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GRADUATE SCHOOL OF SOCIAL SCIENCES
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**AVIATION SAFETY AND INFORMATION SYSTEMS: FLIGHT CREW
PERSPECTIVE**

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THESIS APPROVAL PAGE

DECLARATION

I hereby declare that this master's thesis titled as "Aviation Safety and Information Systems: Flight Crew Perspective" has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honor.

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ABSTRACT

Master's Thesis

Aviation Safety and Information Systems: Flight Crew Perspective

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Aviation safety and pilots' behavior standardization have long been regarded as a keystone by checklist usage. The checklist mainly used in aviation which is kept as a hard-copy format. Nowadays, the electronic form is subrogated the checklist hard copy usage with developing technology. The aim of this thesis is to identify the interaction between interactive checklist and cockpit information systems. The advantages and disadvantages of interactive checklist's effectiveness are analyzed and compared with traditional forms to make recommendations for aviation safety. Flight Information Systems; such as, Electronic Flight Bags (EFB) and Flight Management Systems (FMS) that are used in cockpit, supports the novelty of interactive checklist usage and endorses the significance of checklist usage.

The results of different checklist field studies are examined with the following four methods in order to scale up the aviation safety with checklist usage. The accident in 2017 which are recorded in National Transport Safety Board database, have been analyzed and four main aircraft accidents are evaluated in detail as an interactive checklist perspective. Interviews have been conducted by 10 pilots who have active duty in aviation industry; such as, Corendon Airlines, Freebird Airlines and Sunexpress Airlines. Addition to this, questionnaires is conducted with 50 pilots.

All the accidents analysis, interviews and surveys show that the interactive checklists are empowers the flight safety. It also minimizes the human factors, which are involved in accidents and incidents. Also, interactive checklist provides time efficiency and accurate information accessibility.

Keywords: Aviation Safety, Flight Information Systems, Interactive Checklists, EFB, FMS

ÖZET

Yüksek Lisans Tezi

Havacılık Emniyeti ve Bilgi Sistemleri: Uçuş Ekibi Bakış Açısı

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Havacılık emniyeti ve pilotların kokpitteki davranış standartları, kontrol listeleri (checklists) tarafından belirlenen ve amaçlanan temel etkenlerdir. Havacılıkla, kontrol listeleri genellikle kâğıt üzerinden takip edilmiştir. Günümüzde, teknolojinin de gelişmesiyle elektronik yapıdaki kontrol listeleri eski yöntemlerin yerini almaya başlamıştır. Bu tezin amacı "interaktif kontrol listesi" ve elektronik uçuş bilgi sistemlerinin etkileşime geçerek kokpite sağladığı faydayı ortaya çıkarmaktır. İnteraktif modelin avantajları ve dezavantajları sorgulanıp geleneksel yöntemler ile mukayese edilerek uçuş güvenliğine katkıları araştırılmıştır. Kokpitte kullanılan "Elektronik Uçuş Çantaları" ve Uçuş Yönetim Sistemleri ile desteklenen bu yeni sistem, kontrol listesi kullanımının uçuş emniyetine önemi göz önüne getirmiştir.

Kontrol listesinin önemini kavramak için dört ana başlık altında araştırmalar yapıldı. 2017 yılındaki National Transport Safety Board'a kayıtlı tüm kazalar incelenerek kaç tanesinin kontrol listesi kullanım hatalarından dolayı meydana geldiği ortaya çıkarıldı. Ayrıca, dört küresel kaza, örnek teşkil etmesi için detaylıca incelendi ve interaktif model bakış açısıyla yorumlandı. Kontrol listesi kullanımının sahadaki etkilerinin de gözlemlenebilmesi için Corendon Hava Yolları ağırlıklı olmak üzere Freebird ve Sunexpress Hava Yolları'nda ikinci pilot, kaptan, eğitmen pilot, emniyet uzmanı ve müdür olarak

alışan toplam 10 pilot ile mlakatlar yapıldı. İnteraktif model ile ilgili grşler alındı. Buna ek olarak yine sahada rol olan 50 pilota kontrol listesi ve interaktif model ile ilgili anket uygulandı.

Tm kaza raporu incelemeleri, rportajlar ve anketler sonucunda, interaktif modelin uuş gvenlięini arttırdıęı ayrıca, insan hatalarına baęlı kazaların ve olayların azalmasına yardımcı olacaęı belirlendi. Son olarak interaktif model zaman kullanımı ve doęru veriye erişim aısından incelendięinde kokpit ierisinde pilotların iş ykn azaltacak bir model olarak kabul ediliyor.

Anahtar Kelimeler: Havacılık Emniyeti, Uuş Bilgi Sistemleri, İnteraktif Kontrol Listesi, EFB, FMS

**AVIATION SAFETY AND INFORMATION SYSTEMS: FLIGHT CREW
PERSPECTIVE**

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ABBREVIATIONS

AC: Accident

ATC: Air Traffic Control

ATPL: Airline Transport Pilot License

CAA: Civil Aviation Authority

CRM: Customer Resource Management

CVR: Cockpit Voice Recorder

CL: Checklists

DGCA: Directorate General of Civil Aviation

ECAM: Electronic Centralized Aircraft Monitor

EFB: Electronic Flight Bag

EFIS: Electronic Flight Information Screens

EPR: Engine Pressure Ratio

FAA: Federal Aviation Administration

FDAU: Flight Data Acquisition Unit

FDR: Flight Data Recorder

FDM: Flight Data Monitoring

FMS: Flight Management Systems

F/O: First Officer

GPWS: Ground Proximity Warning Sensor

ICAO: International Civil Aviation Organization

NASA: National Aeronautics & Space Administration

NTSB: American National Transportation Safety Board

PFD: Primary Flight Display

PIC: Pilot in Command

RA: Resolution Advisory

QAR: Quick Access Recorder

SMS: Safety Management System

SMM: Safety Management Manual

SOP: Standard Operation Procedures

T/O: Takeoff

WQAR: Wireless Quick Access Recorder

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INTRODUCTION

The air transport continues to prosper with development of aviation industry. The aviation safety is one of the most major issues, which should remain up-to-date. In particular, the effect of aviation safety is substantial matter that should be set for airline operators. It has been generally accepted that today's information systems concept has more decisive effects on aviation safety in terms of the flight crew perspective. In this day and age, technological developments also play a vital role for aviation safety, which lead to new researches of aviation information systems. The technological developments and requirements in aviation safety generate the setting of new ambitious safety targets for air transportation. Human factors and operational environments are corner stone elements in aviation. In other words, the enlarging technologies are guaranteed the aviation safety in these days, indeed it needs to be researched and fostered.

A great deal of progress has been made in all aspects of aviation activities, in terms of increasing safety concept significance, establishing different expertise areas due to aviation safety and taking necessary precautions. Safety management increases the confidence of customers as well as the employee in air transportation. In addition, the optimal airport operation's safety management plays a critical role for preventing aviation accidents.

The first part of this thesis focuses on the aviation safety and importance of aviation safety into section one which is "Aviation Safety". It shows how flight crew is affected by the aviation safety. Moreover, Swiss Cheese Model (James Reason, 2000) is explained in terms of supporting the accident investigations. The system failure is analyzed and explained in detail based on Swiss Cheese Model.

Cockpit technologies and information systems are explained in section two which is "Cockpit and Information Systems". It is clarified how concept of information systems' used by flight crew and how it's pivotal for aviation companies. The checklist evolution history has been examined from the beginning of the flight invention. The applicability of the interactive checklist concept is investigated with literature review and examined the related cases.

In the last section of this thesis, the research findings are scrutinized the interactive checklist usage in cockpit. The aircraft accidents and incidents are analyzed and various statistics are obtained by examined research findings. In this thesis, the interviews were fulfilled by pilots, Safety Management System Department employees and a Type Rating Instructor. Questionnaires were used to identify and analyze the checklist attributes, which are caused the accidents or incidents by pilots. The questionnaire's participants also have an active duty at aviation industry in 2017. Findings show that the interactive checklist concept is supported considerably.

SECTION ONE

AVIATION SAFETY

Aviation safety is one of the most important issues that must be ensured by all areas of aviation and all its employees. It is stated as flight safety in terms of evaluation during flight. While the airport activities are carried out, there are two types as ground safety. These two types are concepts that are tightly bound together when considered in terms of safety, even if they are dedicated to different areas of expertise.

Most of the aviation accidents are important to analyze for flight safety. As the flight occurs at various stages, the consequences of accidents in flight cost more damage than the ones that occur on the ground. The rapid development of civil aviation in the world leads to insufficient capacity at airports. This development also increases workload of airport and office personnel. This also reveals some of the safety-threatening elements and provides the groundwork to increase safety.

1.1. Safety and Its Importance in Aviation Authority

There are many definitions of aviation safety given by Soekkha, Wiener & Curry and Reason. Definition of Gereade is used as a guide of Aviation safety which is the realization of civil aviation activities at acceptable levels of risk. These known levels of risk factors are avoided in real life situations (Gereade, 2010).

Depending on the perspective, the concept of safety in aviation may have different meanings, such as:

- Zero accident or serious event - an opinion widely accepted by travelers;
- Being distant from the hazards, i.e. causing a bad result;
- Attitudes of aviation organizations employees towards unsafe actions and conditions;
- Avoidance of errors;

- Compliance with regulations. (International Civil Aviation Organization, 2011)

Air transport is the safest type of travelling comparing to other transport modes. When the number of passengers carried and the number of fatal accidents are calculated in order to figure out the statistics, results can be found as just 0.07 deaths per one billion passenger miles (Savage, I., 2013). The results show that traveling by aero planes is rather safer mode of transportation. However, the repercussions of accidents in the aviation sector are much more effective than the accidents in other sectors. For this reason, aviation safety is a common goal for all aviation units and employees. It is one of the most important issues to be addressed in case of any abnormal situations in aviation industry.

All national and international authorities draw strict rules from negative events' inspections in the past and provided aviation safety. The reason of these issues can be given example in aeronautics, geographical and meteorological conditions, technology, and most importantly, people are interacting very closely with each other. However, there is always the possibility of an event that has not happened before. For this reason, it is not possible to achieve 100% aviation safety. Given that, even a single person has the possibility of being harmed, it is clear that there is no end point for safety improvements. In this thesis, it is shown that pilots' individual behaviors which are not controlled with the strict rules may play a critical role.

The concept of safety in the civil aviation sector has a great importance to the states as well as airline operators, which are the most important actors of this industry. Since the provision of aviation safety is essential for public safety, it is the duty of governments to take necessary measures to ensure aviation safety. Accidents that occur in an aviation system where the level of safety is not sufficient, can damage airborne vehicles or persons on the ground that directly benefit from airline service. For this reason, states develop and adhere to various standards in all civil aviation activities in the national aeronautical authorities which they established.

1.2. Concepts of Safety

Providing safety is possible by only realizing concepts which are related to it and having an idea of how to ensure safety by creating solutions. Safety concepts are examined under four sub-headings: hazard, risk, incident and accident.

1.2.1 Hazard

Hazard is defined as a situation or object that has the potential to cause injury to people, damage to equipment or work, loss of resources, or a reduction in the ability to perform a function of a predefined function. (ICAO Doc 9859, 2009: 4-1) In other words, danger can be stated that factors which create unwanted events, situations or things (Gerede, 2010). Some hazards occur with no injury or damage. However, it can be defined as a potential condition or threat that could lead to injury or damage. (Wood, 2003: 30).

It is clear that aeronautical safety concepts are learned in order to achieve the goal of improving the safety of aviation. So, the concept of danger is used for this purpose. It must be analyzed whether there is a danger to a situation, object, activity or subject. This detection can be performed in three steps. First of all, a general threat in the area is inspected. In the second step, the constituents of the identified elements are evaluated separately and specific lower threat elements are revealed and compared. Thirdly, the subordinate threat element's potential hazards and probable consequences are evaluated. Then, the logical ones are identified as dangerous. The following is an example for the detection of a hazard.

Situation1: Every year, an international airport with a hundred thousand landing and departure traffic have to carry out maintenance and repair work on one of the two crossing roads.

- Step 1: General threat elements are identified; such as, airport maintenance and repair work.
- Step 2: The sub-components of the general threat component are identified: maintenance-repair vehicles, closed taxi routes etc.

- Step 3: The threats and possible consequences of the subcomponents are determined; such as, collision of the aircraft with maintenance-repair vehicles, departure of the aircraft from the wrong tracks (ICAO Doc 9859, 2009: 4-6). As explained in the above example, a general hazard is identified in step 1 and step 2. The result of the occurrence of the danger action is evaluated in step 3.

Hazards are grouped under three headings according to their area. These are natural hazards, technical hazards and economic hazards. Natural hazards can be seen as a potential that can threaten operations in relation to environmental conditions. Events related to public health; such as, epidemics can be shown as examples of natural hazards. Natural hazards can be compromised climatic events, meteorological conditions, geophysical events and environmental issues. For instance, climatic events can be storms and hurricanes. Meteorological conditions are example of snow, rain, icing etc. Geophysical events are consisting of the earthquakes, tsunamis, volcanoes. Environmental issues are known as fires and wildlife. These all natural hazards are explained as natural dangerous examples (ICAO Doc 9859, 2009: 4-3). Technical hazards are the dangers associated with the use of energy sources; such as, electricity, fuel, and other issues that are closely related to flight safety. For example, software & hardware malfunctions, and warning systems. Samples of technical hazards are the issues that concern the suitability of aircraft systems, subsystems and components for their hardware (ICAO Doc 9859, 2009: 4-3). Economic dangers are the dangers that the operational zone can be threatened with economic and socio - political factors and movements. Economic issues such as economic growth, economic stagnation, resource and equipment costs are examples of economic dangers (ICAO Doc 9859, 2009: 4-4).

