the expert validity, the “expectation” had been replaced by “anticipation”, which was more closed to pilots’ real mental state. Finally, this component was called “Pilot anticipation”.

(iv) Component 4: Similar call sign

There were three questions in this component, including A-3 as “Confusion would occur if there are aircraft’s call signs with the same airline designators and similar numbers on the same frequency”, A-2 as “Confusion would occur if there are aircraft’s call signs with the same numbers but in different orders on the same frequency”, and A-3 as “Confusion would occur if there are aircraft’s call signs with the same airline designators and similar numbers on the same frequency”. These questions apparently indicated problems involved in the call sign similarity. Hence, the name of this component was “Similar call sign”.

(v) Component 5: Frequency change

Two questions consisted of this component, which were A-14 as “Communication errors occur when pilots tune in the wrong frequency”, and A-15 as “Communication errors occur when ATC neglects to hand the pilot off to the next controller”. Two situations occurred when pilots in flight changing the radio frequency, and this component therefore was named “Frequency change”.

(2) Reliability analysis

With reliability analysis, eliminating A-16, A-13 and A-5 in order to obtain higher components’ reliability. The final reliability analysis results for factors were presented in Table 4.11. Cronbach’s alpha values of all components were between 0.70 and 0.95, reaching the acceptable value.

Table 4.10 Factor loads of factors of communication errors

| Question | Component 1 | Component 2 | Component 3 | Component 4 | Component 5 |
|---|---|---|---|---|---|
| A-8 | 0.823 | 0.155 | 0.088 | 0.158 | 0.000 |
| A-7 | 0.767 | 0.050 | -0.068 | 0.059 | -0.046 |
| A-9 | 0.728 | 0.141 | 0.077 | 0.239 | 0.075 |
| A-6 | 0.726 | 0.034 | 0.050 | 0.061 | 0.080 |
| A-18 | 0.595 | 0.071 | 0.012 | 0.091 | 0.323 |
| A-23 | 0.099 | 0.742 | 0.101 | -0.039 | -0.031 |
| A-22 | 0.028 | 0.678 | 0.056 | 0.162 | 0.074 |
| A-25 | 0.100 | 0.672 | -0.005 | 0.134 | 0.088 |
| A-24 | 0.189 | 0.601 | 0.043 | 0.080 | 0.107 |
| A-21 | -0.123 | 0.580 | -0.161 | 0.077 | 0.302 |
| A-20 | 0.088 | 0.556 | -0.171 | 0.086 | 0.056 |
| A-12 | -0.143 | -0.016 | 0.832 | 0.011 | 0.007 |
| A-11 | 0.110 | 0.101 | 0.788 | 0.045 | 0.035 |
| A-4 | 0.154 | -0.158 | 0.765 | -0.025 | -0.124 |
| A-3 | 0.146 | 0.024 | 0.075 | 0.803 | 0.074 |
| A-2 | 0.109 | 0.209 | 0.043 | 0.797 | 0.121 |
| A-1 | 0.234 | 0.195 | -0.102 | 0.694 | 0.044 |
| A-14 | 0.079 | 0.195 | -0.007 | 0.101 | 0.842 |
| A-15 | 0.168 | 0.144 | -0.053 | 0.101 | 0.835 |
| Eigenvalue | 2.935 | 2.697 | 2.011 | 1.948 | 1.683 |
| % of Variance | 15.448 | 14.193 | 10.583 | 10.254 | 8.859 |
| Cumulative % | 15.448 | 29.640 | 40.223 | 50.477 | 59.337 |

Table 4.11 Reliability analysis of communication errors' factors

| Component | Question | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted | Cronbach's Alpha |
|---|---|---|---|---|
| Workload | A-8 | 0.724 | 0.722 | 0.804 |
| | A-7 | 0.575 | 0.775 | |
| | A-9 | 0.632 | 0.753 | |
| | A-6 | 0.580 | 0.779 | |
| | A-18 | 0.482 | 0.796 | |
| Linguistic Factors | A-23 | 0.515 | 0.689 | 0.735 |
| | A-22 | 0.490 | 0.692 | |
| | A-25 | 0.524 | 0.681 | |
| | A-24 | 0.463 | 0.700 | |
| | A-21 | 0.437 | 0.709 | |
| | A-20 | 0.409 | 0.714 | |
| Pilot Anticipation | A-12 | 0.580 | 0.601 | 0.722 |
| | A-11 | 0.529 | 0.650 | |
| | A-4 | 0.531 | 0.654 | |
| Similar Call Sign | A-3 | 0.546 | 0.625 | 0.720 |
| | A-2 | 0.598 | 0.565 | |
| | A-1 | 0.503 | 0.684 | |
| Frequency Change | A-14 | 0.594 | - | 0.741 |
| | A-15 | 0.594 | - | |

### 4.2.2 Factor and reliability analysis for communication errors

(1) Factor analysis

For communication error dimension, Table 4.12 shows the EFA results. The value for KMO test was 0.722 and as for the Bartlett's test of sphericity, the chi-square was 728.291 and it reached the level of significance (< 0.05). With EFA, B-7 were deleted because of the factor loads not reaching 0.50. At the end, it extracted two components for this dimension and total variance explained was 67.706%. The components were named as below.

(i) Component 1: Readback and hearback error

This component included B-3 as “Pilots’ wrong readbacks are difficult to be corrected by ATC when frequency is congested”, B-8 as “Pilots read back correctly but ATC fails to notice that the clearances or instructions are not those he/she intended to issue”, B-9 as “ATC fails to notice that pilots make a request that might contain potential occurrence.”, and the last, B-2 as “ATC neither notice nor correct pilots’ readback error.” These questions related to pilots’ readback errors and/or controller’s hearback errors. Numbers of events were pilots’ readback error complemented controllers’ hearback errors, while some cases were just controllers’ hearback errors. Literatures named the two kinds of situations respectively as readback/hearback error and hearback error. However, based on responses of pilots and controllers in Taiwan, they might treat them as same nature to be combined. Hence, this research named this component as “Readback and hearback error”.

(ii) Component 2: No pilot readback

Three questions were in this component, including B-5 as “Pilots do not read back ATC’s safety-related clearances (takeoff or landings) or instructions (Altitude, speed or heading)”, B-4 as “Pilots do not read back ATC’s clearances or instructions”, B-6 as “Pilots do not read back ATC’s clearances or instructions because of pilots’ complacency”. Because the description above all related to the absent of pilots’ response to the instructions or clearances, the component was given name as “No pilot readback.”

(2) Reliability analysis

B-1 was deleted for higher component reliability. The final reliability analysis results for factors are presented in Table 4.13. Cronbach's alpha values of all components were between 0.70 and 0.95, which met the acceptable value.

Table 4.12 Factor analysis of communication errors

| **Questions** | **Component 1** | **Component 2** |
|---|---|---|
| B-3 | 0.777 | -0.009 |
| B-8 | 0.776 | 0.179 |
| B-9 | 0.764 | 0.151 |
| B-2 | 0.756 | -0.084 |
| B-5 | 0.066 | 0.917 |
| B-4 | 0.027 | 0.862 |
| B-6 | 0.083 | 0.849 |
| Eigenvalue | 2.374 | 2.366 |
| % of Variance | 33.911 | 33.795 |
| Cumulative % | 33.911 | 67.706 |

Table 4.13 Reliability analysis of communication errors

| Components | Questions | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted | Cronbach's Alpha |
|---|---|---|---|---|
| Readback and Hearback Error | B-3 | 0.571 | 0.717 | 0.768 |
| | B-8 | 0.600 | 0.700 | |
| | B-9 | 0.574 | 0.709 | |
| | B-2 | 0.547 | 0.724 | |
| No Pilot Readback | B-5 | 0.8 | 0.727 | 0.854 |
| | B-4 | 0.707 | 0.813 | |
| | B-6 | 0.674 | 0.845 | |

### 4.2.3 Factor and reliability analysis for aviation occurrences

(1) Factor analysis

The EFA results of aviation occurrences dimension are presented in Table 4.14.

KMO test value was 0.823 and the Bartlett's test of sphericity, the chi-square was 1577.978 and it also reached the level of significance (< 0.05). With EFA, C-5 was deleted for all its factor loads were lower than 0.50. Two components were extracted and the names were introduced as following.

(i) Component 1: Runway Incursion

This component was composed of five questions, including C-7 as "An aircraft made a runway incursion during its landing due to communication errors", C-8 as "An aircraft crossed a runway hold marking and made a runway incursion due to communication errors", C-10 as "ATC failed to provide required minimum separation between aircraft and ground obstacle/terrain due to communication errors", C-9 as "ATC failed to provide required minimum separation between aircraft (in flight or during takeoff/landing with other aircraft on adjacent runways), and C-6 as "An aircraft made a runway incursion during its takeoff due to communication errors". C-6, C-7, and C-8 were the scenarios of runway incursion, and C-9 and C-10 were controllers' operational errors, which were one type of runway incursion (FAA, 2015). Thus, these circumstances were synthesized to this component named "Runway incursion".

(ii) Component 2: Altitude/Heading deviation

This component had two situations, which were C-1 as "Pilots deviated from ATC assigned altitude due to communication errors" and C-2 as "Pilots deviated from ATC assigned heading due to communication errors". The two questions were the situations that pilot did not follow or mistook ATC instructions or clearances, which was pilots' deviation, and the deviation usually included altitude and/or heading discrepancy. Therefore, the name of this component was “Altitude/Heading deviation”.

(2) Reliability analysis

For improving the component reliability, C-3 and C-4 were deleted. The analysis results for factors are presented in Table 4.15. Two components’ values of Cronbach’s alpha were between 0.70 and 0.95, reaching the acceptable value.

Table 4.14 Factor analysis of aviation occurrences

| **Questions** | **Component 1** | **Component 2** |
|---|---|---|
| C-7 | 0.915 | 0.186 |
| C-8 | 0.889 | 0.220 |
| C-10 | 0.874 | 0.058 |
| C-9 | 0.864 | 0.079 |
| C-6 | 0.851 | 0.190 |
| C-1 | 0.142 | 0.924 |
| C-2 | 0.149 | 0.920 |
| Eigenvalue | 3.905 | 1.830 |
| % of Variance | 55.785 | 26.143 |
| Cumulative % | 55.785 | 81.928 |

Table 4.15 Reliability analysis of aviation occurrences

| Components | Questions | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted | Cronbach’s Alpha |
|---|---|---|---|---|
| Runway Incursion | C-7 | 0.799 | 0.924 | 0.934 |
| | C-8 | 0.889 | 0.907 | |
| | C-10 | 0.860 | 0.913 | |
| | C-9 | 0.785 | 0.928 | |
| | C-6 | 0.798 | 0.924 | |
| Altitude/Heading Deviation | C-1 | 0.750 | - | 0.857 |
| | C-2 | 0.750 | - | |

## 4.3 T-Test for difference between means for pilots and controllers

This section adopted T-Test for difference between means to examine that there were cognitive differences on each dimension and component between pilots and air traffic controllers. The results pointed out that pilots and controllers' cognition to "Workload", "Linguistic factors", "Pilot anticipation", "Readback and hearback error", "No pilot readback", "Runway Incursion" and "Altitude/Heading deviation" had significant differences, which validated H1 as "Pilots and controllers have significantly different cognitions to the dimensions of factors, errors, and related aviation occurrences". The results are presented in Table 4.16.

(1) There were significant differences between pilots and controllers' attitude to the "Workload" component, and the mean of controllers was higher than that of pilots, indicating controllers perceived much more increasing workload during duties.

(2) Pilots and controllers' agreement on "Linguistic factors" had significant differences, where the mean of pilots was much higher than that of controllers, suggesting that pilots more recognized the problems related to accent, controllers' numbers of instructions and speech rate, and so on, which may lead to communication errors. Besides, this component included some situations resulted from controllers' speech problems, but controllers were not inclined to agree on them. The probable reason was that it was very easy to blame others for our behavior and for what happens to us (Cox, 2017). As a human nature, people found others' mistakes more easily.

(3) The "Pilot anticipation" component also revealed the difference between pilots

and controllers. The mean of controllers was obviously much more than pilots', showing that generally pilots did not recognize that they flew with their own concepts, but controllers could perceive this kind of phenomena. Similarly, it was more easily for controllers to find this negative behavior of pilots.

(4) For "Similar call sign" and "Frequency change", pilots and controllers had no significant different cognition, indicating they had similar experiences and perceptions of the two factors.

(5) According to the mean scores, pilots had higher scores on readback and hearback error, implying that based on experiences, pilots may have more perception of this kind of communication error.

(6) As for "No pilot readback", controllers got pretty higher scores than pilots, meaning that controllers had pretty more perception of pilots' absent responses.

(7) Controllers had higher mean scores on "Altitude/Heading deviation", while pilots had higher scores on "Runway incursion", indicating that they experienced different occurrences due to communication errors.

Table 4.16 T-Test for difference between means for pilots and controllers

| Dimension | Component | Mean score | | T-value |
|---|---|---|---|---|
| | | Pilot (n=173) | Controller (n=112) | |
| Factors | Workload | 4.2925 | 4.5661 | 4.888** |
| | Linguistic factors | 4.1214 | 3.872 | -4.463** |
| | Pilot Anticipation | 1.8613 | 2.6845 | 10.229** |
| | Similar call sign | 4.1175 | 4.1607 | 0.571 |
| | Frequency change | 3.8064 | 3.6429 | -1.648 |
| Error | Readback and hearback error | 2.4971 | 2.1362 | -5.459** |
| | No pilot readback | 1.3815 | 2.2054 | 10.918** |
| Occurrence | Runway incursion | 1.422 | 1.2179 | -3.482** |
| | Altitude/Heading deviation | 1.4538 | 1.7679 | 4.171** |

Note: The grid with gray were the significantly higher means.
*Notes: **p<0.05 and ***p<0.01.

## 4.4 Differences among responses categories

Section 4.1 has displayed the results of descriptive statistical analysis, showing the response categories of pilots and controllers. This section presents the different cognition of the response categories to the components of every dimension, and these of pilots and controllers are analyzed separately. Most demographic profiles had three or more categories, which were analyzed with one-way ANOVA, and other few profiles encompassed only two categories, which were with T-Test for difference between means.

(1) Examination of pilots' different cognition among responses categories

First was the ANOVA test for age, professional status, flight training background, and years experiences and T-Test for difference between means for gender and nationality. Next, using Scheffe for post hoc tests to explore the detail of ANOVA, figuring out which categories were significantly different from each other. Table 4.17 displays the results embodying that pilots' cognition to components had significant differences according to flight training background, years experiences, and nationality.

Table 4.17 ANOVA and t-test for pilots' responses categories

| Dimension | Component | Professional Status | Flight training background | Years experiences | Nationality (T-value) |
|---|---|---|---|---|---|
| Factors | Workload | 0.411 | 1.893 | 1.224 | 1.374 |
| | Linguistic factors | 2.489** | 0.426 | 2.468** | 2.928** |
| | Pilot anticipation | 0.971 | 0.471 | 1.210 | 0.369 |
| | Similar call sign | 1.930 | 3.863** | 0.758 | 1.375 |
| | Frequency change | 1.454 | 0.703 | 1.171 | -0.510 |
| Error | Readback and hearback error | 0.531 | 0.743 | 0.932 | -0.016 |
| | No pilot readback | 0.969 | 4.679** | 1.307 | -0.326 |
| Occurrence | Runway incursion | 0.933 | 2.879** | 3.433** | -0.752 |
| | Altitude/Heading deviation | 0.730 | 2.219 | 0.798 | -0.245 |

Note: The values in Nationality column were t-values, and others were F values.
*Notes: Grids with gray indicated that the values had significance. **p<0.05

After the ANOVA test, "Professional status" and "Years experiences" turned to have no significant difference at "Linguistic factors" component with the Scheffe post hoc tests, and other results were narrated as following.

According to Table 4.18, with different flight training background, "Company training" had significantly higher mean scores than "Military" on "Similar call sign". Besides, "Others" entirely obtained significant higher mean scores than other flight training background on "No pilot readback" and "Runway incursion".

Table 4.18 Pilots' cognitive comparation by different flight training backgrounds

| Dimension | Component | (a) Military (N=33) | (b) CPL/ATPL (N=47) | (c) Company Training (N=90) | (d) Others (N=3) | Significant Differences (Scheffe) |
|---|---|---|---|---|---|---|
| Factor | Similar call sign | 3.909 | 4.000 | 4.259 | 4.000 | (a,c) |
| Error | No pilot readback | 1.283 | 1.426 | 1.359 | 2.444 | (a,d), (b,d), (c,d) |
| Occurrence | Runway incursion | 1.449 | 1.319 | 1.433 | 2.400 | (b,d) |

Note: The last column presented significant differences, and the latter value was higher than the former's in the brackets.

Presented in Table 4.19, the "Years experiences" had a significance among the group as ">20 years" possessed much higher mean score than "<5 years" did at the "Runway incursion" component in the dimension of aviation occurrence. This could be inferred that with more experiences, senior pilots encountered or learned of more incidents than junior did.

Table 4.19 Pilots' cognitive comparation by different years experiences

| Dimension | Component | (a) < 5 years (N=33) | (b) 5-10 years (N=46) | (c) 11-15 years (N=35) | (d) 16-20 years (N=23) | (d) >20 years (N=35) | Significant Differences (Scheffe) |
|---|---|---|---|---|---|---|---|
| Occurrence | Runway incursion | 1.165 | 1.404 | 1.394 | 1.435 | 1.714 | (a,d) |

Note: The last column presented significant differences, and the latter value was higher than the former's in the brackets.

The profile of nationality was divided to two categories, which were Taiwanese and other countries, and the differences were examined with T-Test for difference between means. From Table 4.20, it shows that foreign pilots had lower mean scores on "Linguistic factors" than Taiwanese pilots, and it reached the significance level

(<0.05), pointing out that they had less problem of statement with air traffic controllers. This may be because pilots from other countries had good English proficiency or were accommodated to Taiwanese controllers' speech practices.

Table 4.20 Pilots' cognitive comparation by different nationality

| Dimension | Component | (a) Taiwan, R.O.C. (N=164) | (b) Others (N=9) | Differences Between Means |
|---|---|---|---|---|
| Factor | Linguistic factors | 4.1453 | 3.6852 | (b,a) |

Note: The last column presented significant differences, and the latter value was higher than the former's in the brackets.

(2) Examination of controllers' different cognition among responses categories

Same as the examination for pilots, the one-way ANOVA and T-Test for difference between means were first carried out to present the preliminary results of significant differences. Afterward, Scheffe method was used to do the post hoc test to view the detail of those differences. By first step, Table 4.21 demonstrates that categories of "Professional status" and "Years experiences" had significant differences with one another.

Table 4.21 ANOVA for controllers' responses categories

| Dimension | Component | Professional Status | Years Experiences |
|---|---|---|---|
| Factors | Workload | 3.231** | 0.995 |
| | Linguistic factors | 1.100 | 1.609 |
| | Pilot anticipation | 0.836 | 1.775 |
| | Similar call sign | 5.388*** | 1.357 |
| | Frequency change | 0.594 | 0.630 |
| Error | Readback and hearback error | 0.334 | 0.373 |
| | No pilot readback | 0.372 | 0.997 |
| Occurrence | Runway incursion | 1.929 | 1.371 |
| | Altitude/Heading deviation | 8.587*** | 10.802*** |

Note: The values were F values.
*Notes: Grids with gray indicated that the values had significance. **p<0.05 and ***p<0.01

Table 4.22 shows the detailed ANOVA results of controllers' professional status. By Scheffe post hoc tests, this profile turned to have no significant difference in "Workload" component, while it still had significance in "Similar call sign" and "Altitude/Heading deviation". Supervisors significantly had higher scores than managers did on "Similar call sign" component, indicating supervisors perceived more frequencies of this occurrence. As for "Altitude/Heading deviation", tower controllers in general had lower mean scores than other categories did on this component because tower controllers were mainly responsible for issuing take-off or landing clearances and supervising ground movements, less relating to altitude or heading clearances.

Table 4.22 controllers' cognitive comparation by different professional status

| Dimension | Component | (a) Tower (N=34) | (b) Radar (N=44) | (c) Supervisor (N=25) | (d) Manager (N=9) | Significant Differences (Scheffe) |
|---|---|---|---|---|---|---|
| Factor | Similar call sign | 3.921 | 4.318 | 4.387 | 3.667 | (d,c) |
| Occurrence | Altitude/Heading deviation | 1.382 | 1.863 | 2.040 | 2.000 | (a,b), (a,c) (a,d) |

Note: The last column presented significant differences, and the latter value was higher than the former's in the brackets.

The detailed mean scores of controllers' years experiences are listed in Table 4.23. The table shows that mean scores of "Less than ten years" were significantly lower than other years experiences categories, inferred that junior controllers have less experiences of this kind of situations.

Table 4.23 controllers' cognitive comparation by different years experiences

| Dimension | Component | (a) <10 years (N=43) | (b) 10-15 years (N=17) | (c) 16-20 years (N=20) | (d) >20 years (N=32) | Significant Differences (Scheffe) |
|---|---|---|---|---|---|---|
| Occurrence | Altitude/Heading deviation | 1.407 | 1.912 | 2.075 | 1.984 | (a,b), (a,c) (a,d) |

Note: The last column presented significant differences, and the latter value was higher than the former's in the brackets.

## 4.5 Factor-error-occurrence regression analysis

The results of T-Test for difference between means indicated that pilots and controllers had significantly different cognition to the three dimensions and components belonging them. In this section, computing the mean of each component as summated scales and adopting both simple and multiple regression analysis to verify the relations between factors and communication errors as well as between communication errors and aviation occurrences.

To avoid collinearity, this study used components' summated scales to execute multiple regression test and had analysis of correlation among the independent variables in advance, of which results were shown in Appendix III. The results indicated that most independent variables had modestly correlated (R value was between 0.1 and 0.39 or -0.39 and -0.1), and only few had moderately correlated (R value was between 0.4 and 0.69 or -0.69 and -0.4). Besides, VIF of each independent variable was not greater than 10, which meant there were no collinearity, and the data were suitable for multiple regression analysis.

### 4.5.1 Regression analysis of factors and communication errors

(1) Regression analysis of factor-error relation for pilots

First, based on H2a to H2e, taking all factors contributed to communication errors as the independent variables, and readback and hearback error as the dependent variable for the multiple regression analysis. As Table 4.24 presents, the adjusted $R^2$ was 0.111, F value was 5.308 and the P-value was 0.000, lower than 0.05, meaning the independent variables' 11.1% variance explained for dependent variables reached statistical significance. Lastly, the DW value was 1.980, indicating no autocorrelation. The regression results showed that "Workload", "Pilot anticipation", and "Frequency change" had significant positive influence on "Readback and hearback error". Therefore, H2a, H2c, and H2e for pilots were valid. Finally, among all factors, "Frequency change" and "Workload" have more significant relation to readback and hearback error.

Table 4.24 Analysis of factor-error relation (Pilots-1)

| Dependent Variables: Readback and hearback error<br>Independent Variables: Factors leading to communication error | | | Adjusted $R^2$: 0.111<br>F: 5.308<br>P-value: 0.000<br>Durbin-Watson: 1.980 |
|---|---|---|---|
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H2a-Workload | 0.139 | 0.088* | 1.281 |
| H2b-Linguistic factor | 0.127 | 0.130 | 1.350 |
| H2c-Pilot anticipation | 0.177 | 0.018** | 1.060 |
| H2d-Similar call sign | -0.087 | 0.278 | 1.253 |
| H2e-Frequency change | 0.210 | 0.012** | 1.321 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

The other regression analysis was for H2f, setting "Pilot anticipation" as the independent variable and "No pilot readback" as the dependent variable. Displayed by Table 4.25, the adjusted $R^2$ was 0.159, F value was 33.468 and the P-value was 0.000, lower than 0.05, suggesting that the 15.9% independent variables' variance explained for dependent variables had statistical significance. The regression results showed that "Pilot anticipation" had significant positive relation to "No pilot readback". Thus, H2f for pilots was valid and the standardized coefficient was 0.405.

Table 4.25 Analysis of factor-error relation (Pilots-2)

| Dependent Variables: No pilot readback<br>Independent Variables: Pilot anticipation | | Adjusted $R^2$: 0.159<br>F: 33.468<br>P-value: 0.000 |
|---|---|---|
| **Independent variables** | **Beta** | **p-value** |
| H2f-Pilot anticipation | 0.405 | 0.000*** |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

Based on the results above, H2a, H2c, H2e, and H2f were valid, which meant H2 for pilots also had validation; that is, factor has significantly positive relation with communication error.

(2) Regression analysis of factor-error relation for controllers

Same as the analysis for pilots, to verify H2a to H2d, all factors contributed to communication errors were set as the independent variables, and readback and hearback error as the dependent variable. Table 4.26 presents that the adjusted $R^2$ was 0.152, F value was 4.986 and the P-value was 0.000, lower than 0.05, thus the independent variables' 15.2% variance explained for dependent variables had statistical significance. Besides, the DW value was 1.768, without autocorrelation. The regression results showed that "Linguistic factors", "Pilot anticipation", and "Similar call sign" influence significantly and positively on "Readback and hearback error". The validation of H2b, H2c, and H2d for controllers was supported, and among these factors, "Frequency change" and "Pilot anticipation" and "Linguistic factors" related more significant to readback and hearback error.

Next step was also to set "Pilot anticipation" as the independent variable and "No pilot readback" as the dependent variable to execute the simple regression analysis for the verification of H2f. The adjusted $R^2$ was 0.039, F value was 5.527 and the P-value was 0.000, lower than 0.05, showing the 3.9% independent variables' variance explained for dependent variables reaching statistical significance. The regression results indicated that "Pilot anticipation" possessed significantly positive relation to "No pilot readback", which validated H2f for controllers and the standardized coefficient was 0.219. The results are shown in Table 4.27.

Table 4.26 Analysis of factor-error relation (Controllers-1)

| Dependent Variables: Readback and hearback error<br>Independent Variables: Factors leading to communication error | | | Adjusted $R^2$: 0.152<br>F: 4.986<br>P-value: 0.000<br>Durbin-Watson: 1.768 |
|---|---|---|---|
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H2a-Workload | -0.097 | 0.352 | 1.408 |
| H2b-Linguistic factor | 0.226 | 0.023** | 1.253 |
| H2c-Pilot anticipation | 0.238 | 0.012** | 1.134 |
| H2d-Similar call sign | 0.178 | 0.097* | 1.488 |
| H2e-Frequency change | -0.012 | 0.893 | 1.090 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

Table 4.27 Analysis of factor-error relation (Controllers-2)

| Dependent Variables: No pilot readback<br>Independent Variables: Pilot anticipation | | Adjusted $R^2$: 0.039<br>F: 5.527<br>P-value: 0.000 |
|---|---|---|
| **Independent variables** | **Beta** | **p-value** |
| H2f-Pilot anticipation | 0.219 | 0.021** |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

Referring to the results above, H2b, H2c, H2d, and H2f were valid, supporting H2 for controllers also had validation; that is, factor has significantly positive influence on communication error.