The consequences of hazards are elements that create a risk for aviation industry (Gerede, 2010). For this reason, the concepts of danger and risk are closely related to each other.

1.2.2 Risk

Risk is measured by two attributes. First one is called as probability. Second one is effectiveness of the probability that people will be harmed by equipment or structures, cause loss of resources, or prevent a previously defined function from being performed. Briefly, according to the ICAO CAP 760, the likelihood of encountering an undesirable event is multiplied by the effect that this probability will have when it occurs.

$$\text{Risk} = \text{probability} \times \text{effect.}$$

Risks can be examined under six sub-headings: real risks, statistical risks, predicted risks, perceived risks, acceptable risks and unacceptable risks. Real risks are defined as the risk a person faces after an event has occurred. All the risk headings are explained in detail.

- The actual risk is determined by the circumstances that will arise in the future.
- Statistical risks are the risks that are determined by using the statistical data for the accident or events studied.
- Predicted risks are the risks that can be determined based on the models developed according to the information obtained from the subject and past events.
- Perceived risks are the risks felt in a person-specific manner based on intuition. These risks are not related to scientific criteria because they are related to feelings.
- Acceptable risk is defined as the allowed risk to remain in the system without the needing for additional management work. It is difficult to make this decision due to the responsibility of management activities. This decision can be made when the user has sufficient knowledge.
- Unacceptable risks which are never overlooked by management. It is a type of risk that must be removed or kept under control.

All of the risks of flight operations may not be completely removed. Risks are not existing today may arise later. The main concern about safety, consequences and severity of the risks are controllable. Since risk will never be zero, each flight contains risks that are defined or unidentified in the operation. If a risk factor is identified, it is determined whether it is acceptable to risk with the risk analysis to be applied to the risky flight operation. It is decided according to this risk.

1.2.3 Incident

Incident is the one that affects an air vehicle operation and a safe flight of the operation (ICAO Annex 13, 2001: 1-1). In incident, flight safety becomes dangerous and hazards have emerged that may cause accidents, but there is no accident. Hazardous events can also be investigated under the severely hazardous event subdivision according to the degree of occurrence of the incident situation. The only difference between serious dangerous incidents and accidents is the results they emerge (Wood, 2003: 29). That can be explained as incidents, which lead to cause accidents.

1.2.4 Accident

Aircraft accident, involving the death or serious injury of any part of the aircraft (in or around the aircraft) within the period of time until the person has disappeared from the aircraft by reason of flight: resulting with the loss of or inaccessibility of the aircraft to structural damage (ICAO Annex 13, 2001: 1-1). Accident is classified in two branches, accidents results in aircraft damage and accidents result in human injury.

1.2.4.1 Accidents Result in Aircraft Damage

Classifications results in the damage to the aircraft are assessed considering the level of damage occurring after the accident. Damage to the airplane is in full damage and major damage. Fully damaged accidents which are enormous aircraft damages that is not economically feasible in terms of cost and efficiency of repair.

Hijacking, terminated investigations without reaching the wrecked plane or a situation that is not possible to find wrecked of an airplane which was severe damaged are classified as fully damaged accidents. Excessive damaged accidents are explained as structural failures that affect the flight's performance, characteristics and structural strength. Large-scaled repairs and replacement of parts of the affected elements are necessary for these accidents.(Koldaş, 2006: 6).

1.2.4.2 Accidents Result in Human Injury

According to the results in the human injury, the accidents are classified into three groups, which are; deathly injured accidents, fatal accidents and serious accidents.

- Fatal accidents are defined as accidents in which death occurs during or immediately after an accident.
- Deathly injured accidents are defined as accidents resulting in injuries caused by the American National Transportation Safety Board (NTSB) within 30 days of accident.
- Injuries are defined as severely injured accidents, which are bleeding or nerve, muscle, tendon damage. Injuries can cause any fracture of any bone other than simple fractures; such as, hand or toe or nasal bone fracture, requiring any treatment within 7 days after injury and requiring more than 48 hours in the hospital. Traumatic injuries are defined as injuries of any internal organ, injury of more than 5% of the body resulting in secondary or tertiary burns, exposure to infectious substances or Injuries determined to have occurred after exposure to radiation (ICAO Annex 13, 2001: 1-1).

1.3. Aircraft Accidents

As the systems that support pilots for a safe flight are constantly being developed. The development processes of these systems are often shaped by fatal accidents. It can be stated as; deadly events force engineers to look for modern implementations. For instance, during assembling the fuselage part of the aircraft, all

the screws that used on skeleton to keep the parts together was made by metal at first. However, stress of the metal caused by the outside pressure was not taken into account and an airplane disassembled while flying. Then the engineers decided to use composite fuselage materials to prevent stress of the metal.

In this section, a sample study is investigated which contains accidental data related to checklist in history, analysis and description of these accidental data. It also emphasizes the significance of the checklist in aviation by presenting small sections from research. Based on the sample research of Doolen T. and Nicolalde R, similar study was conducted for the year 2017.

According to the results from the analysis, 2% of the accidents and incidents registered to NTSB were caused by using wrong or missing checklist from the beginning of the year until the end of June 2017. This ratio has a tremendously serious for aviation industry.

There are many precautions to prevent accidents and incidents with the developing technology. It is expected that the integration of electronic systems with each other and with people increases the security further. But unfortunately, no matter how much preventive it is desired to be, the milestones in aviation are often determined as result of eliminating accidents.

1.3.1. Accident Reports

Before starting the analysis of the accidents, a sample research was shared which includes the data random selection of 100 accidents in Table 1 (Doolen T and Nicolalde R, 2000). After briefly explaining the columns of the sample study, a report that contains 44 accidents or incidents has been partially presented as an example. This field was analyzed by dividing into four accident subcategories directly related to the checklist and deduced from the interactive checklist.

1.3.1.1. A Study Report Related with Checklist

This part of the report was investigated and analyzed the checklist accidents from past to present. For this reason, the study report was first shared as an example.

The research data were accessed via the National Transport Safety Board (NTSB) database using the checklist, check, and list keywords.

The data reveals that the checklist has a direct relationship with 10 out of the 100 accidents which researched in 1997. Also, it was determined that 5 out of every 97 events were directly related to the checklist in 1996. Accidents were selected by Random Sample Selection method. Considering on the published study, Table 1 illustrates only a small piece of the study below.

Table 1: Sample Selection from the 100 Accident Inspections in 1997

Number	Checklist Involved?	# Out of 2163	Report Type, Location Of the Accident, Type of Plane & Accident Number
13	Yes	245	Final SITKA, AK Buesing SX-300 N357SX Fatal (2)
14	No	267	Final KIRKSVILLE, MO Cessna 182 N869L Nonfatal
15	No	289	Final FAIRBANKS, AK Cessna 170B N3486C Nonfatal
16	No	311	Final BENTON, TN Schweizer SGS 1-26E N33WP Nonfatal
21	Yes	421	Final TUCSON, AZ Cessna 182D N9000X Nonfatal

Source: Doolen, T. and Nicolalde, R. 2000

At the Table 1, there are 5 sample report results of 100 accidents which were examined in 1997. The test results of this accident examples are ascertained that the accidents are caused directly using incomplete or wrong checklist.

First column point out the 1-100 ordering, the second column depicts these accidents whether is related to checklist, the third column signifies the number of accidents during the year as #2163. The 100 sample selected randomly from 2163 accidents reports. And the fourth column demonstrates a brief summary of the accident.

The results of this study shared as follows;

- number of not completed checklist is 7
- incorrect checklist used during abnormal situation is 5
- checklist not used is 11
- checklist not followed properly 19
- and checklist item not “rechecked” is 2

The other research in this area has examined 45 checklist issued accidents which are analyzed by asking questions about the checklist. (The questions are consisted of ‘when and what kind of checklist it is, why is this accident occurs, which type of checklist faults are eventuated.’)

This research has gone through the attribute, which are Accident/Incident Number, Date, Reason, Phase of Flight Where Error Occurred (Phase of Error), Synopsis of Issue with Checklist, Descriptions. The research is scrutinized under these headings. The following Table 2 contains a sample section of the research.

Table 2: A Random View from the 45 Sample Accidents

Accident Id	1
Accident Number	AAR-97/01
Date	02/19/1996
Reason	Checklist item skipped
Phase of Error	Cruise & Before landing
Synopsis of Issue with Checklist	The flight crew failure is caused by incomplete checklist situation which resulted in indication of lower hydraulic pressure. That indication blocks lowering the landing gear and deploying flaps. Fault of the pilots was omitting an item in the landing checklist which is checking landing gear visually.
Description	Wheels up landing of DC-9-32 omission of checklist item may have been due to captain being distracted / interrupted, the checklist item being obscured by a fold, the captain’s expectation that the FO would perform the item because it was the norm.

Source: Doolen, T. and Nicolalde, R. 2000

In this table, the first row indicates accident event number which is recorded in NTSB database, the second row connotes the day of the accident happened, the third row exhibits what kind of checklist fault is happened. Fourth row represents the phase of the flight that the accident was observed. The fifth row reveals the synopsis of issue with checklist, which was directly taken by NTSB Database. Finally, “Description” row is taken from the NTSB considering on accident/incident description section.

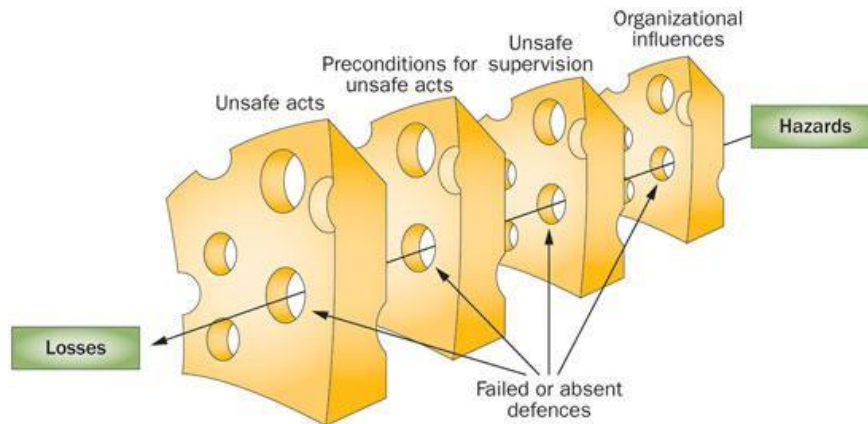
1.4. Reason - Swiss Cheese Model

The Reason Model is developed by Professor James Reason, which is recognized by the aviation industry, to understand the causes of accidents and how successful & safe flight operations can be accomplished in aviation. According to this model, there is usually no single cause of accidents, and the occurrence of accidents is only possible by combining the factors that are effective in the accident (ICAO Doc 9859, 2009: 2-5).

The Reason model demonstrates how people can collapse complex, highly interactive, well-preserved systems, like aviation that cause accidents. According to reason, the aviation sector consists of well-protected strict rules, high standards & control methods, and complex surveillance equipment. Accidents due to technological advances and excellent defensive measures are rarely caused by operator or vehicle failures. James Reason mentioned that the decision makers who have to aim balancing between; safety, management, passengers and cargo as first reason of his model is developed. The second one is the flight line managers, who implement the decisions.

In the Reason Model, the causes of various accidents were evaluated under four headings: Organizational influences, unsafe supervision, preconditions for unsafe acts and unsafe acts are shown by Figure 1.

Figure 1: Reason Swiss Cheese Model



Source: Thomas G. W, Michael P. P & Ronald V. M, 2013

1.4.1. Organizational Influences

Organizations have been accepted as the first and most important factor affecting the provision of aviation safety as the places where strategic and operational plans are made, where decisions are taken and where work is done in this regard. In organizations, the erroneous decisions of senior management can directly affect the management practices of all the institutions and organizations that are involved in an operation as well as the actions of the carrier enterprises and the conditions of the operations (Shappell and Wiegmann, 2001: 6). Unfortunately, these organizational influences cannot prevent accident investigators and aviation employees from facing situations where aviation safety is threatened by missed or unreported actions despite their most self-sacrificing activities.

Traditionally, covert organizational failures are grouped under three headings: Resource management, organizational climate and organizational process. Resource management includes decision-making processes related to the separation and preservation of resources such as people, money and equipment. Activity items related to resource management are shown in the Table 3 below.

Table 3: Resource Management Activity Items

HUMAN RESOURCES	BUDGED RESOURCES	HARDWARE RESOURCES
Staff Selection	Cost Limitation	Poor Design
Team	Insufficient Capital	Lack of Hardware
Staff Training		

Source: Shappel, A., Wiegmann, D. (2004)

At Resource Management Activity Items Table, it examines that the human resources are consisted of staff selection, team manning, and staff training.

Decisions about business combine around two different purposes: First goal is to ask how to manage resources through secure and safety. Second purpose is how we make timely, cost-effective operations. If the business becomes successful for these purposes, both the safety-cost ratio will be optimal and a complete safety satisfaction will be achieved. It may also be possible to create financial savings by taking control of requests between the two purposes.

The organizational climate, which is the second of organizational failures, is defined as the naming of organizational variables that are shaped by the coherent behaviors of organizational people and affect employee performance in a certain category (Wiegmann and Shappell, 2001: 7). Organizational climate activities are shown in the following Table 4.

Table 4: Organizational Climate Activities

Organizational Structure	Organizational Culture	Organizational Policy
Chain of Command	Norms and Rules	Incentives
Authority, responsibility sharing	Values and Beliefs	Drug Regulation
Communication Channels	Organizational Merit	Hiring
Authority to Sign		Firing

Source: Shappel, A. Wiegmann, D. Workshop (2009).

Factors that reflect the organizational structure of an organization are classified as command-chain, authority, responsibility sharing, communication channels and official responsibility for actions (signature authority, bureaucracy). Factors are key indicators of an organizational climate. In addition, an organization culture and policies are also among the clear indicators of organizational climate (Wiegmann and Shappell, 2001: 7).

An organization culture consists of concepts, such as norms, values, beliefs, attitudes, not written, which are developed together by the employees. Policies are official guidelines to help managers make decisions. When policies are wrongly determined, or they are in conflict with each other, unofficial rules and values are likely to create a chaos within the organization when these policies take place.

The organizational policy is the last sub-title of the safety-related organizational impacts of the Reason Model. The organization policy also states the rules of the company that used to manage day-to-day activities within the organization. These are creation & use of official methods, standardized operational procedures to ensure control and supervision mechanisms between management and employees. For this reason, creation of decisions is defined as the implementation process (Wiegmann & Shappell, 2000: 13). In this process, procedures are set out to determine the activities that could disrupt flight operations and to carry out actions that will increase safety accordingly. These procedures are built on the basis of a safety management system that are formed by identifying and reporting problems related to human error in the subjects that are reducing risk of the safety. The activities of this subject are shown in the Table 5.

Table 5: Activity Topics Assessed within the Scope of Organizational Process

Operations	Procedures	Oversights
Work Pace	Standards	Risk Management
Time Pressure	Predefined Subjects	Safety System
Productions Limits	Instructions	
Perks and Bonuses	Documentation	
Performance Evaluation		
Programming		

Source: Shappell, S. & Wiegmann, D (February, 2000).

1.4.2. Unsafe Supervision

In ensuring aviation safety, each staff member is responsible for their actions and should check the appropriateness of these actions. However, since automation in this way is very difficult on an individual basis, surveillance and inspection are coordinated between the staff. This coordination can also be achieved through careful attention to the issue in a managerial sense. Otherwise, surveillance and supervision practices are carried out in an unsafe and inefficient manner. Also it can be confronted as a threat pretended to deal with in terms of aviation safety.

Unsafe supervision is examined under four headings: inadequate supervision, improper acts, correction of problems, supervision violations.

Inadequate supervision is one of the tasks that managers have to accomplish. For this reason, the necessary training programs should be organized by the managers, whatever the level of the subject studied or the level of action, guidance, leadership, motivation and a model should be set up. Unfortunately, these conditions are not always available. Failure to perform these functions adequately can lead to many violations and cause errors.

Improper acts are an area of study where issues are assessed by some applications that managers make incorrect or incomplete. To check the suitability of the practices of the safety concepts which are determined by the managers, such as not arranging the working hours of the staff, making inappropriate work planning,

not delivering the correct data to the personnel, not having enough briefing time before the operation flight, assigning tasks contrary to existing regulations.

1.4.3. Preconditions for Unsafe Acts

Preparatory conditions for unsafe actions are defined as effective or latent preconditions, which are factors in an accident by creating human error or unsafe situations by the practice, situation, movement of practitioners, the environment or personnel etc. These prerequisites are considered under three sub-headings, which are environmental factors, staff factors and individual situation factors.

First of all, this research is going to analyze the environmental factors. The environmental factors are classified in two sub-categories. These are physical environment and technological environment. The second of the preliminary conditions of unsafe factors are originating from the employees. These factors are separated into two groups. These sub-groups are originating from Crew Resource Management (CRM) factors and the personal preparation factors. The third and final condition is the state of the individual. This condition is examined under three headings; these are, unfavorable cognitive factors, unfavorable physiological factors and physical - mental limitations.

The physical environment assessed under the heading of environmental factors is defined as environmental concepts affects the movements of implementer that cause human error or impropriety; such as, weather, climate, snow or sand storm. The technological environment is called cockpit, vehicle, workplace design or automation. Human error or unsafe preconditions cause accident. The implementer is a main factor for causing accident. Issues related to environmental factors are classified in the Table 6.

Table 6: Physical and Technological Environment

Physical Environment	Technological Environment
Meteorological situation	Hardware Designs
Altitude	Display features
Lighting issues	Automations
Quake	Checklist organization
Noise issues	

Source: Shappel, A., Wiegmann, D. (2004), The Human Factors Analysis and Classification System (HFACS).

Personnel-originated factors are defined as conditions that are assessed in event of a human error movement or an unsafe situation or faulty crew resource management practices. All these options cause an accident. The factors which result from crew resource management are individuals or crew that involved in the preparation of tasks and interactions during implementation. Therefore, creating human error or unsafe situations are factors in the accident. Table 7 illustrates the factors that are related to the staffing factors. The following table shows the factors related personnel faults in below.

Table 7: Person-related Inappropriate Situations & Crew Resource Management

Person-related Inappropriate Situations	Crew Resource Management
Inadequate training	Inappropriate communication
Faulty case risk prosecution	Insufficient leadership
Inadequate rest	Distrust of the team
	Insufficient teamwork
	Team strain

Source: Shappel, A., Wiegmann, D. (2004), The Human Factors Analysis and Classification System (HFACS).

The final condition is assessed as the individual's condition, physiological condition, mental condition, physical and mental limitations which affects the individual practice and movement. These lead human error or unsafe conditions. The individual cognitive status or attention management conditions are factors that are examined if these factors are led to human error or unsafe conditions by effecting the perception or individual performance (Çetinkaya, 2008: 49). If the cognitive state is not appropriate: misdetection of an object, a threat, or a situation; such as, visual, auditory, balance or attention deficits can create an unsafe situation.

An unfavorable physiological condition is termed as factors that prepare the condition. The physical and physiological state of the individual can affect the action to reduce or eliminate safety.

Visual errors such as vertigo and physical fatigue are very important in aviation. It is known to affect human performances, which are the effects of the unfavorable situation of the individual (Shappell &, Wiegmann 2000: 7).

Physical - mental limitations are defined as the situation in which an individual's job requirements cross the person's abilities or characteristics physically and mentally. Vision is emerging as one of the subcategories of preparation for insecurity conditions; such as, night-vision abilities. The night vision abilities are related to the physical condition which evaluate on matters related to the mental state; such as, information processing. Information processing clarifies that the ability to generate the necessary reaction against this knowledge (Gerede, 2010). Information processing references situational awareness for a pilot while flying at night conditions. Some topics related to the position of individuals are demonstrated in the Table 8.

Table 8: Topics Related to the Position of Individuals

Inconvenient Cognitive situation	Physiological situation	Physical Mental Limits
Stress	Illness	Reaction time
Loss of situational awareness	Rhythm disturbance	Loading information
Cognitive fatigue	Fatigue of body	Memory recall ability
Confusion of mind	Drug use	Visually capabilities

Source: Dongping, F., Chen Z. and Mengchun Z. (2016). Cognitive Model of Construction Workers' Unsafe Behaviors

1.4.4 Unsafe Acts

Unsafe acts are defined as active faults and movements which lead to human error or unsafe conditions. Unsafe actions are closely related to the accident. 'These actions occur due to mistakes and violations.'(Çetinkaya, 2008: 48). As a result of such actions, conditions that will cause accidents have already been set up. An unsafe act occurs both organizationally, actively and confidentially. All the factors that accumulate together with the action come out to reveal the unsafe situation. Detection errors are the type of error for physical or mental factors which an object of threat or situation is mistaken. It is resulting in an unsafe environment (Çetinkaya, 2008: 48). Activity items related to error types are listed in the Table 9.

Table 9: Operational Issues Related to Error Types

Skill Based	Decision Based	Perception Based
Distractibility	Incorrect reaction	Visual errors
Forgetfulness	Insufficient information about the situation	Vertigo
Inadequate technique	Capability status	Loss of sense
Incorrect procedure		

Source: Shappell, S. & Wiegmann, D (February, 2000).

Deliberate violations of regulations adjust the process of activity. Violations often occur less frequently than faults. Routine and unusual violations are divided into two sub-groups which are routine violations and unusual violations. Routine violations are habits that are tolerated by the authorities. Unusual violations are entirely independent of the authorities. At the Table 10, violations are shown below.

Table 10: Activities Against Error Types

Routine Violations	Unusual violations
Unauthorized approaches	Acrobatic maneuvers
Operation in bad weather conditions	Cruising at unauthorized flight level
Violation of procedures	Violations of training rules
Violations of training rules	Inappropriate action against aircraft limits

Source: Shappell, S. & Wiegmann, D (February, 2000).

- The routine violations are explained as unauthorized approaches, operation in bad weather conditions, violation of procedures and violations of training rules.
- Unusual violations are clarified as acrobatic maneuvers, cruising at unauthorized flight level, violations of training rules and inappropriate action against aircraft limits.

SECTION TWO

COCKPIT AND INFORMATION SYSTEMS

The cockpit is the name given to the part where the aircraft is operated and this operation is supported by multiple computers with an electronic information infrastructure. Information system is another important issue that must be ensured by all areas of aviation and all its employees. On cockpit side, these systems provide information about aircraft's current position, track, heading, weather information, traffic information, altitude warnings and after flight information. After flight analysis is assessed by Flight Data Monitoring (FDM) Specialists according to the received data from recording devices is considered. FDM is known as the office side information system.

The use of checklists is a vital for flights. Since the aircrafts are composed of complex systems, it is necessary for the pilots to check all steps; such as, before and after landing, during landing, before and after departure, during departure, taxi and in emergency situations as well. A step to be missed when considering flight stress is mostly ended up with a fatal accident unfortunately.

Due to the content of the thesis, first the checklist evaluation process and the transition to the electronic system will be explained. Then, the answer will be searched for checklist automation.

2.1. Checklist

Degani, A., and E.L. Wiener (1990) clarified that the flight deck checklist is fundamental function which ensures the crew configuration of airplane properly for any given flight segment. "It forms the basis of procedural standardization in the cockpit. The complete flight checklist is subdivided into specific task-checklists for almost all segment of the flight, i.e., preflight, taxi, before landing, etc. and in particular before the critical segments: takeoff, approach, and landing. Two other checklists are also used on the flight-deck: the abnormal and emergency checklist." A checklist for 737-800 is located on the yoke which includes "Before takeoff, after takeoff, descent, approach and landing" is shown Figure 2 below.

Figure 2: Boeing 737 Yoke Checklists.



Source: <https://www.flickr.com/photos/golfcharlie232/14948475956>, May, 2017

Boeing locates frequently used checklists into control column of the aircraft which allows users to reach these checklists without any effort. Design is also considered as ergonomic which faces with pilots during any phase of the flight.

2.1.1 Evolution of Checklist

2.1.1.1. Checklist Necessity

As the complexity of system increases, the need for checklist has also risen due to having some accidents and injuries in aviation. It is proved that the use of checklist reduces the human factor in accidents. Thus, flights become safer. By following the instructed steps regularly, it helps to prevent a possible problem in a timely manner. Use of checklist provides the control of the sequence of steps to be taken in an emergency and it also reduces stressed out situations. In everyday life, there are checklists that are not written yet but always applied. These basic instances

can be considered as a basic checklist; such as, to check the key when leaving the house, to keep the gas switched off, to prepare the suitcase before the planned trip, to prepare the list to be bought for shopping and so on. As shown in the examples, as the workload increases, the number of attributes to be controlled increases. In situations where the workload is becoming more and more complicated, it causes the human go beyond the memory, and it forces the person to use different control methods. When these workloads which are fairly light samples compared to the flight phase, it allows the grasp of the essential checklist during the flight. Because of this reason, checklists have been developed with new methods in aviation and they have become an indispensable part of the routine flight. The checklist design has evolved over the years and has become a current model.

2.1.1.2. Checklist Items Memorization Method

In the beginning, the checklist items were memorized by human and applied during the flight. All information has been given to the pilots on training phase. Hence, pilot could have applied those essential steps by their retention. Just as it is practiced while driving today, human memories were being used for checklist operation, instead of reading steps on paper. However, as the intensity of flight traffic, position information, radio conversations, flight procedures were increased, the important steps begun to be forgotten. In the case of the war plane pilots taking significant decisions in seconds under pressure, the checklists mistakes was encountered. Unfortunately, it has become inevitable for these kinds of mistakes to result in serious accidents.

Addition to this, the human factor did not participate in the method of memorizing the checklist and this method was abandoned. Thus, the paper based checklist method was adopted and used for safety purposes.

2.1.1.3. Checklist Paper Method

This section helps to understand why the checklist paper method is needed and figure out the checklist paper method. By the way, the electronic flight bag (EFB) is analyzed detail in following section 2.2.1. Meteorology and Jeppesen charts

are investigated at the next stage which is explained in detail in cockpit and information systems section. Checklist functions are used to ensure that the crew members configure the plane properly and keep maintenance the flight. The checklist occurs during all the critical flight phases; such as, (TAKEOFF, APPROACH, and LANDING).