## 4.5.2 Explanation for the factor-communication error

As the questionnaires were responded by pilots and controllers serving for aviation industry in Taiwan to understand the communicative problems, the following was the explanation of the regression analysis, which could reflect some conditions of the air traffic system in Taiwan. This section was divided to two parts as the regression of factors and communication errors and the regression of communication errors and aviation occurrences.

(1) Workload

The results indicated that for pilots, workload was one of the reasons for readback and hearback error, while for controllers, it had no significant effect. The descriptive statistical analysis showed that both pilots and controllers really agreed on the issues increasing workload and considered workload a factor contributing to communication error. However, for controllers in Taiwan, the connection between their workload and readback and hearback error was not significant. Perhaps during their duties, they had not experienced this error because of workload that frequently. Besides, controllers may be accommodated to the high workload duty period.

(2) Linguistic factors

From the results, for controllers, linguistic factors significantly related to readback hearback error, whereas the relation was not significant for pilots. The mean scores of pilots for linguistic factors was 4.1214, and that of controllers was 3.872, which were both high. Though pilots averagely gave higher scores to this component, indicating that they agreed on the relation of linguistic factors and the occurrences of communication errors, they did not associate this factor with the exact "readback and hearback error".

Following are three possible reasons for the results. First, in reality, linguistic factors are not huge issues for pilots in Taiwan. They have traveled around numerous countries or regions that they probably have been accommodated to the high speech rate, different accent, many numbers of instructions, native non-standard phraseology, and so on, especially pilots with rich years experiences. Second, errors might have been reduced because of pilots' rechecking of unclear instructions, which can be supported by pilots' low mean scores (1.61) on A-12, much lower than controllers' 2.30, as they much more disagreed on "pilots do not request the ATC for clarifications, even a clearance or an instruction is not clear".

Lastly, as controllers are responsible for the safe and efficient flow of air traffic, one controller may handle large numbers of aircraft at the same time to keep the sufficient separation, so they have to give instructions continuously to different flights, and the instructions are usually fast along with many items. Serving for lots of flights simultaneously, controllers may lose concentration on the pilot's readback because they had to focus on compiling the next instructions issued to another aircraft. Sometimes when a pilot readback incorrectly, it is too late for controllers to notice and a deviation afterward occurred. Hence, the job characteristics of controllers can be the main reason for their perception of the significant relation between linguistic factors and readback and hearback error.

(3) Pilot anticipation

Pilot anticipation significantly related to readback and hearback error and no pilot readback for both pilots and controllers. However, they inclined to disagree on the situations described in this "pilot anticipation" component. In the T-Test for difference between means, both pilots and controllers' mean scores on this component were low, no more than 3.00. Besides, based on the work experiences of pilots and controllers in Taiwan, actually the occurring frequency of readback and hearback error and no pilot readback were not high. Therefore, the actual significant relation between pilot anticipation and the two errors were low agreement and few occurrences, indicating this kind of events were not frequent, but the factor's effects were positive. This can be inferred that once the situations of pilot anticipation increase, the readback and hearback error or no pilot readback will occur more often.

Although the agreement and error frequency were low, the first case from TACARE in Chapter 2 indeed presented an event of pilot anticipation resulting in no pilot readback in Taiwan. Hence, the positive relation between pilot anticipation and error was empirically verified.

(4) Similar call sign

For controllers, similar call sign was a significant reason for readback and hearback error, while it was not for pilots. Both pilots and controllers in Taiwan gave high scores on this component, but it seemed to have no obvious relation with readback and hearback errors for pilots in reality. Pilots and controllers in Taiwan inclined to disagree on A-4 as "Pilots do not correct the ATC actively when he/she calls pilots the wrong call sign" and A-5 as "ATC does not remind pilots when there is an aircraft with similar call sign on the same frequency." Therefore, chances for the occurrences of communication errors due to similar call sign are presumably lessen.

Nevertheless, the job characteristics of controllers also accounts for the results. As mentioned previously, controllers provide services for many aircraft at the same time. There are many aircraft on the radar and radio, denoting many call signs controllers should pay attention to and remember. However, pilots only need to focus on their own call sign. Once there are similar call signs at the same time and region, chances that controllers mistake the call signs and do not find their incorrect calling for the aircraft, or they do not discover the pilot's wrong readback. This is again the job characteristics causing significant factor-error relation of controller.

(5) Frequency change

Frequency change significantly related to readback and hearback error for pilots but not for controllers. Because during a whole flight, especially for the long haul, the aircraft would pass numbers of flight information regions (FIR) and pilots need to keep changing the radio frequency to communicate with local air traffic control. If there are situations such as no transmission for an abnormally long time or the local ATC informing of the absent area entering report, pilots in flight could perceive these situations that are caused by frequency change problems more easily than controllers on the ground. Consequently, pilots might be more able to perceive a common error that they read back and tuned the frequency incorrectly and controllers do not notice it, contributing to the significant relation between this factor and error.

### 4.5.3 Regression analysis of communication errors and aviation occurrences

(1) Regression analysis of error-occurrence relation for pilots

The first analysis for this part was setting both "Readback and hearback error" and "No pilot readback" as the independent variables and "Runway incursion" as the dependent variable. After the multiple regression analysis, the adjusted $R^2$ was 0.151, F value was 16.346 and the P-value was 0.000, lower than 0.05. This implied the independent variables' 15.1% variance explained for dependent variables achieved statistical significance. Last, the DW value was 2.038, so the variables did not have autocorrelation. The regression results showed that “Readback and hearback error” and “No pilot readback” had significant positive influence on “Runway incursion”. Therefore, H3a and H3b for pilots were valid. Additionally, within the two communication errors, “No pilot readback” had greater relation to runway incursion. The results are displayed in Table 4.28.

Table 4.28 Analysis of error-occurrence relation (Pilots-1)

| Dependent Variables: Runway incursion<br>Independent Variables: Communication errors | | | Adjusted $R^2$: 0.151<br>F: 16.346<br>P-value: 0.000<br>Durbin-Watson: 2.038 |
|---|---|---|---|
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H3a-Readback and hearback error | 0.232 | 0.002*** | 1.107 |
| H3b-No pilot readback | 0.264 | 0.000*** | 1.107 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

Next, defining “Readback and hearback error” and “No pilot readback” as the independent variables and “Altitude/Heading deviation” as the dependent variable. Shown in Table 4.29, the adjusted $R^2$ was 0.270, F value was 32.834 and the p-value was 0.000, lower than 0.05. The independent variables’ 27% variance explained for dependent variables had statistical significance. Furthermore, the DW value was 2.122 that was acceptable, having no autocorrelation. The regression results embodied the significantly positive influence of “No pilot readback” on “Altitude/Heading deviation”. As a result, H3d was valid.

Table 4.29 Analysis of error-occurrence relation (Pilots-2)

| Dependent Variables: Altitude/Heading deviation<br>Independent Variables: Communication errors | | | Adjusted $R^2$ : 0.270<br>F: 32.834<br>P-value: 0.000<br>Durbin-Watson: 2.122 |
|---|---|---|---|
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H3c-Readback and hearback error | 0.041 | 0.551 | 1.107 |
| H3d-No pilot readback | 0.514 | 0.000*** | 1.107 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

According to the results above, H3a, H3b, and H3d were valid, inferring that H3 for pilots was also validated, which was "Communication error has significantly positive influence on aviation occurrence".

(2) Regression analysis of error-occurrence relation for controllers

First, "Readback and hearback error" and "No pilot readback" were the independent variables and "Runway incursion" was the dependent variable. After the multiple regression analysis, the adjusted $R^2$ was 0.070, F value was 5.185 and the P-value was 0.000, lower than 0.05. The independent variables' 7% variance explained for dependent variables measured up statistical significance. What's more, the DW value was 1.892 that the variables had no autocorrelation. The regression results are displayed in Table 4.30, indicating that "Readback and hearback error" had significantly positive influence on "Runway incursion". Hence, H3a for controllers was valid.

Table 4.30 Analysis of error-occurrence relation (Controllers-1)

| Dependent Variables: Runway incursion<br>Independent Variables: Communication errors | | | Adjusted $R^2$: 0.070<br>F: 5.185<br>P-value: 0.000<br>Durbin-Watson: 1.892 |
|---|---|---|---|
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H3a-Readback and hearback error | 0.201 | 0.067* | 1.414 |
| H3b-No pilot readback | 0.132 | 0.226 | 1.414 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

For the validation test for H3c and H3d, setting "Readback and hearback error" and "No pilot readback" as the independent variables and "Altitude/Heading deviation" as the dependent variable. The results are in Table 4.31. The adjusted $R^2$ was 0.246, F value was 19.111 and the p-value was 0.000, lower than 0.05. The 24.6% of independent variables' variance explained for dependent variables attained statistical significance. Next, the DW value was 1.525, which was acceptable with no autocorrelation. Based on the results, the significantly positive influence of "Readback and haerback error" and "No pilot readback" on "Altitude/Heading deviation" were supported; thus, H3c and H3d for controllers were valid.

Table 4.31 Analysis of error-occurrence relation (Controllers-2)

| | | | |
|---|---|---|---|
| Dependent Variables: Altitude/Heading deviation<br>Independent Variables: Communication errors | | | Adjusted $R^2$: 0.246<br>F: 19.111<br>P-value: 0.000<br>Durbin-Watson: 1.525 |
| **Independent variables** | **Beta** | **p-value** | **VIF** |
| H3c-Readback and hearback error | 0.337 | 0.001*** | 1.414 |
| H3d-No pilot readback | 0.241 | 0.016** | 1.414 |

*Notes: *p<0.1, **p<0.05 and ***p<0.01

In line with all results for controllers, H3a, H3c, and H3d were valid, and H3 for controllers also possess validation as “Communication error has significantly positive influence on aviation occurrence”.

### 4.5.4 Explanation of communication errors and aviation occurrences

Both pilots and controllers in Taiwan generally gave low scores to the situations of aviation occurrences, indicating the occurrences must have been managed to a certain extent. However, errors and occurrences are inevitable, as the results still presented some relation between errors and occurrences based on pilots and controllers’ experiences.

For pilots, with their work experiences, they thought both readback and hearback error and no pilot readback affected occurrences of runway incursion positively, and the more obvious reason for altitude/heading deviation was their non-response to ATC instructions or clearances. For controllers, both readback and hearback error and no pilot readback had high relation with altitude/heading deviation, whereas runway incursion was mainly caused by readback and hearback error. The results can be explained by the T-Test for difference between means that pilots thought runway incursion had relatively higher occurring frequencies, while controllers thought altitude/heading deviation occurred more often. Therefore, the occurrence with higher frequencies can be more easily perceived to occur due to more errors.

The pilot samples serving for the airline were not only Taiwanese but also from other countries, and they had flied to various countries for their job and experienced different practices, events and rules in different regions. As for controller samples, they were all Taiwanese and most of their experiences were the "Taiwan circumstances". The different work memories, encountering events and feelings of pilots and controllers is the main reason for the different results of error-occurrence relation. Despite the differences between pilots and controllers' results, the thing in common is that errors and occurrences still have potential to affect flight safety. Therefore, the specific contributing errors and specific occurrences should be concentrated on and be avoided.

### 4.5.5 Verification of the results

The hypotheses of factor-error-occurrence relation were made based on the objective data in literature reviews and the cases in Chapter 2, and the results of subjective perspectives validated all hypotheses completely, or at least partially: pilots or controllers, as the verification for the real data. The relation results are shown in Figure 4.1 and Figure 4.2.