From the beginning, it needs to know why this checklist paper method is started to use. As we know that, the aviation rules are written in blood. With some unfavorable events were occurred when the pilots were using memorization method. The first checklist paper method is known in history was adopted by B-17 aircraft during the Second World War. In this war, three people on the airplane were injured. And what is worse, the aircraft was stalled and three of them lost their lives. After the accident, the investigation reveals that the elevator was not being commanded by captain. By reason of the elevator command by captain is fallen of the map, three of them are lost lives. Because the captain sank into oblivion to command the 'elevator lock on' and this step is skipped. This sample could show how important to follow the steps and infer either one sentence or word could save the life in air. It is understood that the human could make mistakes and could no longer commit all the required steps of configured. The first written checklist in history is shown at Figure 3.

Figure 3: B-17 Checklist: The First Written Checklist in History.

RESTRICTED

APPROVED B-17F and G CHECKLIST

REVISED 3-1-44

PILOT'S DUTIES IN RED
COPILOT'S DUTIES IN BLACK

BEFORE STARTING 1. Pilot's Preflight—COMPLETE 2. Form 1A—CHECKED 3. Controls and Seats—CHECKED 4. Fuel Transfer Valves & Switch—OFF 5. Intercoolers—Cold 6. Gyros—UNCAGED 7. Fuel Shut-off Switches—OPEN 8. Gear Switch—NEUTRAL 9. Cowl Flaps—Open Right— OPEN LEFT—Locked 10. Turbos—OFF 11. Idle cut-off—CHECKED 12. Throttles—CLOSED 13. High RPM—CHECKED 14. Autopilot—OFF 15. De-icers and Anti-icers, Wing and Prop—OFF 16. Cabin Heat—OFF 17. Generators—OFF STARTING ENGINES 1. Fire Guard and Call Clear—LEFT Right 2. Master Switch—ON 3. Battery switches and inverters—ON & CHECKED 4. Parking Brakes—Hydraulic Check—On— CHECKED 5. Booster Pumps—Pressure—ON & CHECKED 6. Carburetor Filters—Open 7. Fuel Quantity—Gallons per tank 8. Start Engines: both magnetos on after one revolution 9. Flight Indicator & Vacuum Pressures CHECKED 10. Radio—On 11. Check Instruments—CHECKED 12. Crew Report 13. Radio Call & Altimeter—SET	ENGINE RUN-UP 1. Brakes—Locked 2. Trim Tabs—SET 3. Exercise Turbos and Props 4. Check Generators—CHECKED & OFF 5. Run up Engines BEFORE TAKEOFF 1. Tailwheel—Locked 2. Gyro—Set 3. Generators—ON AFTER TAKEOFF 1. Wheel—PILOT'S SIGNAL 2. Power Reduction 3. Cowl Flaps 4. Wheel Check—OK right—OK LEFT BEFORE LANDING 1. Radio Call, Altimeter—SET 2. Crew Positions—OK 3. Autopilot—OFF 4. Booster Pumps—On 5. Mixture Controls—AUTO-RICH 6. Intercooler—Set 7. Carburetor Filters—Open 8. Wing De-icers—Off 9. Landing Gear a. Visual—Down Right—DOWN LEFT Tailwheel Down, Antenna in, Ball Turret Checked b. Light—OK c. Switch Off—Neutral 10. Hydraulic Pressure—OK Valve closed 11. RPM 2100—Set 12. Turbos—Set 13. Flaps $\frac{1}{2}$—$\frac{1}{2}$ Down FINAL APPROACH 14. Flaps—PILOT'S SIGNAL 15. RPM 2200—PILOT'S SIGNAL
--	--

RESTRICTED

55

Source:<http://2cu0e82dwys33tkcal49mniykgi.wpengine.netdna-cdn.com/wp-content/uploads/2009/12/checklist03.jpg>, May, 2017

After the accident, the Boeing Company was threatened for this collapse. By implementing the checklists, they flew 1.8 million hours with number of eighteen B-17 aircrafts without any incident or accident. It is proved to the government that they were safe, and eventually nearly 13,000 B-17 aircrafts were built. Due to this situation, it is understood that the checklist paper method is required and needed.

2.1.1.4. Checklist Cross-check Method

A couple of years later, it has been clearly seen that one pilot was not enough to do checklist. The reason of this result can be clarified that complexity of the screens was rising because of the improvement of the technology with the new features. So, checklist task offered to proceed by both pilots on the cockpit due to the having a cross check opportunity. By this method, both screens could be checked by pilots and results should be matched in real time. Hence, the erroneous part could be realized and possible accident could be prevented in this time.

In the beginning, it was used as a control mechanism by means of memorization as a result of experienced accidents. However, later on, pilots was forced to apply a written checklist due to missing some fundamental steps on the memorization methods.

Now, Electronic Flight Bag systems have been deployed for airplanes. With the developments of the technology, new computers have been embedded to the cockpit. This new technology is described in detail at section 2.2.1.

2.1.1.5. Interactive Checklist Method

Interactive Checklist Method is a new model which is the idea of this study for controlling checklist in electronic environment. Interactive Checklist is expected to provide the data automatically which is generated by way of interaction between Electronic Flight Bag (EFB) and other flight information systems. The objective of this model is to visualize the set/check status of each checklist item in the list real time, thus any missing step, reading error or wrong action could be avoided or minimized for pilots.

Moreover, the purpose is to ensure that the actions are taken properly for each item in the checklist and make a double-cross check in addition and supportive to traditional way. As an example, in traditional way, yet Flaps Set 5 item is checked, the pilots double-check each other. But according to new interactive checklist method, FMS interacts with the other built-in flight information systems and ensures that Flaps Set 5 item is checked by the systems itself, then the “check” step ends with an indication of the status as "checked" on the screen. In case the pilots miss a procedural step during checklist, interactive checklist marks the uncompleted items and warns the pilot by indicating an error status message on the preferred screen. Interactive checklist should follow the movement & position of the aircraft and suggest if pilots need to request essential checklist, such as; landing checklist or takeoff checklist.

Interactive checklist can be used when an emergency condition occurs. The system should bring the essential emergency checklist to the screen if flight crew need to use the checklists. For example, when TCAS / RA warns you, it should display on the screen that you need to make an alert immediately according to the warning and SOP of the company. This situation enables the pilots do not need to find paper based checklist. Sink-rate and Pull up warnings may also be evaluated as interactive checklist due to automatic directions given by these systems. For example, “Pull up” is a warning for avoidance maneuver which helps cabin to be aware of the crucial warning to nose up the aircraft in order to avoid crashing. If we assume that the pressurization failure is taken as a malfunction, the normal procedure is going to set as: Go down to 10000 ft. and divert to the nearest aerodrome. According to this scenario, when the system picks up the PACK supply warning, it should redirect pilots for an emergency landing. At first, pilots should be informed by the system as descent to 10000 ft. on the EFB screen, also system should find the nearest divertible airport, and bring up the coordinates if necessary. Some parts are similar to the Electronic Centralized Aircraft Monitor (ECAM) system in Airbus commercial aircraft series. However, if landing flaps setting are determined into Flight Management System as 40 degrees and pilot applied 30 degrees in landing phase. There is no system to warn pilots about setting the flaps 40 degrees instead of

30 degrees. This basic situation may lead incidents or accidents due to the approach speeds are different in any flaps settings.

2.2. Information Systems

Since the importance of the checklist usage has been explained in section 2.1. These systems are explained into five main topics which are Electronic Flight Bags, Flight Data Monitoring, Flight Management Systems, Ground Proximity Warning System, and Airborne Collision Avoidance System. There are also other systems in cockpit however; those five are enough to explain overall information in order to cover accidents analysis in this thesis.

2.2.1. Electronic Flight Bags (EFB)

Technological improvements are leading companies to enhance their cockpit environment. In recent years, the term of the Electronic Flight Bag has been augmented. Mobile technologies have begun to help pilots and flight-related operations. The mobile software that pilots are using is called Electronic Flight Bag (EFB). Pilots have tablets and embedded electronic computers instead of searching some information on papers while flying; such as, chart, procedures, notams etc. Charts are used in cockpit which are majorly “Jeppesen or AIP Charts” for the approaches by airlines. Placing huge amount of charts in cockpit leads to excess of paper situation. EFBs are replacing with these papers to organize the cockpit environment.

Electronic Flight Bags are referred as mobile devices where the crew can perform the necessary flight procedure more easily and efficiently without looking for any paper. In other words, EFB is defined as a system, which enables electronic documents to be created and managed in flight. It can be integrated with avionic systems in flight, which keeps the information that pilots need in flight and keeps them in electronic form.

During the traditional emergency conditions, pilots have to check the QRH to find the exact procedures for “PACK supply” malfunction. In an emergency situation, workloads of the crew are dramatically boosted. Hence, reaching the

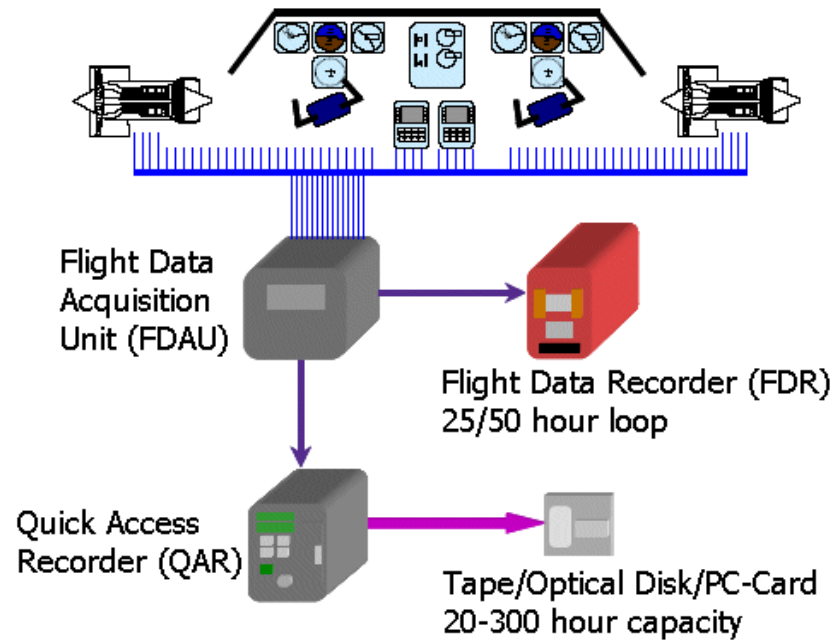
correct information is also getting harder. With EFB, it would take approximately 30 seconds to reach the required information. With a QRH, it would take approximately 1 minute to reach correct information on board, however, with using the suggested interactive checklist method, system should automatically directs the required checklist steps according to the taken warning by FMS or any other information systems on cockpit. As an example of TCAS warning, system warns pilots to pull up, instead of automatically climbing aeroplane itself. Hence, pilots immediately request for climbing from Air Traffic Control (ATC) as a first step to avoid any accidents or incidents.

The benefits of using EFBs are imparted; such as, weight saving resulting from replacing the use of traditional flight bag. This situation reduces the staff's health problems caused by the weight of the bag, and also it reduces the fuel costs and maintenance costs by reducing costs. It also increases efficiency, reduces pilot workload, provides easy access when needed, generates situational awareness for pilots, automatic start and landing calculations etc. With these and many other similar benefits lead airline companies that want to increase the efficiency of their countries and reduce their costs have started to add EFB solutions to their fleet and provide institutional support for EFB projects.

2.2.2. Flight Data Monitoring (FDM)

It is an early warning system that analyzes the flight data to determine the possible risks and to take precautions for risks. The FDM system has several advantages; such as, increasing flight safety, reduce technical costs, eliminating the risk of accidents that may arise by detecting the training needs of pilots, contributing to the development of operations, increase the productivity of the flight operator etc. Recent Research (Bromfield, et al. 2016) has clarified that “FDM is recommended but not mandatory for aircrafts which are between 20 and 27 tones MTOW.” Figure 4 shows the scheme of Quick Access Recorder (QAR), Flight Data Recorder (FDR) and Flight Data Acquisition Unit (FDAU).

Figure 4: Flight Data Recorder and QAR Scheme



Source:http://craigmiddleton.co.uk/757/Biggles/www.crjresets.ca/zMcon/Hard2Find/B757/757_rr/flight_instruments/images/flight_data_recorder.gif, April 2017

To understand the purpose of FDM, the system is examined in three stages which are “Wireless Quick Access Recorder (WQAR)”, “Flight Data Recorder (FDR)” and “Analysis of FDM Data”.

2.2.2.1. Wireless Quick Access Recorder (WQAR)

QAR is placed on the aircraft and the data going to the Flight Data Recorder (FDR) along the flight is recorded in QAR in the same way. QAR records these data in the temporary storage unit called the media (Compact Flash Card, PCMCIA card, MO Disk). When the plane is at the end of the flight, these raw data are taken from the QAR or WQAR on the aircraft through the temporary storage unit called the media.

2.2.2.2. Flight Data Recorder (FDR)

FDR keeps track of more than ninety parameters for the last 25 hours, such as time, altitude, speed, direction, wing angle, which change continuously during flight. According to the records from the FDR, a model of the flight can be uncovered. Thus, the probable cause of the accident can be examined in more detail. A black box can be seen in Figure 5.

Figure 5: Flight Data Recorder Known as Black Box



Source: https://ukr.media/static/ba/aimg/2/0/7/207952_1.jpg, March, 2017

2.2.2.3. Analysis of FDM Data

This is the most crucial point in all this process. Analysis is carried out at this stage where raw data from FDR is processed and very useful results are obtained. As a result of the analysis made, events are displayed in report or graph format.

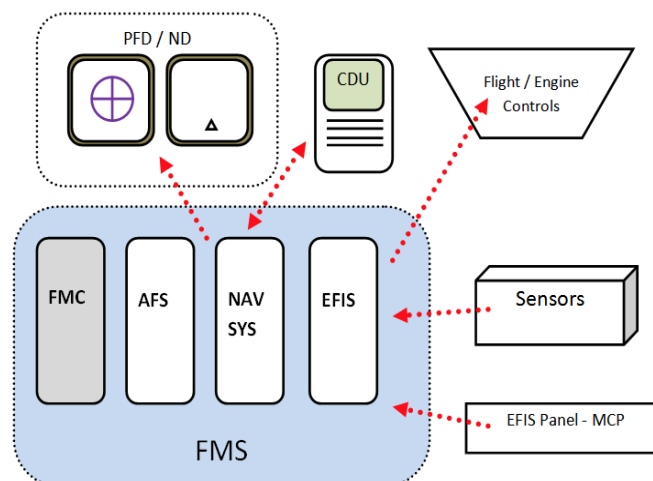
Two types of analysis can be done automatically or manually. Manual analysis management gives more detailed results when examining critical and emergency situations. Corendon Airlines prefers using AeroByte as FDM software to analyze flights in case of any critical event occurs.

2.2.3. Flight Management System (FMS)

A flight management system (FMS) is a core section of a latter day airliner's avionics. An FMS is a dedicated computer system that automates a huge amount of in-flight tasks, minimizing the workload on the flight crew to the note that up to date civilian aircrafts no longer fly with navigators or flight engineers.

An FMS consists of four main parts which are classified as The Flight Management Computer (FMC); The Automatic Flight Guidance System or The Automatic Flight Control (AFGS or AFCS); The Aircraft Navigation System; An Electronic Flight Instrument System (EFIS) or equivalent electromechanical instrumentation. The sample architecture of the FMS is illustrated at Figure 6.

Figure 6: FMS Architecture Overview



Source: <https://i.stack.imgur.com/jE1QI.png>, May, 2017

2.2.3.1 Electronic Flight Instrument Screen (EFIS)

Electronic Flight Instrument system provides the majority of navigation systems. EFIS control panels provide control of the system. These systems are booster electronic devices systems. In this system, the PFD (Primary Flight Display) and ND (Navigation Display) are indicators which are used to show the flight information to pilots and first-officers. EFIS is connected to EIDS (Electronic

instrument display system), which has 4 display and 2 control panel. This system contains EADI (Electronic Attitude Director), EHSI (Electronic Horizontal Situation Indicators), SG (EFIS Symbol Generators), EFIS Control panels, EFI Transfer Switch.

Left and right signal generators provide the video signals display for flying display units (CRT). The EFI transfer switch is responsible for operating aircraft by the pilots and first officer's EADI (Electronic Attitude Director) or EHSI (Electronic Horizontal Situation Indicators) from the left and right SGs (EFIS Symbol Generators) respectively or an SG full of four displays. Left and right symbol generators provide video signals for flying display units (CRTs). The brightness of CRT displays can be adjusted manually. Potentiometers on the EFIS control panel are used for this. The light sensors on the front of the display unit depend on the ambient light variation in the cockpit continuously adjusts the CRT brightness automatically.

Light sensors, which locates outside of the aircraft continuously adjusts the brightness automatically. Form T is used on all flights. Flight information is easily accessible on this page. EFIS systems is demonstrates at Figure 7.

Figure 7: EFIS Systems



Source:http://megep.meb.gov.tr/mte_program_modul/moduller_pdf/Alet%20Sistemleri%202.pdf page 38, June, 2017

2.2.4. Ground Proximity Warning System (GPWS)

It is a system on the airplane that warns when the pilot is in extraordinary dangerous situation. When airplane is lowered and the landing gears are forgotten to extend at a certain altitude, the system automatically warns to cabin crew.

The system automatically works when the altitude of the aircraft is below 2500 feet. The warning can be audible and illuminated. It is developed by way of radio altimeter; the GPWS device provides significant and vital convenience to the pilots on downhill, straight flight and departure when descending.

Its technical features are the same as the low altitude radio altimeter. If the plane is too close, it warns the flight crew. Pilots are visually warned with warning lights or messages on the primary flight display (PFD). Pilots are alerted through synthetic voices with “whoop whoop pull-up” sounds.

Moreover, pilots are alert by beginning from the aircraft flight automatically. Alarm sounds will be removed only by raising the aircraft. This situation gives a great guarantee for the aircraft safety. Ground Proximity Warning System comprises of radio altimeter, vertical speed, glideslope deviation, gear and flap positions.

2.2.4.1. Stages of the Warning GPWS

2.2.4.1.1. Excessive Sink Rate Situation

The crew is warned when the aircraft is descending below 2500 feet with high vertical speed. The audible warning and red GPWS lights up or PULL UP appears on the PFD. If the aircraft continues to descend in the same way, the aural alert turns into a warning with voice warning; such as, “whoop whoop pull up”. An alert or warning is interrupted when the dangerous situation is disappeared.

2.2.4.1.2. Excessive Terrain Closure Rate

When the aircraft is approaching the rising mountain, this situation is resulted that the altitude decreases rapidly. When the altitude decreases rapidly, it gives an alert. If the altitude continues to decrease, the aural alert turns into a “whoop whoop

pull up” voice. “Whoop whoop pull up” warning is interrupted when the dangerous situation is over.

The system warns to crew when the aircraft is at an altitude lost on departure. When the aircraft is at an altitude lost on departure, the audible warning 'do not sink' comes and the red lights are on. If the aircraft continues to dive, the audible warning turns into a "too low terrain". “Too low terrain” audible warning is interrupted when the dangerous situation is over.

2.2.5. Airborne Collision Avoidance System (ACAS)

ACAS is also known ACAS II and TCAS II. The term of ACAS II is exemplified the standards and structure. TCAS II term is representing the device application used. Both terms can be substituted for each other. ACAS is the only system developed to prevent collisions in the air, which is working as independent to ATC.

It is a system located on the airplane that provides pilots with aircraft equipped with SSR transponders and likely to live a conflict (traffic confluence). By means of aerial antennas, the TCAS interrogate the transponders of all ICAO standards. Based on obtaining information, the system calculates the altitude, slant range, bearing etc. The main and significant feature of ACAS is that it generates warnings according to time rather than distance. At the end of the inquisition’s results, it calculates the time to collision point in the traffic. This time value is the actual parameter of triggering ACAS excitations.

ACAS provides two types of advice to pilots which are Traffic Advisory-TA and Resolution Advisory-RA. According to the experience, it is seen that the RA reduces the risk of collision substantially when applied correctly.

2.2.5.1. Traffic Advisory-TA

It warns the pilot about other traffic and advice the pilot to be ready for potential avoidance. TA warns if there are other aircrafts that lead to dangerous condition which have active transponders. The use of "Traffic Advisory (TA) Only" mode is recommended and should be shown on published approach charts.

2.2.5.2. Resolution Advisory-RA

SSR altitude transponders recommend vertical level maneuvers for resolving conflicts of aircrafts. It provides to pilots the vertical avoidances. Videlicet, RA figure outs the threats and recommends vertical maneuvers.

There are two types of RA which are corrective RA and preventive RA. Corrective RA is the resolution advisory which advise the pilot to deviate from the current flight path. Preventive RA is an advisory to avoid certain deviations from current flight path however it does not change in current flight path.

2.2.5.3. Traffic Collision Avoidance System (TCAS)

Traffic Collision Avoidance System (TCAS) is a transponder altitude reporting equipped warning system which detects the problematic aircraft and establishes the level allocation. It has been developed to assist dependent air navigation devices. Aircrafts which have transponders without altitude information are identified in TCAS, but separation is not possible by the system. Airplanes are not identified if there is no transponder into the cockpit.

2.2.5.3.1. TCAS – Cooperation Systems

- Radio Altimeters,
- Flight Data Computer,
- Inertial Navigation System,
- Air / Ground sensor,
- Gear Status,
- GPWS,
- Windshear System,
- Auditory Warning System.

GPWS and Windshear prevent TCAS system to proceed an audible warning and left TCAS to stay only in “TA” position. The performance of the aircraft is not directly related to the TCAS.

2.2.5.3.2. TCAS Alert and Advisories

Traffic alert and collision avoidance system are systems operating with radar system independent of ground radar. There are two types of TCAS. TCAS-1 is used only for traffic accidents but it does not tell which side to aircraft needs to do maneuver.

Developed as the first anti-collision system in aviation, TCAS-1 only gives the traffic advice. Because of this reason, there would be new studies to develop current system. TCAS-2 system is an upgraded version of the TCAS-1. TCAS-2 warns about direction of the avoidance reaction which is mandatory to use for aircrafts in many parts of the world.

SECTION THREE

RESEARCH ON INTERACTIVE CHECKLIST

3.1. Purpose of the Research

Purpose of this research is to receive feedbacks from the employees (student pilot, captains, first officers, instructor, SMS manager, SMS specialist) who are in active duty at aviation industry to cover checklist usage; such as, limitations, benefits either in electronic or in hard copy format comparing to interactive checklist in cockpit. Interactive checklist is examined to analyze pilot's points of view and the limitations of the current models asked for the aviation safety. To minimize the human errors on flight safety, opinions of the experts (pilots) have been collected regarding to new model and analyzed for future interactions of the information systems inside the cockpit.

3.2. Scope of Research

The scope of this research is defined by the accidents analyses, interviews and questionnaires that were asked for employees of the aviation field who are also pilot and working as an airliner, instructor or safety specialist/manager. Scope is comprised of aviation industry, pilots, employees who are working at safety department, and customers. The majority of the interviews were done by Corendon Airlines; however there is one interviewee from the Freebird Airlines and two from Sunexpress Airlines as well.

The questionnaires were conducted by student pilots besides instructors, first officers and captains to understand how newbie pilots are assessing checklist usage. In surveys, the relationship between human errors and information systems in cockpit was examined and pros & cons of the current system were covered same as with the interviews.

Although cockpit environment has been enhanced by technology, accidents which involved checklists are encountered in April, 2017 last. Because of that reason, accident reports which contain checklist issues in 2017 have been inspected

on National Transport Safety Board's database. So that the accident ratio has been found that is related to the checklist in 2017.

Four global aircraft accidents which are including improper checklist usage in accident reports have been analyzed in terms of the interactive checklist and flight safety. Answer of the question of "Would interactive checklist be preventative in accidents" was highlighted. Three of the accident reports belong to airline companies and one of them is a business jet company.

3.3. Type of Research

In order to investigate the drawbacks of the actively using checklists and advantages of the interactive checklist model, four types have been applied to collect data which are defined as local accidents analyses in 2017 from NTSB's database, four detailed global accident reports analyses regarding to interactive checklist, interviews and questionnaires. Qualitative research methods have been preferred to collect and analyze responses rather (Patton 2005). Also, frequencies of interviews questions and surveys evaluated as quantitatively. Based upon the level of the respondents' agreement or disagreement, Likert Scale has been preferred to apply in this research. For instances, from 1 to 5, 1 is strongly disagree and 5 is strongly agree. Research surveys conducted via e-mail.

In local accidents analyses in 2017, as an analyzing method, a research was made in 2000 by Doolen T. and Nicolalde R. which is more or less identical to this research. However, there is no any other study in this field to take advantage of them.

For the four sample global accidents, the literature has been reviewed and some accidents have been selected which have share of checklist as an accident reason besides other factors into the reports. These accidents evaluated by interactive checklist perspective and the background of the accidents have been explained based on the accidents reports.

For the interviews and questionnaires, purposeful sampling method has been selected to reach for maximum variety of responses (Patton, 2002). In the interviewee list, there are 10 pilots who have an experience on Boeing, Airbus, instructor of light aircraft types and graduated pilots without type rating. Some of

them have secondary title on their workplaces; such as, SMS Manager, SMS Specialist, Chief Pilot, Training Coordinator, and Type Rating Instructor. In surveys also, attendants have variety of flight time experiences from 230 hours to 15.000 hours depending on the ages of the pilots.

3.4. Data Collection Method

Database filtering and inspection of the reports are the methods that have been used to define the accidents of the 2017 which were containing any clue considering on checklist issues. As a first step, all accidents filtered by the year “2017” and filtered by “checklist” word including into the accident report. As a result of this inquiry, reports have been inspected and evaluated if regarding accidents involved with “checklist” issue or not.

Database of the “Aviation Safety Network” was utilized as data collection source of the detailed analyses of the four accidents. Also, to reach the reports, Dutch Safety Board, Civil Aviation Accident and Incident Investigation Commission (CIAIAC) and NTSB reports was used as a main source of the analyses.

Interviews were planned as semi-structured question form and conducted individually with the managers, instructors and as well as pilots. Questions defined by support of the experts and total number diminished from 20 to 6 in case of time limitations, distraction and focusing on the main subject. 10 interviewees have been selected from wide range diversity that led to collect data from different point of views. An interview lasts approximately 45 minutes.

Questionnaires were planned as structured form and conducted via e-mail by 50 respondents. Surveys have been sent to 100 pilots however, 50 of them have replied back properly. 5 of the participants apologized and rejected to conduct a survey due to their time constraints. Rest of them did not reply back any response. Attendants were also reminded via telephone calling. Each conversation kept quite short which is 1-2 minutes. Addition to this, they were notified by e-mail twice.