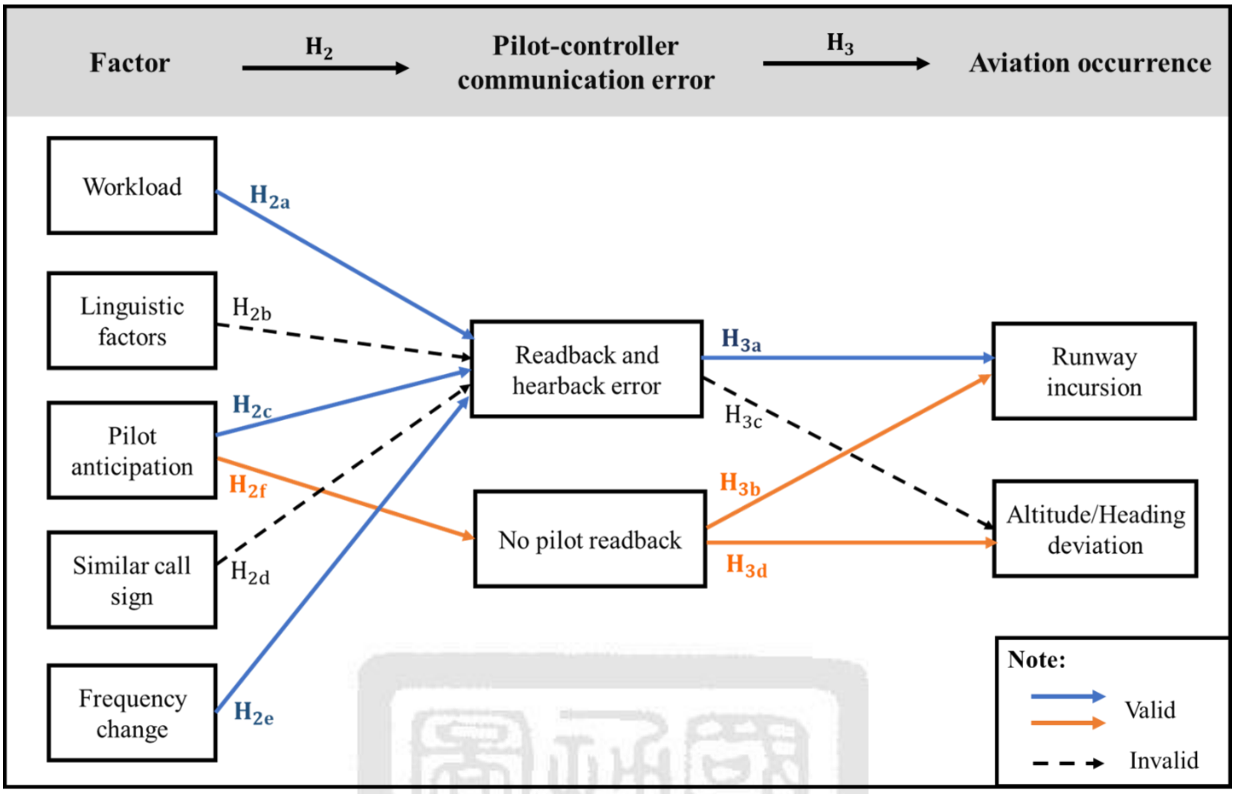


Figure 4.1 Validation of factor-error-occurrence hypotheses (Pilots)

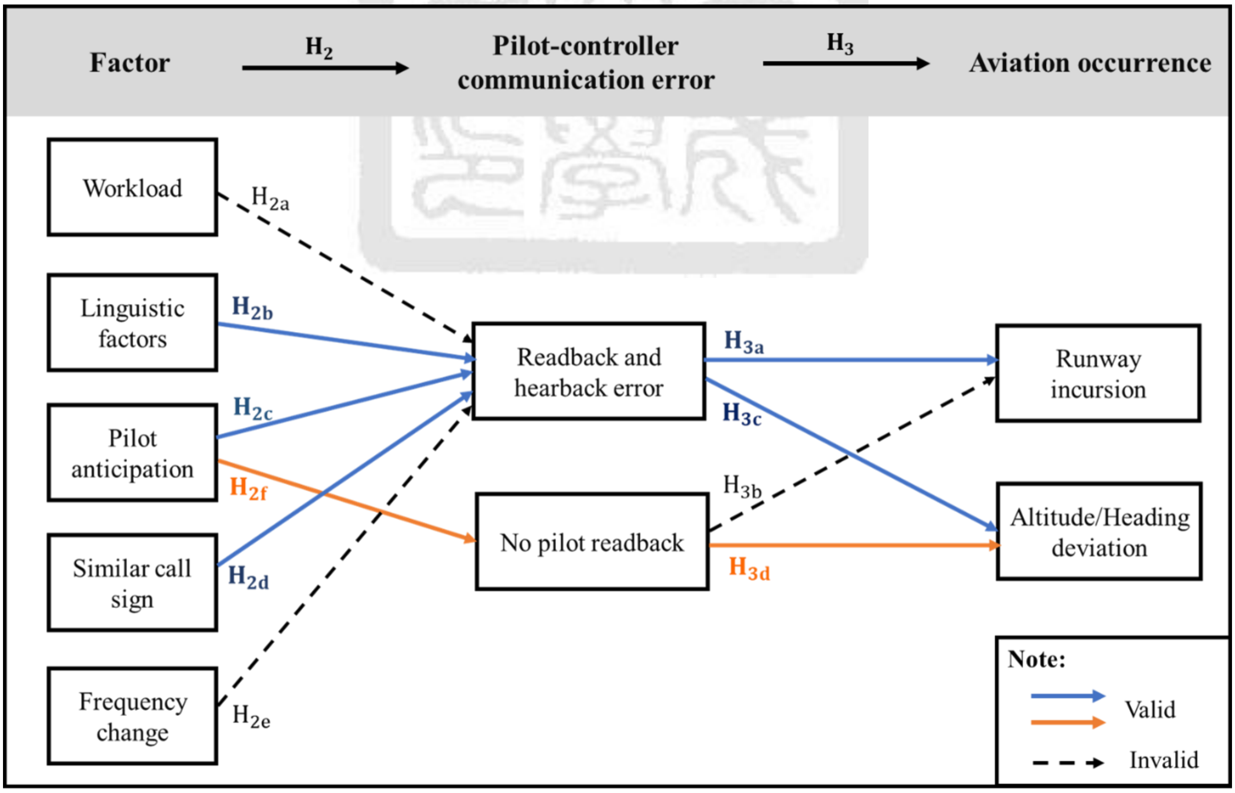


Figure 4.2 Validation of factor-error-occurrence hypotheses (Controllers)

Despite the fact that this study mainly represented for “Taiwan situations”, the results also fitted in the explanation for international cases, which were narrated as following.

(1) The H2a and H3a indicated a coherent relation that workload could result in readback and hearback errors and next lead to runway incursion and this relation was significant for pilots. Pilots’ high workload from the duty time limitation was one of the reasons for Tenerife disaster, inducing the readback and hearback error and the finally deadly runway incursion. On the other hand, even Antonov-124 runway incursion in Taiwan was due to controller’s workload, the case verified that high workload environment still was a common reason for readback and hearback error occurrences.

(2) The H2b and H3a or H3c described the coherent situations from linguistic factors to readback and hearback errors and ended up runway incursion or altitude/heading deviation. This relation was perfectly significant for controllers. Two cases were that the use of non-standard phraseology made the readback and hearback error occur and then lead to the runway incursion of Tenerife disaster as well as the altitude deviation of B1900C’s CFIT accident.

(3) H2c and H3a stated the coherent relation of pilot anticipation causing readback and hearback error and resulting in runway incursion. The relations were completely significant for both pilots and controllers. The verification was the anticipation of KLM pilots made him misunderstood the non-takeoff clearance as the permission of takeoff, which was also one of reasons for the Tenerife disaster.

(4) H2f and H3d represented for the relation of pilot anticipation and no pilot readback and the result as altitude/heading deviation, and the relations were also integrally significant for both pilots and controllers. The results could be verified by the case in Taiwan recorded in TACARE. The aircraft executed an early and inappropriate climb because of pilot anticipation and absent readback.

## 4.6 Summary

With the factor analysis, this study extracted “Workload”, “Linguistic factors”, “Pilot anticipation”, “Similar call sign” and “Frequency change” as the five components of the “Factors” dimension. “Readback and hearback error” and “No pilot readback” belonged to “Communication errors” dimension. Third, the “Aviation occurrence” dimension included two components as “Runway incursion” and “Altitude/Heading deviation”.

The results of the T-Test for difference between means for showed that pilots and controllers had significantly different cognition to most of the components, composed of “Workload”, “Linguistic factors”, “Pilot anticipation”, “Readback and hearback error”, “No pilot readback”, “Runway incursion” and “Altitude/Heading deviation”.

With the one-way ANOVA and T-Test for difference between means, both pilot’s and controllers’ categories of demographic profiles could also have significantly different cognition to the components with one another. For pilots, their flight training background had significant differences in all three dimensions, and their years experiences and nationality had significant differences in the “Occurrence” and the “Factor” dimension respectively. The other, for controllers, their professional status had significant differences with one another in the “Factor” and “Occurrence” dimension, while their years experiences possessed the significant differences in the "Occurrence" dimension.

Finally, the results of the regression analysis were summarized as following with Table 4.32, Table 4.33, presenting the validation of factor-error-occurrence hypotheses for pilots and air traffic controllers. Table 4.34 displaying the validation of all hypotheses in this study.

(1) For pilots, "Workload", "Pilot anticipation" and "Frequency change" were significantly associated with "Readback and hearback error", and "Pilot anticipation" significantly and positively related to "No pilot readback". For the exploration of the relation between communication errors and aviation occurrences, both "Readback and hearback error" and "No pilot readback" significantly related to "Runway incursion", whereas "No pilot readback" possessed significant relation with "Altitude/Heading deviation".

(2) For controllers, "Linguistic factors", "Pilot anticipation" and "Similar call sign" significantly related to "Readback and hearback error", and "Pilot anticipation" significantly and positively related to "No pilot readback". As for the relation between communication errors and aviation occurrences, "Readback and hearback error" had significant influence and caused "Runway incursion", while both "Readback and hearback error" and "No pilot readback" provided high possibility to bring about "Altitude/Heading deviation".

(3) The adjusted $R^2$ values of the regression results mostly fell in the 0.1 to 0.2 interval, which were not high. A big reason was that this research explored the issues on pilots and controllers' communication errors from their subject

experiences and attitudes, and generally studies on human attitudes or behaviors show quite low R-square value because humans were hard to predicted (Ten Hoeve et al., 2016; Frost, 2013). Nevertheless, the significant P-values in the results still drew the conclusion that this model could predict the relation between factors, errors, and aviation occurrences.

Table 4.32 The validation of the factor-error-occurrence relation (Pilots)

<table>
<tr><th colspan="3">Pilot</th></tr>
<tr><th>Factor</th><th>Error</th><th>Occurrence</th></tr>
<tr><td>Workload</td><td rowspan="3">Readback and hearback error</td><td rowspan="3">Runway incursion</td></tr>
<tr><td>Pilot anticipation</td></tr>
<tr><td>Frequency change</td></tr>
<tr><td rowspan="2">Pilot anticipation</td><td rowspan="2">No pilot readback</td><td>Runway incursion</td></tr>
<tr><td>Altitude/Heading deviation</td></tr>
</table>

Table 4.33 The validation of the factor-error-occurrence relation (Controllers)

<table>
<tr><th colspan="3">Controller</th></tr>
<tr><th>Factor</th><th>Error</th><th>Occurrence</th></tr>
<tr><td>Linguistic factors</td><td rowspan="3">Readback and hearback error</td><td>Runway incursion</td></tr>
<tr><td>Pilot anticipation</td><td rowspan="2">Altitude/Heading deviation</td></tr>
<tr><td>Similar call sign</td></tr>
<tr><td>Pilot anticipation</td><td>No pilot readback</td><td>Altitude/Heading deviation</td></tr>
</table>

Table 4.34 The validation of the hypotheses

| Hypotheses | Narration of the hypotheses | Validation |
|---|---|---|
| H1 | Pilots and controllers have significantly different cognitions to the dimensions of factors, errors, and related aviation occurrences. | Valid |
| H2 | Factor has significantly positive influence on communication error. | Valid |
| H2a | Workload has significantly positive influence on readback and hearback error. | Partially Valid |
| H2b | Linguistic factors has significantly positive influence on readback and hearback error. | Partially Valid |
| H2c | Pilot anticipation has significantly positive influence on readback and hearback error. | Valid |
| H2d | Similar call sign has significantly positive influence on readback and hearback error. | Partially Valid |
| H2e | Frequency change has significantly positive influence on readback and hearback error. | Partially Valid |
| H2f | Pilot anticipation has significantly positive influence on no pilot readback. | Valid |
| H3 | Communication error has significantly positive influence on aviation occurrence. | Valid |
| H3a | Readback and hearback error has significantly positive influence on runway incursion. | Valid |
| H3b | No pilot readback has significantly positive influence on runway incursion. | Partially Valid |
| H3c | Readback and hearback error has significantly positive influence on altitude/heading deviation. | Partially Valid |
| H3d | No pilot readback has significantly positive influence on altitude/heading deviation. | Valid |

# Chapter 5 Conclusions and suggestions

This chapter concluded the study founds and provided suggestions for pilots, controllers, airline corporations, and relative government based on the results in Chapter 4. Three sections were included in this chapter. First, reaffirming the factor-error-occurrence relation and the difference between pilots and controllers as the research conclusions. Second, the practical implications listed up the suggestions for current pilot-controller communication problems to make progress of the flight safety in Taiwan. The other was the limitations and the future study suggestions.

## 5.1 Research conclusions

Reflecting to the research purposes of this studies, four research conclusions are drawn as below：

(1) To explore the common contributory factors of pilot-controller communication errors, types of communication errors, and related aviation occurrences.

This research found five factors, two communication errors, and two aviation occurrences from the survey of pilots and controllers' attitude toward their communication. Factors included workload, linguistic factors, pilot anticipation, similar call sign, and frequency change, whereas communication errors included readback and hearback error and no pilot readback. Lastly, common aviation occurrences due to communication errors were runway incursion and altitude/heading deviation.

(2) To explore the significant difference between the cognition of pilots and controllers to the factors, communication errors, and occurrences.

The results showed that pilots and controllers held different agreement on factors, and perceived much different frequencies of communication errors and aviation occurrences, indicating the existence of cognitive gaps, of which the work contents, job characteristics, human nature, and experiences are the reasons.

(3) To verify the significant factor-error-occurrence relationship with line-operating pilots and controllers based on their experiences and professionally viewpoints through a questionnaire survey.

Based on pilots' response, workload, pilot anticipation, and frequency change can lead to readback and hearback error, then possibly followed by occurrence as runway incursion. Besides, pilot anticipation also relates to no pilot readback, which may cause runway incursion and altitude/heading deviation. From the answers of air traffic controllers, linguistic factors, pilot anticipation, and similar call sign can cause readback and hearback errors, leading to altitude/heading deviation and runway incursion. As for pilot anticipation, past research found it easily happening and leading to communication errors, while the objects in this study responses inclined to disagree on it. However, the positive relation between pilot anticipation and communication errors by the regression test and the case in TACARE indicated that it is also treated as the main reason for no pilot readback which may result in altitude/heading deviation.

(4) Based on the results, understanding the current frequencies of the factors, communication errors, and aviation occurrences related to the errors to provide suggestions for pilots, controllers, airline carriers, and government authorities, expecting to improve the flight safety.

According to the results found in Chapter 4, this study found the factors leading to communication errors and this research provides specific suggestions according to the situations and the internal element leading to errors in each factor components for pilots, controllers, airliners and government as the first line of defense of pilot-controller communication errors.

## 5.2 Research suggestions

Under the TEM framework, the first priority is to detect and eliminate the threat. Once the threat has been managed or removed, the occurrences of occurrences can be very low. Hence, this part listed up practical suggestions to reduce and inhibit the situations which may next result in pilot-controller communication error.

(1) Workload issues

From pilots' viewpoints, workload is a significant reason for readback and hearback error. Because adverse conditions such as fatigue, emergent events, and equipment malfunction along with frequency congestion would increase workload, airline corporations should strengthen the training for pilots on situational awareness, standard operating process, urgent problems solving, and crew resources management to enhance pilots' stress resistance and cooperation ability.

Based on the analysis of controllers' responses, they considered workload indeed a factor influencing communication, but the analytic results showed that, experientially, workload did not significantly relate to readback and hearback error. Nevertheless, it should not be inferred that there were no events involved in this factor-error relation in Taiwan as the Antonov-124 runway incursion was the exact case because of a junior controller's high workload. Therefore, the Civil Aeronautics Administration should also provide more training and supervise the performance.

(2) Linguistic factors and similar call sign issues

Most situations included in linguistic factors component relates to controllers' speech problems, and pilots had much higher agreement on those situations. One of the probable reasons is that, as a human nature, people found others' mistakes and blame others more easily. However, the results showed that controllers thought linguistic factors experientially related to readback and hearback error, while pilots did not. Next, for similar call sign, there was no significant differences between both side's agreement. Controllers considered it an obvious reason for readback and hearback error, but pilots did not think so.

The different perspectives on the factor-error relation of pilots and controllers is because the different job characteristics. Controllers need to identify many aircraft and issue continuous instructions at the same time, while pilots only need to pay attention to their own call sign and instructions. Therefore, it is necessary to improve controllers' professional abilities, such as using right phraseology, listening abilities, concentration and giving correctly clear instructions, which are as short as possible. For pilots, enhancing their concentration on controllers' transmissions is also needed.

(3) Phenomena of pilot anticipation

Although the agreement scores given by pilots and controllers on the questions involved in pilot anticipation were not high (controllers still gave obvious higher scores), this factor still had positive relation with readback and hearback error and no pilot readback. Even pilots and controllers in Taiwan did not consider events with pilot anticipation common situations, the second case study in Taiwan in Chapter 2 indeed presented the incident that pilot anticipation caused no pilot readback and an altitude deviation occurred. Therefore, pilots always have to look out their readback completeness and follow controllers' instructions. If there is any doubtful or infeasible instruction or clearance, pilots are supposed to remind controllers of the problematic transmission, not keep going by their own decision, as the way to hinder the flight from occurrences. Controllers should focus on whether pilots have readback completely to ensure the message has been received and decoded precisely.

(4) Frequency change

This kind of factor includes pilot's wrong readback and tuning of the radio frequencies or controllers' neglect of handing off the flight to the next sector. Even pilots readback with right frequencies numbers, chances are they still tuning erroneously, embodying the inconsistency between performances and minds. The suggestion is that airlines should train pilots and elevate their listening comprehension as well as their concentration. Besides, CRM is also needed to be highlighted since the error can be avoided if other flight crews can perceive one's readback or tuning of incorrect radio frequency and amends it immediately. For controllers, the importance of concentration on the movement of aircraft should be promoted. Finally, as mentioned before, situational awareness should be gained for both pilots and controllers. With more awareness, the long-suspended communication can be easily discovered and restored to be linked, excused from risky circumstances.

(5) NextGen works

The scientific and technical method for the prevention of communication errors, NextGen, a significant evolution of air traffic management initiated by Federal Aviation Administration, now is working. Among the great works, Data communication, partially replaces voice communication with digitally texted-based messages. One of the completed work is CPDLC DCL, which has been used for departure clearance. The similar facility has also been implemented in Taiwan known as the Data Link Departure Clearance. Data communication can reduce the delay and confusing communication and frequency congestion, lessening pilots and controllers' workload. What's more, with the visual and clear messages, linguistic factors such as accents or non-standard phraseology, similar call sign problems, and incorrectly tuning frequency can be effectively avoided.

FAA now is preparing for adding data communication to en route services, expanding the benefits for all the routing flights (FAA, 2017a). Besides, new Performance Based Navigation (PBN), another great work of NextGen, using satellite-based precision enable aircraft to fly more direct routes, saving fuel and time, and increasing traffic flow (FAA, 2017b), which also decreases workload of both pilots and controllers. As the new application of the CPDLC and other great works being promoted by FAA NextGen program, these works are supposed to be made good use of in Taiwan or particular in busy airports in other countries. It is the government's responsibility to construct the infrastructures as well as airline corporation assist to promote, and the control centers should cooperate and coordinate with one another.

(6) Relationship-oriented factors

While the above suggestions are the approaches to the reduction of pilot-controller communication errors and reaching solid flight safety, which is "task-oriented communication", Kang et al. (2017) pointed out that the more important phase is “relationship-building communications”, emphasizing on communicators’ realizing of each other. The research found that as pilots and controllers are in a team for upholding safety, they are supposed to cultivate the mutual understanding and communicate with courtesy, professionalism, and attentive to attain good team performance, i.e. A safe and efficient air traffic system. Therefore, imperative solutions are not only holding more seminars for the opinions exchanging the but also observation learning of counterpart’s workplaces and procedures for pilots and controllers to understand each other more, building the consensus and decreasing the cognitive gaps to reach better pilot-controller cooperation.

## 5.3 Research contributions

The contributions of this study are listed as following：

(1) As previously past research mostly generalized the factor-error-occurrence relation of pilots and controllers’ communication by real reporting data, and few studies investigated it from on-line workers’ perspectives, this study conducts a questionnaire survey to assemble personal experiences and subjective viewpoints of pilots and controllers to understand the individual feeling and attitude toward pilots and controllers’ communication error. By this way this study found different cognition between pilots and controllers on this issue, giving a chance to focus on the conflicts and difficulties at both sides, and provide solutions for them.

(2) This study found the relation of specific factors contributing to specific pilot-controller communication errors and leading to specific aviation occurrences.

(3) Although this research was mainly based in Taiwan, an approach was derived from the results to predict pilots and controllers’ problematic behaviors, which

can be the general application to the exploration of pilot-controller communication errors and occurrences around the world, providing the situations which should be focused. The suggestions in this research provide the references for worldwide airliners and governments to improve communication between pilots and air traffic controllers.

## 5.4 Limitation and Future research suggestions

The limitation was that since the two groups of objects have different job characteristics and tasks from each other, the questions were designed in a generally-understood term, which may cause the loss of some specifically professional viewpoints from both sides.

As for future suggestions, the pilot-controller communication is not limited to vocal messages exchange. As mentioned previously that it also embraces CPDLC, which is the interaction with texting message to reduce vocal communication error. However, the message transfer time with data link appears to be longer; thus, if there are increased multiple open message transactions, the transmissions would be delayed and the efficiency would be lessened (Rakas & Yang, 2007). As CPDLC nowadays is a trend, there is necessary for the future research to add this issue for discussion.

Next, this study only focused on the factors and occurrences related to pilot-controller communication errors that the results only showed the problematic phases which are supposed to be more emphasized on and be solved. It is suggested that future research explore positive or superior elements for improving the communication quality which are supposed to be promoted and kept.

Finally, this research has constructed a factor-error-occurrence relation framework for the communication of pilots and controllers as presented in Figure 4.1 and Figure 4.2. Based on this empirical framework, structural equation modeling (SEM) is recommended to use for future research as this method is able to present a clearer relation graph at one time and the causal effects between factors and factors, errors and errors, as well as occurrences and occurrences can also be explored simultaneously to enrich the cognition to pilot-controller communication, concepting more strategies to keep flight safety.

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# Appendix I-Preliminary Questionnaire

## 航空器駕駛員及飛航管制員溝通疏失問卷調查表

### 【給專家學者的一封信】

敬愛的專家學者，您好！

晚輩為國立成功大學交通管理科學系碩士班學生，目前於指導教授　張有恆博士指導下進行有關「航空器駕駛員及飛航管制員溝通疏失與飛航安全風險之探討」研究，藉由了解駕駛員與管制員對各溝通疏失肇因、溝通疏失種類以及飛航安全風險之看法，期能作為提升飛航安全之參考。

本研究問卷已初步草擬完成，素仰　臺端學識淵博、經驗豐富，冒昧懇請就「航空器駕駛員及飛航管制員溝通疏失問卷調查表」給予意見與修正，使此問卷能更趨完善。如蒙　惠允，不勝感激。

本問卷分為**兩份**，分別予**駕駛員**與**飛航管制員**填寫，係參考國內外文獻及報告等綜合整理編製。兩份問卷之題項敘述無太大差異，僅依據填寫對象不同而修改敘述方式。各問項中所提及「**溝通**」或「**溝通疏失**」，其範疇皆針對駕駛員與飛航管制員之間的口語溝通。

問卷共分為三部分：

第一部分為**造成駕駛員與飛航管制員溝通疏失之因素**，包括相似呼叫代號(Similar Call Sign)、工作負荷(Workload)、駕駛員預期心理(Pilot Anticipation)、頻率轉換(Frequency Change)以及語句型態(Speech Production)等五項因素，利用同意程度衡。

第二部分為**溝通疏失種類**，包括覆誦錯誤(Readback/hearback error)、駕駛員無覆誦(No Pilot Readback)以及管制員覆聽錯誤(Hearback error)等三種，利用發生之頻率衡量。

第三部分為**飛航事故**，包括偏航(Deviations)、隔離不足(Loss of separation)、指令接收錯誤(Wrong Aircraft accepted clearance)、指令頒布錯誤(Instruction issued to wrong aircraft)、跑道入侵(Runway Incursion)以及管制員操作錯誤(Operational Error)等六項風險，利用發生之頻率衡量。

懇請　臺端逐一閱讀題目，並根據您的專業與經驗，對本問卷提供指正。

本問卷修改方式分為三種：

1. **保留**：題目意義與敘述符合該層面且適合駕駛員及飛航管制員填答。
2. **修改**：題目意義與敘述部分符合該層面且適合駕駛員及飛航管制員填答，
   但仍須修改。
3. **刪除**：題目意義與敘述不符合該層面且不適合駕駛員及飛航管制員填答。

非常感謝您百忙抽空審查問卷，您的協助與指導對本論文之完成有莫大助益，再次感謝您的支持與協助！

祝您 平安健康 萬事如意！

國立成功大學 交通管理科學系碩士班
指導老師 張有恆 博士
研究生 周翊暉 敬上

## 以下為駕駛員問卷：

**第一部分 造成駕駛員與飛航管制員溝通疏失之因素**

(回答之同意程度分別為：

☐非常不同意 Strongly Disagree ☐不同意 Disagree

☐普通 Neutral ☐同意 Agree ☐非常同意 Strongly Agree)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 相似呼叫代號 | 1 | 同一頻率上之不同航空器,若呼叫代號(Call Sign)擁有**相同數字**，會造成混淆。<br>Confusion would occur if there are aircrafts with the **same** number in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | ☐ | ☐ | ☐ | |
| | 2 | 同一頻率上之不同航空器，若呼叫代號擁有**相同數字但順序不同**，會造成混淆。<br>Confusion would occur if there are aircrafts' call signs with the same **numbers but in different orders** on the same frequency (e.g. 432 and 342). | ☐ | ☐ | ☐ | |
| | 3 | 同一頻率上之不同航空器，若呼叫代號擁有**相同航空代碼且數字相似**，會造成混淆。<br>Confusion would occur if there are aircrafts' call signs with the **same airline designators and similar numbers** on the same frequency (e.g. Dynast254 and Dynasty255). | ☐ | ☐ | ☐ | |
| | 4 | 管制員呼叫航班代號有誤時，我未積極指正。<br>I do not correct the ATC actively when he/she calls me with the wrong call sign. | ☐ | ☐ | ☐ | |
| | 5 | 當同一頻率上有相似呼叫代號之航空器時，管制員未提醒我。<br>ATC does not remind me when there is an aircraft with similar call sign on the same frequency. | ☐ | ☐ | ☐ | |