3.5. Limitations of Research

It is plausible that a number of limitations might have influenced the results obtained. To begin with, it is really difficult to get an appointment with the pilots for interview. Pilot's flight time planning is irregular; the meetings did not carried out through the planned time. Besides, their flight plans were frequently revised. So, delays were occurred in meetings.

The analysis of the accidents in 2017 took quite long time than expected, due to listing so many accident reports. Each report contains huge amount of information. Some of accident or incident reports belong to 2017 has not been published which were not containing final edition and comments. Because of this reason, these reports were not taken into consideration.

Another arduousness of this research is reaching hundred pilots for survey, it was substantially uneasy to get feedbacks. Unfortunately, it was not possible to get responses from 100 pilots. Only 50 pilots were responded to questionnaire. Indeed, the pilots were get two evocative messages for completing the survey.

When the working ethics are considered, the names of the attendees have been kept as confidential in questionnaires. Some of the apprehension questions; such as, interview question 2 and questionnaire question 1 and 2 are obtaining personal experiences. This situation could lead bias errors in this research. Hence, the lists of the participants were shared but randomly ordered to prevent in order to conceal the owner of the answers in interviews.

In order to prepare the questionnaire and survey, it is consulted by the field experts (experienced pilots, airline managers, instructors). Although the more question has been decided to prepare for questionnaires and interviews, the number of questions are reduced due to time constraints of the pilots by experts.

3.6. Study

Study initiated with accidents investigations in 2017 which involves accidents or incidents resulting in checklist usage. Addition to this, four main accidents has been examined in details and evaluated in interactive checklist perspective. Interviews with the pilots and experts were analyzed considering on

interactive checklist to reinforce the field study. Lastly, questionnaires were conducted with 50 pilots who are working for airlines companies and pilot training organizations.

3.6.1. Accident Investigations in 2017

Based on the research in section 1.3, all accidents involving NTSB were scanned without any additional filter for a report in the year 2017. Lastly, on 3rd of June, 2017, 96 accidents or incidents have been reached.

“Checklist” keyword was applied as an additional filtering for these 96 accidents to identify which reports were including “checklist” word. The date was filtered from 1st of January 2017 to June 2017. There were 8 accidents/incidents reports listed as a result of these filtering. It was determined that 2 out of 8 accidents were directly related to the checklist from the obtained data. While relationship between checklist and accident reports was being determined, all 8 accident reports were read to clarify if the meaning of the keyword used appropriately as an erroneous usage of checklist. So, 2 of these reports found as an erroneous usage of checklist. Rest of the reports were including such as; “checklist completed successfully” or “pilots applied before landing checklist” which were not matching up with our purpose.

As a result of this research, reports were ordered as a table according to the findings which including the rows of the accident id, accident number, date, reason, phase of flight where error occurred ,synapsis of issue with checklist and description.

At the Table 11 and Table 12, accidents occurred which are related with the checklist in 2017 are shared.

At the Table 11 and 12, when data have been analyzed, it is seen that the first row is indicated as “Accident Id” to follow the order of the accidents better. ”Accident Number” is given in second row which lead readers to reach regarding accident via internet in details. At the third row accident date is defined as “Date”. At the row four, it is signified what kind of checklist fault was done or any checklist fault was occurred. It is expressed the accidents occurred in which phase at the row five. For instance, before landing, after landing, taxi or after takeoff are the possible values of that column. The sixth row is inferred the synopsis of issue with checklist which was taken from the accident analysis reports, to define relation between checklist and accident. And, the final row explains the description of accidents reports where the word of checklist is locating into the report.

Table 11: Accident Id 1 Occurred Related with the Checklist in 2017

Accident Id	1
Accident Number	GAA17CA197
Date	03/18/2017
Reason	Use of checklist - Pilot (Cause)
Phase of Flight Where Error Occurred	Before landing
Synopsis of Issue with Checklist	-
Description	The pilot stated that while at 400 ft. on a 1-mile final to runway 32 at FTY, a multiengine airplane was cleared onto the runway in front of him. This occurred at a point in the approach when the pilot normally would have completed his final pre-landing checklist/call-out, which consisted of checking the fuel, flaps for approach, landing gear down, and approach stabilized. The pilot also stated that the winds were "howling" with gusts to 25 knots. He stated that the other airplane on the runway was a "distraction" and that he did not "remember doing my usual call outs."

Source: NTSB, 2017

Table 12: Accident Id 2 Occurred Related with the Checklist in 2017

Accident Id	2
Accident Number	ERA17LA151
Date	04/07/2017
Reason	Checklist not followed
Phase of Flight Where Error Occurred	Before landing
Synopsis of Issue with Checklist	The pilot of the retractable-landing-gear airplane reported that, during the approach of a simulated 180° power-off landing, he became fixated on his touchdown point and did not complete the landing checklist. He added that he did not look outside to check that the main landing gear was down or to "confirm a green [landing gear position indicator] light." The airplane landed with the gear retracted.
Description	The pilot's failure to complete the landing checklist and to extend the landing gear before touchdown.

Source: NTSB, 2017

The rest of the accident reports that have been taken from the NTSB database which have been filtered as “checklists” keyword, have assessed as “not related with checklist usage”. Because of that reason, only the “Accident Number”, “date” and “Reason” columns have been shared in Table 13. The columns of “Phase of Flight”, “Synopsis of with Checklist” and “Description” were not included in Table 13.

Table 13: Accident Id from 3 to 8 not Caused by the Checklist Usage in 2017

Accident Id	Accident/Incident Number	Date	Reason
3	ERA17LA141	03/29/2017	Not Related with Checklist
4	ERA17LA134	03/21/2017	Not Related with Checklist
5	ENG17IA017	03/19/2017	Not Related with Checklist
6	ERA17LA125	03/08/2017	Not Related with Checklist
7	CEN17LA068	01/04/2017	Not Related with Checklist
8	WPR17LA049	01/02/2017	Not Related with Checklist

Source: NTSB, 2017

3.7. Detailed Analysis of Four Global Accidents

The common feature of the four selected global fatal accidents in this section is about the checklist. These four accidents were examined in detail, and each resulted in an additional result with the interactive checklist perspective. Accidents, report information, accident summary, accident history and checklist were analyzed in three main sections.

The flights were ordered by SQ006 on Singapore Airlines, the second Spanair JK5002, the third Gulfstream GIV-SP (Private Jet) and the last THY TK1951. No chronological order has been observed. Table 14 summarizes the data of accidents.

Table 14: Flight Numbers and Accident Codes of Four Accidents

Accident Name	Flight Number	Accident Code
Singapore Airlines	SQ006	AC-1
Spanair	JK5002	AC-2
Gulfstream GIV-SP	Private Jet	AC-3
Turkish Airlines	TK1951	AC-4

In Table 14, column 1 “Accident Name” indicates the company who crashed. Column 2 “Flight Number” indicates the number of flight to reach online information. Column 3 “Accident Code” represents accident as AC abbreviation.

Overall outcomes of this study are represented in “Findings” section which includes accidents resulting in checklists in 2017 recorded at NTSB Database, four sample global accidents, interviews and questionnaires.

3.7.1. Singapore Airlines SQ006 Taipei Accident Report - AC-1

As shown in Table 15, first row: event date and time, second row: company name, call sign and flight number, third row: aircraft type, fourth row: damage type, fifth row: phase of flight and sixth row: accident location. Besides, when the reader follows the accident, the accident column is used to extinguish the heading confusion to reader.

Table 15: Singapore Airlines SQ006 Accident Report

Event Date and Time	1997 - 15.17 (UTC)
Company / Call Sign / Flight Number	Singapore Airlines / SQ006 / 9V-SPK
Aircraft Type	Boeing 747-400
Damage Type	Complete Damage
Phase of Flight	Takeoff
Accident Location	Chiang Kai Shek International Airport-Taipei

Source: Aviation Safety Network Database, 2000

3.7.1.1. Summary of Accident - AC-1

Passenger aircraft belongs to Singapore Airlines, which is Boeing 747-400 type, V-SPK tail number and flight number SQ006. This passenger aircraft is collided with maintenance vehicles on the runway during departure at the off-traffic track on Chiang Kai Shek International Airport at maintenance time of 15:17 UTC and 23:17 Taipei local time. After collision, the plane became unserviceable.

In this accident, 4 cabin attendants and 79 passengers lost their lives. 4 cabin attendants and 35 passengers were seriously injured; first officer, 9 cabin attendants, and 22 passengers were slightly wounded. Captain pilot, third pilot and 22 passengers survived from accident without getting any injured.

3.7.1.2. Accident History - AC-1

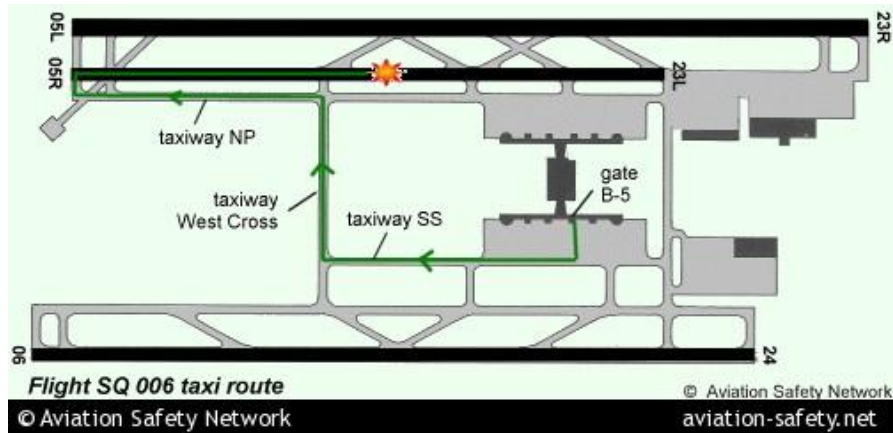
The NOTAM is issued by the Chinese Civil Aviation Authority on 31 December 2000. It indicates to flight team that the 05R route will be closed between 13 September 2000 and 22 November 2000. Also, the work maintenance on the N4

and N5 taxiways will continue in that time. According to NOTAM, track 05R was closed and could only be used as a taxiway.

At the time of the accident, in consequence of severe rain and strong winds are dominated the region because of "Xangsane" named typhoon. At Taipei local time 23:12:02, according to the information posted with ATIS, the view distance on the 05L track was 450 meters. At 23:15:22, the aircraft reached the departure permit SQ006 from tower, and the storm ran from 20 to 28 knots with reaching size 50 knots. The flight SQ006 is reached NP taxiway of the airport from B5 gate via west cross. It starts to move for reaching 05 L to cross 05R from N1 taxiway. All the cabin crew has necessary documents to follow this route. However, when they returned the aircraft from NP taxiway to N1 taxiway and continued to headway to 05R, no one from the crew noticed that they were not on the planned taxiway route. NP made a 90-degree turn from the taxiway and continued straight from the N1 taxiway, instead of going to 05L, a 180-degree turn was made to the 05R track.

Flight number of SQ006 aircraft needs to be passed 05R runway to continue 05L runway according to the planned taxiway route. However, the aircraft is entered to 05R runway and captain gave an instruction to takeoff (CM-1). The second pilot (CM-2) and third pilot (CM-3) did not ask any question for this decision and concede the captain pilot's decision. As a result, the SQ006 is terminated at the beginning of the 05 runway which was closed for maintenance. The representation of this route is analyzed as follows at Figure 8. Current designs of the aerodromes are not represented by any colors.

Figure 8: Flight SQ 006 Taxi Route



Source: <https://cdn.aviation-safety.net/photos/graphics/20001031-0-G-2.jpg>, (June, 2017)

After the departure clearance from the tower officers at the 23:16:44, the departure began to take action. The aircraft was collided with construction vehicles, which are located about 1 km away from the start of the runway at 23:17:16. At 2317: 36, the alarm was declared by tower officials.

A total of 83 people, including four cabin crew members, lost their lives due to the impact of the crash and fire after the collision. Captain pilot and third pilot were saved without any injury, the second (assistant) pilot was evaded as a minor injured.

3.7.1.3. Checklist Perspective Analysis - AC-1

About Singapore Airlines accident, there are seriously mistakes have been made by the whole crew called as human factor in accident. Firstly, they did not cross-check the runway in use. Also, the first officer and captain did not initiate the standard callouts considering on exact runway before takeoff intention. However, we have an opportunity to minimize human factors on accidents or incidents with the technological enhancements. Concept of the interactive checklist systems, may also offer to receive NOTAMs and represent it on the electronic map that includes which runway is closed or information about active runway.

Furthermore, in the simplest way, it could possible in future to show taxiways in a different color to warn pilots on the electronic screens even if a runway or a taxiway is under construction. In Figure 8 above, runway 05R may be highlighted in red color as an indication of closed runway. It could also be preventative option to land on closed runways in uncontrolled airspaces considering on the training aircrafts for candidate pilots such as Cessna-172.