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| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 工作負荷 | 6 | 飛行時之工作量與難度會增加我的工作負荷。<br>Amount and difficulty of tasks increase my workload. | ☐ | ☐ | ☐ | |
| | 7 | 惡劣情況(劇烈天氣、疲勞以及設備故障)會增加我的工作負荷。<br>Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | ☐ | ☐ | ☐ | |
| | 8 | 無線電頻率擁擠之狀況會增加我的工作負荷。<br>ATC congestion increases my workload. | ☐ | ☐ | ☐ | |
| | 9 | 工作負荷增加會影響溝通。<br>Increased workload affects communication. | ☐ | ☐ | ☐ | |
| 駕駛員期望 | 10 | 若我熟悉該次飛行之航路，對於管制員的指令會有我自己的預期 (Anticipation)。<br>If I'm familiar with the route, I will have anticipation to ATC instructions. | ☐ | ☐ | ☐ | |
| | 11 | 我所聽到的許可頒布內容來自於我個人預期，並非管制員確切所頒布。<br>I hear what I anticipate to hear, not the ATC's actual clearance. | ☐ | ☐ | ☐ | |
| | 12 | 管制員頒布之許可或指令有疑慮時，我未提出質疑。<br>I don't request the ATC for clarifications, even a clearance or an instruction is not clear. | ☐ | ☐ | ☐ | |
| | 13 | 我與管制員溝通時，我是很自信的。<br>I'm complacent when communicating with ATC. | ☐ | ☐ | ☐ | |

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| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| | 14 | 當我疏忽而撥選了錯誤的頻率，會發生溝通疏失。<br>Communication errors occur when I tune in the wrong frequency. | ☐ | ☐ | ☐ | |
| 頻率轉換 | 15 | 當管制員疏忽而未將我交付下一位管制員時，會發生溝通疏失。<br>Communication errors occur when ATC neglects to hand me off to the next controller. | ☐ | ☐ | ☐ | |
| | 16 | 當我忽略管制員的呼叫時，會發生溝通疏失。<br>Communication errors occur when I miss a call from ATC. | ☐ | ☐ | ☐ | |
| | 17 | 當無線電訊息同時傳送時，會發生溝通疏失。<br>Simultaneous transmission would cause communication errors. | ☐ | ☐ | ☐ | |
| 傳送阻礙 | 18 | 無線電訊息同時傳送容易發生在頻率擁擠之時。<br>Simultaneous transmission easily occurs due to congested frequency. | ☐ | ☐ | ☐ | |
| | 19 | 無線電受到其他訊號干擾時，會發生溝通疏失。<br>Radio interference would cause communication errors. | | | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | 20 | 口音會造成溝通疏失。<br>Different accents would result in communication errors. | □ | □ | □ | |
| | 21 | 使用非標準術語會造成溝通疏失。<br>Using non-standard phraseology would result in communication errors. | □ | □ | □ | |
| 語句型態 | 22 | 管制員傳送指令時，語句缺乏停頓會造成溝通疏失。<br>ATC giving instructions without pause would result in communication errors. | □ | □ | □ | |
| | 23 | 管制員傳送指令時，語速過快會造成溝通疏失。<br>ATC giving instructions with high speech rate would result in communication errors. | □ | □ | □ | |
| | 24 | 管制員傳送之指令若包含四個以上之項目，會造成溝通疏失。<br>ATC giving more than four instructions at one time would result in communication errors. | □ | □ | □ | |

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**第二部分 溝通疏失種類（第一部分所列因素，可能造成溝通疏失之種類）**

（回答之頻率分別為 □沒有發生 Never □很少發生 Few □偶爾發生 Sometimes □經常發生 Often □常常發生 Always)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 覆誦錯誤 | 25 | 我錯誤地覆誦管制員頒布的許可或指令。<br>I read back ATC's clearances or instructions incorrectly. | □ | □ | □ | |
| | 26 | 管制員未察覺並修正我的覆誦錯誤。<br>ATC neither notice nor correct my readback error. | □ | □ | □ | |
| | 27 | 頻率擁擠時，管制員難以修正我的覆誦錯誤。<br>My incorrect readbacks are difficult to be corrected by ATC when frequency is congested. | □ | □ | □ | |
| 駕駛員無覆誦 | 28 | 我沒有覆誦管制員的許可或指令。<br>I do not read back ATC's clearances or instructions. | □ | □ | □ | |
| | 29 | 我沒有覆誦管制員所頒布**與安全相關**的許可(起飛及降落等)或指令(高度、速度及航向等)。<br>I do not read back ATC's safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | □ | □ | □ | |
| | 30 | 我因為自滿而沒有覆誦管制員的許可或指令。<br>I do not read back ATC's clearances or instructions because of my complacency. | □ | □ | □ | |
| | 31 | 頻率擁擠使我無法覆誦管制員的許可或指令。<br>I cannot read back ATC's clearances or instructions because of the frequency congestion. | □ | □ | □ | |
| 管制員覆聽錯誤 | 32 | 我覆誦正確，但管制員未發現其所頒佈之許可或指令非其原意。<br>I read back correctly but ATC fails to notice that the clearances or instructions are not those he or she intended to issue. | □ | □ | □ | |
| | 33 | 管制員未察覺我發出的請求具有潛在風險。<br>ATC fails to notice that I make a request that might contain potential risk. | □ | □ | □ | |

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**第三部分 飛航安全風險（發生第二部分所列溝通疏失，可能造成之飛安風險）**

（回答之頻率分別為 □沒有發生 Never □很少發生 Few □偶爾發生 Sometimes □經常發生 Often □常常發生 Always)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 偏航 | 34 | 由於溝通疏失，我的航班**高度**與管制員之指示產生偏航。<br>I deviated from ATC assigned **altitude** due to communication errors. | □ | □ | □ | |
| | 35 | 由於溝通疏失，我的航班**航向**與管制員之指示產生偏航。<br>I deviated from ATC assigned **heading** due to communication errors. | □ | □ | □ | |
| | 36 | 由於溝通疏失，我的航班高度或航向與管制員之指示產生偏航，並造成隔離不足。<br>I deviated from ATC assigned **altitude** or **heading** and **lost standard separation** with other aircrafts due to communication errors. | □ | □ | □ | |
| 指令接收與須布錯誤 | 37 | 由於溝通疏失，我誤收原本應頒布給其他班機的許可或指令。<br>I took the ATC's clearance or instruction that was for another aircraft due to communication errors. | □ | □ | □ | |
| | 38 | 由於溝通疏失，管制員發送許可或指令予錯誤之班機。<br>ATC issued a clearance or an instruction to the wrong aircraft due to communication errors. | □ | □ | □ | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 跑道入侵 | 39 | 由於溝通疏失，使航空器於起飛時發生跑道入侵。<br>An aircraft made a runway incursion during its takeoff due to communication errors. | ☐ | ☐ | ☐ | |
| | 40 | 由於溝通疏失，使航空器於降落時發生跑道入侵。<br>An aircraft made a runway incursion during its landing due to communication errors. | ☐ | ☐ | ☐ | |
| | 41 | 由於溝通疏失，使航空器超出跑道停等線而發生跑道入侵。<br>An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | ☐ | ☐ | ☐ | |
| 管制員操作錯誤 | 42 | 由於溝通疏失，管制員的指示違反航空器之間(包含航空器起降時與其他鄰近跑道之航空器之間)。<br>ATC failed to provide required minimum separations between aircrafts (in flight or during takeoff/landing with other aircrafts on adjacent runways). | ☐ | ☐ | ☐ | |
| | 43 | 由於溝通疏失，管制員的指示違反航空器與地面或障礙物之間之最低隔離。<br>ATC failed to provide required minimum separations between aircrafts and ground obstacle/terrain due to communication errors. | | | | |

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駕駛員問卷題目到此為止，謝謝您的協助！若有其他寶貴意見請書寫於下方空白處，謝謝您。

## 以下為飛航管制員問卷：

**第一部分 造成駕駛員與飛航管制員溝通疏失之因素**

(回答之同意程度分別為：

☐非常不同意 Strongly Disagree ☐不同意 Disagree

☐普通 Neutral ☐同意 Agree ☐非常同意 Strongly Agree)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 相似呼叫代號 | 1 | 同一頻率上之不同航空器，若呼叫代號(Call Sign)擁有**相同數字**，會造成混淆。<br>(例如 Dynastry123 與 EVA123).<br>Confusion would occur if there are aircrafts with the same numbers in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | ☐ | ☐ | ☐ | |
| | 2 | 同一頻率上之不同航空器，若呼叫代號擁有**相同數字但順序不同**，會造成混淆。<br>(例如 432 與 342)<br>Confusion would occur if there are aircrafts's call signs with the same **numbers but in different orders** on the same frequency (e.g. 432 and 342). | ☐ | ☐ | ☐ | |
| | 3 | 同一頻率上之不同航空器，若呼叫代號擁有**相同航空代碼且數字相似**，會造成混淆。<br>Confusion would occur if there are aircrafts' call signs with the **same airline designators and similar numbers** on the same frequency (e.g. Dynast254 and Dynasty255). | ☐ | ☐ | ☐ | |
| | 4 | 我呼叫航班代號有誤時，駕駛員未積極指正。<br>Pilots do not correct me actively when I call his/her flight with the wrong call sign. | ☐ | ☐ | ☐ | |
| | 5 | 當同一頻率上有相似呼叫代號之航空器時，我未提醒駕駛員。<br>I do not remind pilots when there is an aircraft with similar call sign on the same frequency. | ☐ | ☐ | ☐ | |

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| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 工作負荷 | 6 | 工作時之任務量與難度會增加我的工作負荷。<br>Amount and difficulty of tasks increase my workload. | □ | □ | □ | |
| | 7 | 惡劣情況(劇烈天氣、疲勞以及設備故障)會增加我的工作負荷。<br>Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | □ | □ | □ | |
| | 8 | 無線電頻率擁擠之狀況會增加我的工作負荷。<br>Frequency congestion increases my workload. | □ | □ | □ | |
| | 9 | 工作負荷增加會影響溝通。<br>Increased workload affects communication. | □ | □ | □ | |
| 駕駛員期望 | 10 | 若駕駛員熟悉該次飛行之航路，對於我的指令，駕駛員會有自己的預期 (Anticipation)。<br>If Pilots are familiar with the route, they have their own anticipation to my instructions. | □ | □ | □ | |
| | 11 | 駕駛員所聽到的頒布許可內容來自於其個人期望，並非我確切所頒布。<br>Pilots hear what they anticipate to hear, not my actual clearance. | □ | □ | □ | |
| | 12 | 我頒布之許可或指令有疑慮時，駕駛員未提出質疑。<br>Pilots do not request for clarifications, even a clearance or an instruction I gave was not clear. | □ | □ | □ | |
| | 13 | 我與駕駛員溝通時，他們是很自信的。<br>Pilots are complacent when communicating with me. | □ | □ | □ | |

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| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 頻率轉換 | 14 | 當駕駛員撥選了錯誤的頻率，會發生溝通疏失。<br>Communication errors occur when they tune in the wrong frequency. | ☐ | ☐ | ☐ | |
| | 15 | 當我疏忽而未將航班交付下一位管制員時，會發生溝通疏失。<br>Communication errors occur when I neglect to hand the flight off to the next controller. | ☐ | ☐ | ☐ | |
| | 16 | 當駕駛員忽略我的呼叫時，會發生溝通疏失。<br>Communication errors occur when Pilots miss a call from me. | ☐ | ☐ | ☐ | |
| 傳送阻礙 | 17 | 無線電訊息同時傳送時，會發生溝通疏失。<br>Simultaneous transmission would cause communication errors. | ☐ | ☐ | ☐ | |
| | 18 | 無線電訊息同時傳送容易發生在頻率擁擠之時。<br>Simultaneous transmission easily occurs due to congested frequency. | ☐ | ☐ | ☐ | |
| | 19 | 無線電受到其他訊號干擾時，會發生溝通疏失。<br>Radio interference would cause communication errors. | ☐ | ☐ | ☐ | |

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|---|---|---|---|---|---|---|
| | 20 | 口音會造成溝通疏失。<br>Different accents would result in communication errors. | ☐ | ☐ | ☐ | |
| | 21 | 使用非標準術語會造成溝通疏失。<br>Using non-standard phraseology would result in communication errors. | ☐ | ☐ | ☐ | |
| 語句型態 | 22 | 我傳送指令時，語句缺乏停頓會造成溝通疏失。<br>When I give instructions without pause, it would result in communication errors. | ☐ | ☐ | ☐ | |
| | 23 | 我傳送指令時，語速過快會造成溝通疏失。<br>When I give instructions with high speech rate, it would result in communication errors. | ☐ | ☐ | ☐ | |
| | 24 | 我傳送之指令若包含四個以上之項目，會造成溝通疏失。<br>When I give more than four instructions at one time, it would result in communication errors. | ☐ | ☐ | ☐ | |

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**第二部分 溝通疏失種類（第一部分所列因素，可能造成溝通疏失之種類）**