3.7.2. Spanair JKK 5022 Madrid Accident Report- AC-2

Table 16: Spanair JKK5022 Accident Report

Event Date and Time	20.08.2008- 14.24 (UTC)
Company / Flight Number / Call Sign	Spanair / JKK5022/ EC-HFP
Aircraft Type	McDonnell Douglas DC 9-82 (MD-82)
Damage Type	Destroyed
Phase of Flight	Takeoff – Takeoff Run
Accident Location	Madrid-Barajas Airport (MAD/LEMD), Spain

Source: CIAIAC, 2008

3.7.2.1. Summary of Accident - AC-2

An MD-82 passenger plane, registered EC-HFP, commenced to takeoff from Madrid-Barajas Airport. After reaching the rotate speed (V_r), PIC rotated airplane and stall warning immediately heard by crew. In a minute aircraft was destroyed on takeoff at Madrid-Barajas Airport (MAD), Spain. As a result of that accident, 154 people were killed, including all six crew members, and 18 were seriously injured.

3.7.2.2. Accident History of - AC-2

The MD-82 aircraft operated Spanair flight JKK5022 from Madrid-Barajas (MAD) to Gran Canaria (LPA). The estimated departure time was 13:00 pm.

Engine start-up clearance was given to the aircraft at 13:06:15. Then they taxied to runway 36L from parking stand T21. On the runway threshold, crew realized that the flaps were extended 11°. Because of that reason, pilots decided to cancel takeoff and requested to taxi back to the mechanics.

An overheating Ram Air Temperature (RAT) probe had been detected by the flight crew. A malfunction was confirmed by technician and RAT heating section of the Minimum Equipment probe was checked and opened the electrical circuit breaker that connected the heating element. When the necessary changes applied successfully, aircraft was commenced to dispatch.

3.7.2.3. Checklist Perspective Analysis - AC-2

According to the accident reports of NTSB, it is mentioned that the crew did not identify the stall warnings and did not apply appropriate callouts after takeoff. They did not proceed the stall maneuver properly. Then allow aircraft to deterioration of stall condition.

- Addition to this, crew did not initiate after start checklists correctly selecting flaps/slats for takeoff.
- They also did not cross check the related “after start checklist” item which is “check position of the lever or status of flaps/slats.
- Moreover, they neglected the check flaps/slats during the takeoff briefing and also “taxi” checklist.
- At the takeoff imminent checklist “Final Item”, current settings of the flaps/slats were not verified by the crew.

The Spanair accident shows again that the necessity of the interactive checklist usage in the cockpit. Interactions between cockpit systems and interactive checklist, current position of the flaps/slats could have checked by the system automatically. It provides to check flaps/slats position more than three times in after start checklist, takeoff briefing and takeoff imminent phases respectively.

Hence, human factor which has the biggest effect on the accidents may be minimized or even avoided for these kinds of mistakes and fatal accidents by integrating an interactive checklist on board.

3.7.3. GIV-SP Bedford, MA - AC-3

Table 17: Gulfstream-IV N121JM Accident Report

Event Date and Time	31.05.2014 - 21.40 (UTC)
Company / Flight Number / Call Sign	SK Travel, LLC / Business Jet / N121JM
Aircraft Type	Gulfstream G-IV
Damage Type	Destroyed
Phase of Flight	Takeoff – Takeoff Run
Accident Location	Bedford, MA

Source: NTSB, 2014

3.7.3.1. Summary of Accident - AC-3

A Gulfstream Aerospace Corporation G-IV, N121JM, registered to SK Travel, LLC. It had an accident after the end of runway 11 overran intention of a rejected takeoff at Laurence G. Hanscom Field in Bedford on May 31, 2014 around 2140 UTC.

The aircraft request departure by using the paved runway and it passed over a grassy area. Collision came true with approach lights and a navigational antenna of airport which is used by localizer. After that, aircraft cross over the airport's fence, and stopped in a mountain pass. As a result of the accident the two pilots, a flight attendant, and four passengers died. Also, the airplane was destroyed and burned after collision. The business flight was planned as a route for Atlantic City International Airport. It was conducted under the provisions of 14 Code of Federal Regulations (CFR) Part 91. Flight plan was filled as an instrument flight instead of visual flight. Night visual meteorological conditions were observed.

3.7.3.2. Accident History - AC-3

The flight crew neglected to deactivate the gust lock system which locks the elevator, the ailerons and rudder on parking position on engine starting phase. Gust lock is engaged to protect aircraft in case of a strong wind on parking position.

Pilots did not follow the checklist items of “before takeoff checklist”. Before takeoff checklist includes “locked flight checks” which is controlling gust lock system. According to the NTSB’s accident report, aircraft's QAR also shown that the pilots did not apply complete flight check before 98% of the total 175 flights.

During takeoff, the pilot-in-command (PIC) manually took forward the throttle levers, but the engine pressure ratio (EPR) did not reach the expected level due to the throttles touching the gust lock. The PIC did not quickly take a decision to reject the takeoff. Moreover, autothrottle was activated by PIC and riched throttle levers to keep an EPR value that approaching the expected setting.

The standard takeoff speed callouts were made by the second-in-command as the speed indicator at 80 knots. Rejected Takeoff Decision Speed (V1), and rotation speed (Vr) as the takeoff roll commenced. While rotating of the aeroplane was initiated by the PIC, pilot realized that the yoke could not move. Immediately, PIC was calling out “(steer) lock is on.” But, rejected takeoff procedure was not initiated. If the flight crew had intention of rejected takeoff at the first “lock is on” announcement the airplane could have been survived on the paved field. The extension of runway area used for rejected takeoff. However, 10 seconds postponed braking action followed by delayed taking throttle lever back as an additional 4 seconds; therefore, accident was irrepressible due to the rejected takeoff was not initiated on time.

3.7.3.3. Checklist Perspective Analysis -AC-3

A series of mistakes made by pilots contains omitted checklist and delayed decisions. Two primary faults led airplane to overrun the runway. Firstly the flight crew members skipped the gust lock item from the takeoff checklist. However, it was an essential process for starting engine. Moreover, flight crew did not check the

flight control just before the lining up and departure at the holding point. With integrating the interactive checklist system, this fatal accident could have prevented by warnings and checklist steps on the both pilots. Even if they forgot the gust lock off position before engine starting process, they would have warned by the electronic system to proceed necessary steps on the holding point. For example, a red warning illuminates on the screen of the interactive checklist and it forces pilots to take action on regarding checklist step before takeoff.

3.7.4. THY TK1951 Amsterdam - AC-4

Table 18: Turkish Airlines TK1951 Accident Report

Event Date and Time	25.02.2009- 09.26 (UTC)
Company / Flight Number / Call Sign	Turkish Airlines / TK1951 / TC-JGE
Aircraft Type	Boeing 737-8F2
Damage Type	Destroyed
Phase of Flight	Landing
Accident Location	Amsterdam-Schiphol International Airport (AMS/EHAM), Netherlands

Source: Dutch Safety Board (2009)

3.7.4.1. Summary of Accident - AC-4

Turkish Airlines flight was departed at 08:22 from Ataturk Airport on 25th November 2009, which is named "Tekirdağ" and numbered 1951. It crashed while landing phase at Amsterdam Schipol Airport.

The autopilot and the pilots did not notice that it was a radio alarm error. The autothrottle continued to cut the gas. As a result of this, Aircraft was stalled. Pilots' rescue maneuvers could not prevent this accident. This accident which is resulted to 9 people lost their lives.

In the report is clearly clarified that the checklist was also recorded as an essential factor. From the analysis of this accident, it is clearly see that the check-list control is mandatory.

3.7.4.2. Accident History - AC-4

There are two radio wave altimeters, which are also known as radio altimeters on the airplanes. These radio altimeters work with radio waves. As a concept, these instruments send signals from the far end and determine the height of the aircraft according to the speed of the signals from the ground.

One of these altimeters is located on the captain pilot's side, the other one is situated on the second pilot side. There is also a separate altimeter operating on air pressure on both sides. The radio altimeter is only connected to the automatic landing system on the pilot side. In other words, the autopilot automatically cuts off the aircraft's speed using this altimeter.

The craft has two instruments operating on the same principle in the aircraft, it does not use this algorithm, which compares and verifies the results of the two instruments. The Boeing company is used an algorithm, which is based on the data from one subset.

During the accident, the pilot side altimeter incorrectly shows '-8' value, which was caused cut in the auto-throttle to slow down the aircraft as an outcome of analyzed faulty value.

Although the height value is '-8', the computer continues to process. As the aircraft is approach the runway, autothrottle continues to cut the gas and the speed is set below the critical limit. While the pilot realized the gauge indications, the airplane started stalling through losing speed swiftly. Despite the rescue maneuver, the plane crashed because it was too close to the ground.

3.7.4.3. Checklist Perspective Analysis -AC-4

According to the Dutch Safety Board accident report, pilots were doing landing operations while the non-stabilized approach was proceeding and stick

shaker started shaking. At the same time, workload of the crew was rising gradually. Due to the Standard Operating Procedures of THY, a series of attribute should be considered at the altitude of 1000 feet in low visibility conditions. Mentioned altitude was checked by flight deck and go-around decision would have been taken already. Go-around also did not initiated by crew while passing 500 feet announcement and also landing checklist had not yet been completed even.

If the interactive checklist were on this plane, pilots would be able to follow the before landing checklist more effectively. Pilots must check the current distance from the approach chart and the reading the instant position relative to the distance during the landing phase. However, according to the report, this step has been omitted by flight crew. If an electronic warning system were integrated and active on board, there would have been no situational awareness. In addition, it was shown with digital screens and warning lights that the aircraft had to proceed a go-around procedure while the aircraft was flying below the glideslope. So instead of waiting for a bad scenario to do rescue maneuver, a go-around decision could be taken immediately in accordance with the procedures.

3.8. Interview with the Pilots

This subject contains the interview questions and analysis of the given answers by 10 interviewees. Those 10 people are all pilots and working for Airline Companies in Turkey; such as, Corendon Airlines, Freebird Airlines and Sunexpress Airlines. The attendants were selected according to their flight experiences as pilots, instructor pilots, pilots responsible from the training department or other type rated captain than Boeing 737 for instance Airbus 320.

The interview includes 6 questions which were degraded from the 20 questions advised by the experienced pilots, a safety specialist in aviation industry to cover requirements and analysis of the checklist usage in details. Before preparing the questions, early negotiations were begun with the SMS department and draft questions were sent by e-mail to the responsible employee. Scope and number of the questions were discussed by telephone conversations two times. Duration of the

interviews last about 30-45 minutes and took place at the Antalya, Corendon Airlines working place for the staff of Corendon Airlines. Rest of the interviews was completed at suitable locations and times by taking into account the flight plans of the pilots.

Due to sensitivity of the question number 2 by taking into consideration of flight carrier of the interviewees, the names of the participants have been kept confidential. Hence, given answers for the second question were observed objectively and prevented to have any false statements. Given data have been ordered from 1 to 10 randomly. There is no relationship between the pilot's hierarchy and the list of the participants below. List of the attendees is demonstrated in the Table 19.

Table 19: The Interviewee List

Name	Job	Position	Experience
Erezan SEZGİN	Pilot	Chief Pilot(Boeing 737)	15.000 hrs.
Leyal SEMERCİ	Pilot	Captain(Airbus320)	6.000 hrs.
Selami Selçuk ÇAKMAKLI	Pilot and SMS Manager	SMS Manager	3.000 hrs.
Ahmet ÖZKAN	Pilot	Training Manager(Boeing 737)	15.000 hrs.
Nazır BAŞARA	Pilot	First Officer(Boeing 737)	2.500 hrs.
Uluç SEMERCİ	Pilot	First Officer(Boeing 737)	3.000 hrs.
Tolga ŞAHİN	Pilot	First Officer(Boeing 737)	3.200 hrs.

Name	Job	Position	Experience
Ümit DEMİRCAN	Pilot/SMS	SMS Specialist, Non-Type Rated Pilot	230 hrs.
Nedim ÇAKIR	Pilot/Instructor	Captain (Boeing 737)	12.000 hrs.
Fatih ÇALIŞKAN	Pilot	First Officer(Boeing 737)	500 hrs.

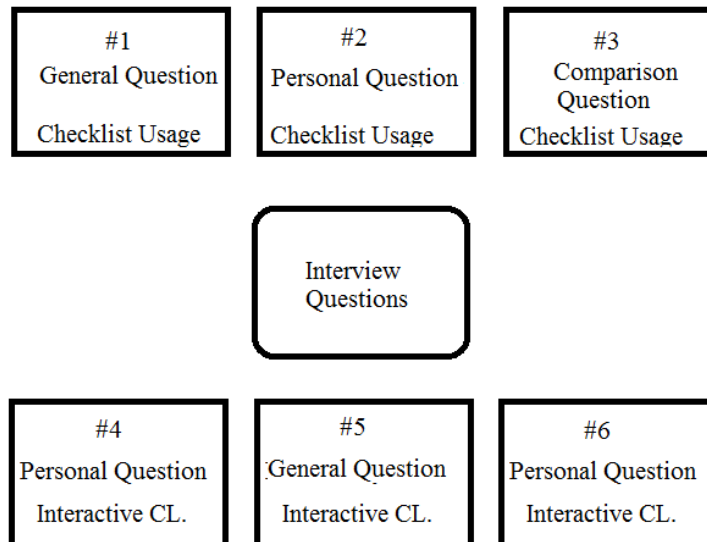
3.8.1. Interview Questions

The questions which were asked during the interview and responses given below from Interview-1 to Interview-10 ordered in randomly to protect confidential information considering on participant's flight career.

Interviews have been initiated after a brief explanation about interactive checklist and purpose of the thesis. So, it took approximately 45 minutes to complete each of them. Questions and given answers of the interviews are clarified one by one in sections starting from 3.8.1.1.

Questions were designed and shown at Figure 9.