(回答之頻率分別為 □沒有發生 Never □很少發生 Few □偶爾發生 Sometimes □經常發生 Often □常常發生 Always)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 覆誦錯誤 | 25 | 駕駛員錯誤地覆誦我頒布的許可或指令。<br>Pilots read back my clearances or instructions incorrectly. | □ | □ | □ | |
| | 26 | 我未察覺並修正駕駛員的覆誦錯誤。<br>I didn't notice nor correct Pilots' readback errors. | □ | □ | □ | |
| | 27 | 頻率擁擠時，我難以修正駕駛員的覆誦錯誤。<br>It's difficult for me to correct Pilots' wrong readbacks when frequency is congested. | □ | □ | □ | |
| 駕駛員無覆誦 | 28 | 駕駛員沒有覆誦我的許可或指令。<br>Pilots do not read back my clearances or instructions. | □ | □ | □ | |
| | 29 | 駕駛員沒有覆誦我所頒布**與安全相關**的許可(起飛及降落等)或指令(高度、速度及航向等)。<br>Pilots do not read back my safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | □ | □ | □ | |
| | 30 | 駕駛員因為自滿而沒有覆誦我的許可或指令。<br>Pilots do not read back ATC's clearances or instructions because of their complacency. | □ | □ | □ | |
| | 31 | 頻率擁擠使駕駛員無法覆誦我的許可或指令。<br>Pilots cannot read back my clearances or instructions because of the frequency congestion. | □ | □ | □ | |
| 管制員覆聽錯誤 | 32 | 駕駛員覆誦正確,但我未發現我所頒佈之許可或指令非我的原意。<br>Pilots read back correctly, but I fail to notice that the clearance or instruction are not what I intended to issue. | □ | □ | □ | |
| | 33 | 我未察覺駕駛員發出的請求具有潛在風險。<br>I fail to notice that pilot makes a request that might contain potential risk. | □ | □ | □ | |

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**第三部分 飛航安全風險(發生第二部分所列溝通疏失,可能造成之飛安風險)**

(回答之頻率分別為 □沒有發生 Never □很少發生 Few □偶爾發生 Sometimes □經常發生 Often □常常發生 Always)

| | 題號 | 問項 | 保留 | 刪除 | 修改 | 修改意見 |
|---|---|---|---|---|---|---|
| 偏航 | 34 | 由於溝通疏失,駕駛員偏離我所指示的航班**高度**。<br>Pilots deviated from the **altitude** assigned by me due to communication errors. | □ | □ | □ | |
| | 35 | 由於溝通疏失,駕駛員偏離我所指示的航班**航向**。<br>Pilots deviated from the **heading** assigned by me due to communication errors. | □ | □ | □ | |
| | 36 | 由於溝通疏失,駕駛員偏離我所指示的航班**高度**或**航向**,並造成**隔離不足**。<br>Pilots deviated from the **altitude** or **heading** assigned by me and **lost standard separation** with other aircrafts due to communication errors. | □ | □ | □ | |
| 指令接收或頒布錯誤 | 37 | 由於溝通疏失,駕駛員誤收我原本應頒布給其他班機的許可或指令。<br>Pilots took the clearance or instruction that was for another aircraft due to communication errors. | □ | □ | □ | |
| | 38 | 由於溝通疏失,我頒布許可或指令予錯誤之班機。<br>I issued a clearance or an instruction to the wrong aircraft due to communication errors. | □ | □ | □ | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 跑道入侵 | 39 | 由於溝通疏失，使航空器於起飛時發生跑道入侵。<br>An aircraft made a runway incursion during its takeoff due to communication errors. | ☐ | ☐ | ☐ | |
| | 40 | 由於溝通疏失，使航空器於降落時發生跑道入侵。<br>An aircraft made a runway incursion during its landing due to communication errors. | ☐ | ☐ | ☐ | |
| | 41 | 由於溝通疏失，使航空器超出跑道停等線而發生跑道入侵。<br>An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | ☐ | ☐ | ☐ | |
| 管制員操作錯誤 | 42 | 由於溝通疏失，我的指示違反航空器之間(包含航空器起降時與其他鄰近跑道之航空器之間)，以及航空器與地面或障礙物之間之最低隔離。<br>I failed to provide required minimum separation between aircrafts (in flight or during takeoff/landing with other aircrafts on adjacent runways). | ☐ | ☐ | ☐ | |
| | 43 | 由於溝通疏失，我的指示違反航空器與地面或障礙物之間之最低隔離。<br>I failed to provide required minimum separation between aircrafts and ground obstacle/terrain due to communication errors. | ☐ | ☐ | ☐ | |

飛航管制員問卷題目到此為止，謝謝您的協助！若有其他寶貴意見請書寫於下方空白處，謝謝您。

## 您的資料

職位：______________________________

工作年資：__________________________

目前工作部門與公司：_____________________________中華民國一零六年三月

聯絡方式(Email 或電話)：__________________________

**您的資料將絕對保密**

本問卷到此結束，再次感謝您的協助！

# Appendix II-Formal Questionnaire

## 航空器駛員及飛航管制員溝通疏失問卷調查表（駕駛員問卷）

## Communication Errors between Pilots and Air Traffic Controllers Questionnaire (For pilots)

親愛的受訪者您好，

這是一份有關「**航空器駕駛員及飛航管制員溝通疏失與飛航安全風險之探討**」之問卷，並且是一份**不記名**問卷。您的填答將影響此項調查之成功與否，請依照您對各題的第一直覺勾選答案即可，答案無所謂對與錯。各問項中所提及「**溝通**」或「**溝通疏失**」，其範疇皆針對駕駛員與飛航管制員之間的口語溝通。感謝您撥冗填寫。

**您的資料將絕對保密**

Dear respondents,

This is a questionnaire about “Pilots-Air Traffic Controllers Communication Errors and Aviation occurrences” which is **anonymous**. The success of the survey depends on your contribution. There are no right or wrong answers, and please answer all questions from your perspectives with intuition. The questions including **“communication”** or **“communication errors”** are all limited to the voice communication between pilots and air traffic controllers (ATC). Thank you for your time.

**Individual responses are absolutely confidential**

國立成功大學　交通管理科學系碩士班
指導老師　張有恆　博士
研究生　周翊暉　敬上

**以下問題(第 1~25 題)，請依據您的看法，選出符合您同意程度之答案(單選)。**

**Please answer the following questions according to your level of agreement (check one only).**

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 1 | 同一頻率上之不同航空器，若呼號(Call Sign)擁有**相同數字**，會造成混淆(例如 Dynasty123 and EVA123)。<br>Confusion would occur if there are aircraft with the **same** number in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 | 同一頻率上之不同航空器，若呼號擁有**相同數字但順序不同**，會造成混淆 (例如 432 與 342)。<br>Confusion would occur if there are aircraft's call signs with the same **numbers but in different orders** on the same frequency (e.g. 432 and 342). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 | 同一頻率上之不同航空器，若呼號擁有**相同航空公司且呼號的數字相似**，會造成混淆(例如 Dynasty254 and Dynasty255)。<br>Confusion would occur if there are aircraft's call signs with the **same airline designators and similar numbers** on the same frequency (e.g. Dynasty254 and Dynasty255). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4 | 管制員呼叫航班呼號有誤時，我未積極指正。<br>I do not correct the ATC actively when he/she calls me with the wrong call sign. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5 | 當同一頻率上有相似呼號之航空器時，管制員未提醒我。<br>ATC does not remind me when there is an aircraft with similar call sign on the same frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6 | 飛行時之工作量與難度會增加我的工作負荷。<br>Amount and difficulty of tasks increase my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 7 | 惡劣情況(劇烈天氣、疲勞以及設備故障)會增加我的工作負荷。<br>Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8 | 無線電頻率擁擠之狀況會增加我的工作負荷。<br>Frequency congestion increases my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9 | 工作負荷增加會影響溝通。<br>Increased workload affects communication. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10 | 若我熟悉該次飛行之航路，對於管制員的指令會有我自己的預期 (Anticipation)。<br>If I am familiar with the route, I will have anticipation to ATC instructions. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11 | 我所聽到的許可頒布內容來自於我個人預期，並非管制員確切所頒布。<br>I hear what I anticipate to hear, not the ATC's actual clearance. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12 | 管制員頒布之許可或指令有疑慮時，我未提出質疑。<br>I do not request the ATC for clarifications, even a clearance or an instruction is not clear. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13 | 我與管制員溝通時，我是很自信的。<br>I'm complacent when communicating with ATC. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14 | 當我疏忽而撥選了錯誤的頻率，會發生溝通疏失。<br>Communication errors occur when I tune in the wrong frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15 | 當管制員疏忽而未將我交付下一位管制員時，會發生溝通疏失。<br>Communication errors occur when ATC neglects to hand me off to the next controller. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 16 | 當我忽略管制員的呼叫時，會發生溝通疏失。<br>Communication errors occur when I miss a call from ATC. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17 | 當無線電訊息同時傳送時，會發生溝通疏失。<br>Simultaneous transmission would cause communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18 | 無線電訊息同時傳送容易發生在頻率擁擠之時。<br>Simultaneous transmission easily occurs due to congested frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19 | 無線電受到其他訊號干擾時，會發生溝通疏失。<br>Radio interference would cause communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20 | 口音會造成溝通疏失。<br>Different accents would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21 | 使用非標準術語會造成溝通疏失。<br>Using non-standard phraseology would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22 | 管制員傳送指令時，語句缺乏停頓會造成溝通疏失。<br>ATC issuing instructions without pause would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23 | 管制員傳送指令時，語速過快會造成溝通疏失。<br>ATC issuing instructions with high speech rate would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24 | 管制員傳送之指令若包含四個以上之項目，會造成溝通疏失。<br>ATC issuing more than four instructions at one time would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25 | 管制員短時間內頻繁修改指示，會造成溝通疏失。<br>ATC frequently modifying the instructions during a short time would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |

**以下問題(第 26~34 題)，請依據您的看法，針對以下敘述情形之發生頻率，勾選最適當之答案(單選)。**

**Please answer the following questions according to the frequency from your perspective (check one only).**

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 26 | 我錯誤地覆誦管制員頒布的許可或指令。<br>I read back ATC’s clearances or instructions incorrectly. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 27 | 管制員未察覺並修正我的覆誦錯誤。<br>ATC neither notice nor correct my readback error. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 28 | 頻率擁擠時，管制員難以修正我的覆誦錯誤。<br>My wrong readbacks are difficult to be corrected by ATC when frequency is congested. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 29 | 我沒有覆誦管制員的許可或指令。<br>I do not read back ATC’s clearances or instructions. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 30 | 我沒有覆誦管制員所頒布**與安全相關**的許可(起飛及降落等)或指令(高度、速度及航向等)。<br>I do not read back ATC’s safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 31 | 我因為自滿而沒有覆誦管制員的許可或指令。<br>I do not read back ATC’s clearances or instructions because of my complacency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 32 | 頻率擁擠使我無法覆誦管制員的許可或指令。<br>I cannot read back ATC’s clearances or instructions because of the frequency congestion. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 33 | 我覆誦正確，但管制員未發現其所頒佈之許可或指令非其原意。<br>I read back correctly but ATC fails to notice that the clearances or instructions are not those he/she intended to issue. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 34 | 管制員未察覺我發出的請求具有潛在風險。<br>ATC fails to notice that I make a request that might contain potential risk. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 35 | 由於溝通疏失，我的航班**高度**與管制員之指示產生偏航。<br>I deviated from ATC assigned **altitude** due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 36 | 由於溝通疏失，我的航班**航向**與管制員之指示產生偏航。<br>I deviated from ATC assigned **heading** due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 37 | 由於溝通疏失，我的航班**高度**或**航向**與管制員之指示產生偏航，並造成**隔離不足**。<br>I deviated from ATC assigned **altitude** or **heading** and **lost standard separation** with other aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 38 | 由於溝通疏失，我誤收原本應頒布給其他班機的許可或指令。<br>I took the ATC's clearance or instruction that was for another aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 39 | 由於溝通疏失，管制員發送許可或指令予錯誤之班機。<br>ATC issued a clearance or an instruction to the wrong aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 40 | 由於溝通疏失，使航空器於起飛時發生跑道入侵。<br>An aircraft made a runway incursion during its takeoff due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 41 | 由於溝通疏失，使航空器於降落時發生跑道入侵。<br>An aircraft made a runway incursion during its landing due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 42 | 由於溝通疏失，使航空器超出跑道停等線而發生跑道入侵。<br>An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 43 | 由於溝通疏失，管制員的指示違反航空器之間(包含航空器起降時與其他鄰近跑道之航空器之間)之最低隔離。<br>ATC failed to provide required minimum separation between aircraft (in flight or during takeoff/landing with other aircraft on adjacent runways). | □ | □ | □ | □ | □ |
| 44 | 由於溝通疏失，管制員的指示違反航空器與地面或障礙物之間之最低隔離。<br>ATC failed to provide required minimum separation between aircraft and ground obstacle/terrain due to communication errors. | □ | □ | □ | □ | □ |

**受訪者基本資料 Background Information**

1. 您的性別 Gender：□男性 Male；□女性 Female。
2. 您的年齡 Age：□21-25；□26-30；□31-35；□36-40；□41-45；□46-50； □50-55；□56-60；□>61。
3. 您的國籍 Nationality：□中華民國 Taiwan, ROC；□其他 Others______________。
4. 您的職別 Professional Status： □管理階層 Management； □檢定、教練機師 CPIP；□正機師 CA；□巡航正機師 RP；□副機師 FO；□其他 Others___________。
5. 您的訓練背景 Flight Training Background：
   □軍職轉業 Military；□自訓 CPL/APTL；□培訓 Company Training；
   □其他 Others__________。
6. 工作年資 Years Experiences：□<5 年(years)；□5-10 年(years)；
   □11-15 年(years)；□16-20 年(years)；□>20 年(years)。

**萬分感謝您的寶貴時間完成此問卷的填寫，祝您飛行平安。**

**Thank you for taking the time to complete the questionnaire. Happy landing.**

## 航空器駕駛員及飛航管制員溝通疏失問卷調查表（管制員問卷）

## Communication Errors between Pilots and Air Traffic Controllers Questionnaire (For air traffic controllers)

親愛的受訪者您好，

這是一份有關「**航空器駕駛員及飛航管制員溝通疏失與飛航安全風險之探討**」之問卷，並且是一份**不記名**問卷。您的填答將影響此項調查之成功與否，請依照您對各題的第一直覺勾選答案即可，答案無所謂對與錯。各問項中所提及「**溝通**」或「**溝通疏失**」，其範疇皆針對駕駛員與飛航管制員之間的口語溝通。感謝您撥冗填寫。

**<u>您的資料將絕對保密</u>**

Dear respondents,

This is a questionnaire about "Pilots-Air Traffic Controllers Communication Errors and Aviation occurrences" which is **anonymous**. The success of the survey depends on your contribution. There are no right or wrong answers, and please answer all questions from your perspectives with intuition. The questions including **"communication"** or **"communication errors"** are all limited to the voice communication between pilots and air traffic controllers (ATC). Thank you for your time.

**<u>Individual responses are absolutely confidential</u>**

國立成功大學 交通管理科學系碩士班
指導老師 張有恆 博士
研究生 周翊暉 敬上

**以下問題(第 1~25 題)，請依據您的看法，選出符合您同意程度之答案(單選)。**

**Please answer the following questions according to your level of agreement (check one only).**

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 1 | 同一頻率上之不同航空器，若呼號(Call Sign)擁有**相同數字**，會造成混淆 (例如 Dynastry123 與 EVA123)。<br>Confusion would occur if there are aircraft with the same numbers in the call signs on the same frequency (e.g. Dynasty123 and EVA123). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 | 同一頻率上之不同航空器，若呼號擁有**相同數字但順序不同**，會造成混淆 (例如 432 與 342)。<br>Confusion would occur if there are aircraft's call signs with the same **numbers but in different orders** on the same frequency (e.g. 432 and 342). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 | 同一頻率上之不同航空器，若呼號擁有**相同航空公司且呼號的數字相似**，會造成混淆。(例如 Dynast254 and Dynasty255)。<br>Confusion would occur if there are aircraft's call signs with the **same airline designators and similar numbers** on the same frequency (e.g. Dynast254 and Dynasty255). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4 | 我呼叫航班呼號有誤時，駕駛員未積極指正。<br>Pilots do not correct me actively when I call his/her flight with the wrong call sign. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5 | 當同一頻率上有相似呼號之航空器時，我未提醒駕駛員。<br>I do not remind pilots when there is an aircraft with similar call sign on the same frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6 | 工作時之任務量與難度會增加我的工作負荷。<br>Amount and difficulty of tasks increase my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 7 | 惡劣情況(劇烈天氣、疲勞以及設備故障)會增加我的工作負荷。<br>Adverse conditions (such as severe weather condition, fatigue and/or equipment malfunction) increase my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8 | 無線電頻率擁擠之狀況會增加我的工作負荷。<br>Frequency congestion increases my workload. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9 | 工作負荷增加會影響溝通。<br>Increased workload affects communication. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10 | 若駕駛員熟悉該次飛行之航路，對於我的指令，駕駛員會有自己的預期 (Anticipation)。<br>If Pilots are familiar with the route, they have their own anticipation to my instructions. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11 | 駕駛員所聽到的頒布許可內容來自於其個人期望，並非我確切所頒布。<br>Pilots hear what they anticipate to hear, not my actual clearance. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12 | 我頒布之許可或指令有疑慮時，駕駛員未提出質疑。<br>Pilots do not request for clarifications, even a clearance or an instruction I gave was not clear. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13 | 我與駕駛員溝通時，他們是很自信的。<br>Pilots are complacent when communicating with me. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14 | 當駕駛員撥選了錯誤的頻率，會發生溝通疏失。<br>Communication errors occur when they tune in the wrong frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15 | 當我疏忽而未將航班交付下一位管制員時，會發生溝通疏失。<br>Communication errors occur when I neglect to hand the flight off to the next controller. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Strongly Disagree<br>2. Disagree<br>3. Neutral<br>4. Agree<br>5. Strongly Agree | 非常不同意<br>1. | 不同意<br>2. | 無意見<br>3. | 同意<br>4. | 非常同意<br>5. |
|---|---|---|---|---|---|---|
| 16 | 當駕駛員忽略我的呼叫時，會發生溝通疏失。<br>Communication errors occur when Pilots miss a call from me. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17 | 無線電訊息同時傳送時，會發生溝通疏失。<br>Simultaneous transmission would cause communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18 | 無線電訊息同時傳送容易發生在頻率擁擠之時。<br>Simultaneous transmission easily occurs due to congested frequency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19 | 無線電受到其他訊號干擾時，會發生溝通疏失。<br>Radio interference would cause communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20 | 口音會造成溝通疏失。<br>Different accents would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21 | 使用非標準術語會造成溝通疏失。<br>Using non-standard phraseology would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22 | 我傳送指令時，語句缺乏停頓會造成溝通疏失。<br>When I issue instructions without pause, it would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23 | 我傳送指令時，語速過快會造成溝通疏失。<br>When I issue instructions with high speech rate, it would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24 | 我傳送之指令若包含四個以上之項目，會造成溝通疏失。<br>When I issue more than four instructions at one time, it would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25 | 我短時間內頻繁修改指示，會造成溝通疏失。<br>My frequent modification of the instructions during a short time would result in communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |

**以下問題(第 26~44 題)，請依據您的看法，針對以下敘述情形之發生頻率，勾選最適當之答案(單選)。**

**Please answer the following questions according to the frequency from your perspective (check one only).**

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 26 | 駕駛員錯誤地覆誦我頒布的許可或指令。<br>Pilots read back my clearances or instructions incorrectly. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 27 | 我未察覺並修正駕駛員的覆誦錯誤。<br>I didn't notice nor correct Pilots' readback errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 28 | 頻率擁擠時，我難以修正駕駛員的覆誦錯誤。<br>It's difficult for me to correct Pilots' wrong readbacks when frequency is congested. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 29 | 駕駛員沒有覆誦我的許可或指令。<br>Pilots do not read back my clearances or instructions. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 30 | 駕駛員沒有覆誦我所頒布**與安全相關**的許可(起飛及降落等)或指令(高度、速度及航向等)。<br>Pilots do not read back my safety-related clearances (take off or landings) or instructions (Altitude, speed or heading). | ☐ | ☐ | ☐ | ☐ | ☐ |
| 31 | 駕駛員因為自滿而沒有覆誦我的許可或指令。<br>Pilots do not read back ATC's clearances or instructions because of their complacency. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 32 | 頻率擁擠使駕駛員無法覆誦我的許可或指令。<br>Pilots cannot read back my clearances or instructions because of the frequency congestion. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 33 | 駕駛員覆誦正確，但我未發現我所頒佈之許可或指令非我的原意。<br>Pilots read back correctly, but I fail to notice that the clearance or instruction are not what I intended to issue. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 34 | 我未察覺駕駛員發出的請求具有潛在風險。<br>I fail to notice that Pilot makes a request that might contain potential risk. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 35 | 由於溝通疏失，駕駛員偏離我所指示的航班**高度**。<br>Pilots deviated from the **altitude** assigned by me due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 36 | 由於溝通疏失，駕駛員偏離我所指示的航班**航向**。<br>Pilots deviated from the **heading** assigned by me due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 37 | 由於溝通疏失，駕駛員偏離我所指示的航班**高度**或**航向**，並造成**隔離不足**。<br>Pilots deviated from the **altitude** or **heading** assigned by me and **lost standard separation** with other aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 38 | 由於溝通疏失，駕駛員誤收我原本應頒布給其他班機的許可或指令。<br>Pilots took the clearance or instruction that was for another aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 39 | 由於溝通疏失，我頒布許可或指令予錯誤之班機。<br>I issued a clearance or an instruction to the wrong aircraft due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 40 | 由於溝通疏失，使航空器於起飛時發生跑道入侵。<br>An aircraft made a runway incursion during its takeoff due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 41 | 由於溝通疏失，使航空器於降落時發生跑道入侵。<br>An aircraft made a runway incursion during its landing due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 42 | 由於溝通疏失，使航空器超出跑道停等線而發生跑道入侵。<br>An aircraft crossed a runway hold marking and made a runway incursion due to communication errors. | ☐ | ☐ | ☐ | ☐ | ☐ |

| 題號 | 1. Never<br>2. Few<br>3. Sometimes<br>4. Often<br>5. Always | 沒有發生<br>1. | 很少發生<br>2. | 偶爾發生<br>3. | 經常發生<br>4. | 常常發生<br>5. |
|---|---|---|---|---|---|---|
| 43 | 由於溝通疏失，我的指示違反航空器之間(包含航空器起降時與其他鄰近跑道之航空器之間)之最低隔離。<br>I failed to provide required minimum separation between aircraft (in flight or during takeoff/landing with other aircraft on adjacent runways). | □ | □ | □ | □ | □ |
| 44 | 由於溝通疏失，我的指示違反航空器與地面或障礙物之間之最低隔離。<br>I failed to provide required minimum separation between aircraft and ground obstacle/terrain due to communication errors. | □ | □ | □ | □ | □ |

**受訪者基本資料 Background Information**

1. 您的性別 Gender：□男性 Male；□女性 Female。
2. 您的年齡 Age：□21-25；□26-30；□31-35；□36-40；□41-45；
□46-50；□51-55；□56-60；□>61；。
3. 您的職別 Professional Status：□塔台管制員；□雷達管制員；
□督導(協調員)；□管理階層；□其他__________。
4. 工作年資 Years Experiences：□<10 years；□10-15 years；□16-20 years；
□>20 years

問卷到此結束

This is the end of the questionnaire.

非常感謝您的寶貴時間完成此份問卷，祝您工作順利、萬事如意。

Thank you for taking the time to complete the questionnaire.

Your participation is appreciated.

# Appendix III- Correlation Analysis

1. Correlation analysis of the factors contributed to communication errors (Pilots)

**Correlations**

| | | Workload | Linguistic Factor | Pilot Expectation | SimilarCall Sign | Frequency Change |
|---|---|---|---|---|---|---|
| Workload | Pearson Correlation | 1 | .364** | -.188* | .281** | .352** |
| | Sig. (2-tailed) | | .000 | .013 | .000 | .000 |
| | N | 173 | 173 | 173 | 173 | 173 |
| LinguisticFactor | Pearson Correlation | .364** | 1 | -.014 | .354** | .402** |
| | Sig. (2-tailed) | .000 | | .851 | .000 | .000 |
| | N | 173 | 173 | 173 | 173 | 173 |
| PilotExpectation | Pearson Correlation | -.188* | -.014 | 1 | -.160* | -.057 |
| | Sig. (2-tailed) | .013 | .851 | | .036 | .459 |
| | N | 173 | 173 | 173 | 173 | 173 |
| SimilarCallSign | Pearson Correlation | .281** | .354** | -.160* | 1 | .344** |
| | Sig. (2-tailed) | .000 | .000 | .036 | | .000 |
| | N | 173 | 173 | 173 | 173 | 173 |
| FrequencyChange | Pearson Correlation | .352** | .402** | -.057 | .344** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .459 | .000 | |
| | N | 173 | 173 | 173 | 173 | 173 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

2. Correlation analysis of the factors contributed to communication errors (Controllers)

**Correlations**

| | | Workload | Linguistic Factor | Pilot Expectation | SimilarCall Sign | Frequency Change |
|---|---|---|---|---|---|---|
| Workload | Pearson Correlation | 1 | .298** | .169 | .512** | .214* |
| | Sig. (2-tailed) | | .001 | .076 | .000 | .023 |
| | N | 112 | 112 | 112 | 112 | 112 |
| LinguisticFactor | Pearson Correlation | .298** | 1 | .278** | .347** | .240* |
| | Sig. (2-tailed) | .001 | | .003 | .000 | .011 |
| | N | 112 | 112 | 112 | 112 | 112 |
| PilotExpectation | Pearson Correlation | .169 | .278** | 1 | .281** | .041 |
| | Sig. (2-tailed) | .076 | .003 | | .003 | .667 |
| | N | 112 | 112 | 112 | 112 | 112 |
| SimilarCallSign | Pearson Correlation | .512** | .347** | .281** | 1 | .170 |
| | Sig. (2-tailed) | .000 | .000 | .003 | | .072 |
| | N | 112 | 112 | 112 | 112 | 112 |
| FrequencyChange | Pearson Correlation | .214* | .240* | .041 | .170 | 1 |
| | Sig. (2-tailed) | .023 | .011 | .667 | .072 | |
| | N | 112 | 112 | 112 | 112 | 112 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3. Correlation analysis of communication errors (Pilots)

**Correlations**

| | | ReadbackandHearback Error | NoPilot Readback |
|---|---|---|---|
| ReadbackandHearback Error | Pearson Correlation | 1 | .311** |
| | Sig. (2-tailed) | | .000 |
| | N | 173 | 173 |
| NoPilotReadback | Pearson Correlation | .311** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 173 | 173 |

**. Correlation is significant at the 0.01 level (2-tailed).

4. Correlation analysis of communication errors (Controllers)

**Correlations**

| | | ReadbackandHearback Error | NoPilot Readback |
|---|---|---|---|
| ReadbackandHearback Error | Pearson Correlation | 1 | .541** |
| | Sig. (2-tailed) | | .000 |
| | N | 112 | 112 |
| NoPilotReadback | Pearson Correlation | .541** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 112 | 112 |

**. Correlation is significant at the 0.01 level (2-tailed).