Figure 9: Content of Interview Questions



Note: CL indicates “checklist”. In Figure 9, Question numbers from 1 to 3 highlights the questions regarding to general checklist usage, questions numbers from 4 to 6 are related with the concept of interactive checklist.

3.8.1.1. Questions of Checklist Usage

3.8.1.1.1. Reasons for Partially Completion of Checklists

Question-1

In 2017, 2 of the 10 total accidents/incidents filtered out on the checklist according to the National Transport Safety Board (NTSB) were resulting in direct checklist usage error. For which reason, a pilot does not apply or complete partially the checklist?

Q1 - Interview-1

I think that human factors which are caused by time pressure, fatigue, and stress lead to not using the checklist properly are the most important sources for a pilot in flight.

Q1 - Interview-2

Reduced situational awareness of the pilot due to fatigue, time pressure, etc. may cause errors or violations in the use of the resulting checklist. In addition, routines created by commonly used checklist items can lead to an issue of the pilot's perception as well. Frequently used and recurring items also cause pilots to have a negative conception of the appropriate behavior in CRM called "Habit & Expectation".

Q1 - Interview-3

Flight operation is a process that many departments participate in and which should be realized in a specified time. The human factor is the most basic reason for deviating procedures in flight operations. Often, there is a race against time, and at the same time the safety must be kept on the front line in all activities. Aviation is based on a perception of perfection that is strict rules. This understanding creates difficulties for flight staff in time management at first. To do too many works in a short period of time can lead to staff faults and even violations. I think that human factors are formed by the time pressure under not using the checklist which is one of the most important sources in flight for a pilot.

Q1 - Interview-4

I think that human factors are caused by excessive self-confidence, fatigue, lack of CRM and indiscipline under the fact that the neglected using checklist or proceeding steps in checklists not properly.

Q1 - Interview-5

I think that human factors are caused by excessive self-confidence and fatigue under the condition that a pilot does not use the checklist which is one of the most important sources to use in flight. Another factor is that the correct and up-to-date checklist sometimes may not available on board. So if an out-of-date checklist is on board, it is really difficult for a pilot to notice it. Therefore, it is possible to prepare for unsafe incidents/accidents caused by using the wrong checklist.

Q1 - Interview-6

I think that human factors are caused by time pressure and fatigue under the fact that the pilot does not use the checklist which is one of the most important sources to use for a pilot in flight.

Q1 - Interview-7

I think that human factors are caused by time pressure and lack of CRM competencies in using the checklist which is one of the most important sources to use for a pilot in flight.

Q1 - Interview-8

I think the workload and CRM issues are caused to checklist error in usage. Fatigue and stress can also negatively affect cockpit performance of the pilots.

Q1 - Interview-9

In my opinion, human factors and out-of-updated checklists on board are caused that kind of mistakes in flight.

Q1 - Interview-10

In my opinion, rush is a major factor of omitting checklist usage. Just before the landing, around 1500 feet, checklist must be requested and checked in order to reach at 1000 feet smoothly. But, in some conditions such as, traffic, runway change or emergency situations the workload of pilots excessively go up. In this case, checklist item mistakes could be occurred.

3.8.1.1.1. Analysis of Partially Checklist Usage Factors

In question-1, the reason of the wrong usage or neglected to use of checklist were inquired. Generally, participants point out the human factors as a cause of checklist issue; such as, fatigue, time pressure, stress, routine jobs and CRM. Addition to these, in interview-5 explains that the issue of not up-to-date checklists in cockpit. Latest version of the hard copy and electronic checklists should be double checked before every flight by company staff and pilots. The most distinct answer is including the term of indiscipline which was indicated in interview-4. The term of indiscipline may lead to over self-confident feeling for a pilot, which also found the reason of checklist issue.

3.8.1.1.2. Incident or Accident Resulting in Checklist Usage

Question-2

Have you ever encountered with any checklist issue (missing step, incorrect checklist)? And, have you ever experienced an incident or accident about the use of a missing steps, or incorrect checklist?

Q2 - Interview-1

No. Since I know the importance of using a checklist, I have not used the checklist in a way that is never appropriate.

Q2 - Interview-2

Yes. I made mistakes in using the checklist because I was affected by the factors, which I just mentioned in question one. I have experienced in not using checklists because those steps were not critical. For example, there are interrelated items in the "Before Taxi" and "Before Takeoff" checklists used at each flight. According to the Before Taxi checklist, SET flaps 5 are required. At "Before Takeoff" checklists, it is necessary to check that the flaps 5 is "CHECK" which means pilots already have checked each other. If you do not set the flaps 5 during the Before Taxi Checklist, you may think that flaps already SET on "Before Taxi" so while ticking the "Before Takeoff Checklist", necessary flaps setting step may be neglected incorrectly by flight crew.

Q2 - Interview-3

No. I did not use the checklist in a way that would be inappropriate for knowing the importance of using a checklist.

Q2 - Interview-4

Yes. I was affected by the factors I just mentioned and did not use the checklist properly.

Q2 - Interview-5

I have never experienced such an event on my actual flights. But I met this situation in simulator flights.

Q2 - Interview-6

I have flights that sometimes I cannot use the checklist correctly because I have to takeoff early on flights which have short ground times.

Q2 - Interview-7

Yes. In some flights I used the correct checklist without being sure of the required controls because of the reason that sourced from CRM.

Q2 - Interview-8

Yes I used checklist not properly once, but there was no any incident and accident occurred.

Q2 - Interview-9

Yes. I have not used checklist properly in my flight once due to fatigue. I have forgotten to switch off the fuel pumps in my training flight. Fortunately, there was no any accident or incident happen. I realized my mistake while ticking off the approach checklist which should be switched on. However, I already switched the fuel pump on position.

Q2 - Interview-10

Yes, I have once experienced to use checklist incorrectly during my flight. I was flying as PIC, and forgot to check settings of the NAV1 and NAV2. Accidentally, I set the frequency of NAV1 to NAV2. After couple of minutes later, I realized that we were deviating from our route. Immediately, frequencies were changed without any accident occurred.

3.8.1.1.2.1. Analysis of Incident Accident Resulting in Checklist Usage

In question 2, we have 7 out of 10 pilots who involved missing steps of checklists during their flight operations. The reason why they did not apply properly use of checklist was time pressure, CRM and routine tasks. However, there is no any accident/incident recorded due to checklist usage issue. One of the participants also gave an example who involved in neglected usage of checklist during the simulator sessions instead of real flight. In my opinion, creating checklist scenarios during the simulator sessions could be practically great options for the pilots.

3.8.1.1.3. Comparison of Hard Copy and Electronic Checklist

Question-3

Would you compare the Electronic Checklist and Hard Copy Checklist in terms of time, practicality, correct data, mistakes, safety on board?

Q3 - Interview-1

The electronic checklist is easier to reach than the hardcopy checklist, but human factors are the main factor in proper use of the checklist. This means that making the checklist electronically will not be sufficient for the wrong use of the checklist.

Q3 - Interview-2

In my opinion, the hardcopy checklist is easier to use. Because, accessing data in hard copy format is easier than searching in checklist with EFB. Some checklists are even locating on the yoke. There is no need to do anything else to access it. It is more complicated to leave the current page on the EFB and enter the checklist page and search there. In either case, the pilot should already know where the correct checklist is in the quick reference handbook on board.

Q3 - Interview-3

The electronic checklist is easier to reach than the hardcopy checklist, but human factors are the main factor in proper use of the checklist. This means that the electronic checklist will not be sufficient to prevent erroneous usage of the checklist by itself.

Q3 - Interview-4

The electronic checklist has more benefits in these parameters than the hardcopy checklist. Nevertheless, human factors are the main factor in proper use of the checklist. This means that changing the checklist electronically will not be sufficient for the wrong use of the checklist.

Q3 - Interview-5

The electronic checklist is more advantageous than the hardcopy checklist. Nevertheless, human factors are the main factor in proper use of the checklist. This means that the electronic checklist will not be sufficient to prevent the missing use of the checklist.

Q3 - Interview-6

The electronic checklist is easier to reach than the hardcopy checklist, but human factors are the main factor in proper use of the checklist. This means that making the checklist electronically will not be sufficient for the wrong use of the checklist.

Q3 - Interview-7

I think hardcopy for normal checklists and electronic checklist for abnormal checklists are more useful.

Q3 - Interview-8

I think electronic checklist is easier to find any emergency procedures comparing to the hard copy checklist.

Q3 - Interview-9

In my opinion, electronic checklist is more comfortable in terms of accessing information and easy to carry with you. You can also check information anytime and anywhere.

Q3 - Interview-10

I think electronic checklist is more efficient to use in cockpit for emergency situations and in larger aircrafts other than training aeroplanes. For example, using hardcopy checklist in single engine piston aircraft needs less time to check avionics during normal and abnormal conditions due to having less workload when comparing to complex Airbus transport aircraft.

3.8.1.1.3.1. Analysis of “Comparison of Electronic and Hard Copy Checklist”

In question 3, there are 8 pilots answered as electronic checklist is better to use as a result of the comparison of hardcopy and electronic checklist models. 1 pilot claimed that reaching information is more comfortable and easy with the hardcopy method. And 1 is mentioned that he/she prefers electronic checklists in an emergency situation, however, traditional checklist is preferred in normal checklists conditions.

As a significant result of the question three clarifies that, electronic checklist is also not sufficient to prevent accidents/incidents due to issued human factors.

3.8.1.2. Questions of Interactive Checklist

3.8.1.2.1. Interactive Checklist Contributions in Aviation Safety

Question-4

How does the interactive checklist affect you? What are your thoughts on contributing in terms of aviation safety?

Q4 - Interview-1

An interactive checklist is an important factor in reducing and preventing accidents and incidents from human factors. Therefore, it will contribute to aviation safety.

Q4 - Interview-2

The use of an interactive checklist will bring tremendous benefits to aviation. Interactive checklist, comparing to electronic checklist and hardcopy checklist, will be a much more useful application. Of course I think it will be an important factor in reducing and preventing accidents and incidents from human factors. Hence, it will make a great contribution to aviation safety.

Q4 - Interview-3

The interactive checklist is of course an important factor in reducing and preventing accidents and incidents from human factors. Therefore, it will contribute to aviation safety. At present, Airbus aircrafts use that kind of system, and as a pilot I can say that pilot's workload is significantly reduced, and also it is reducing the risk of making mistakes.

Q4 - Interview-4

It is an important factor contributing to aviation safety

Q4 - Interview-5

I think it will make a great contribution to aviation safety.

Q4 - Interview-6

The interactive checklist can, of course, be an important factor in reducing and preventing accidents and incidents from human factors. I think this checklist will contribute positively to aviation safety.

Q4 - Interview-7

The interactive checklist can, of course, be an important factor in reducing and preventing accidents and incidents from human factors. Therefore, it will contribute to aviation safety.

Q4 - Interview-8

It seems that it is going to be a terrific support for us on board. These requisite systems may decrease the workload of us and forestall human factors regarding to checklist issues.

Q4 - Interview-9

I think aviation safety is provided by interactive checklist in cockpit.

Q4 - Interview-10

In my opinion, an interactive checklist in cockpit can be an essential upgrade for aviation safety which needs to be followed by pilots.

3.8.1.2.1.1. Analysis Interactive Checklist Contributions

In terms of the specifications of the interactive checklist, all 10 participants agreed on the contribution of the interactive checklist on aviation safety. The most remarkable inference of the question-4 is all of the light aircraft instructors and also Boeing 737 type rated pilots would like to see that technology on board. However, one interviewee indicates that he/she has experience on new generation checklist model inside the Airbus cockpit.

3.8.1.2.2. Interactive Checklist as a Preventative Method

Question-5

Could the use of an interactive checklist be a method to prevent accidents and incidents originating from the checklist in the world?

Q5 - Interview-1

An interactive checklist is an important factor in reducing and preventing accidents and incidents from human factors.

Q5 - Interview-2

Yes it could be a method to prevent accidents and incidents resulting from checklist.

Q5 - Interview-3

I think it could be a great option to prevent accidents and incidents which are sourced of checklist usage problems.

Q5 - Interview-4

Yes. It would reduce the accidents and incidents originating from the checklist usage.

Q5 - Interview-5

Of course, it may minimize the accidents and incidents and prevent using wrong checklist on board.

Q5 - Interview-6

The interactive checklist can decrease the accidents and incidents resulting from human factors.

Q5 - Interview-7

Exactly, it can prevent the human sourced errors much more than the use of traditional checklists.

Q5 - Interview-8

There is no doubt that it is going to minimize the human factors related accidents which are caused by checklist usage failure.

Q5 - Interview-9

Of course these features are going to decrease the human errors regarding to checklist failures. It is going to be an additional cross check for the pilots besides traditional checklists during flight. So, it is a preventative method for the accidents or incidents which are originating from checklist issues.

Q5 - Interview-10

Due to the support of the interactive checklist, it can minimize the human factors related with the checklist issues which cause accidents or incidents.

3.8.1.2.2.1. Analysis of Interactive Checklist as a Preventative Method

According to the prevention of accidents and incidents originating from checklists, all 10 participants explained that interactive checklist implementation can be an advantageous method. There is no any distinct response to highlight specifically. However, results show that pilots need some reliable improvements on cockpit which are related to interactive checklist.

3.8.1.2.3. Design of Interactive Checklist

Question-6

In this design, do you think the interactions between interactive checklist, FMS, EFB and such cockpit information systems are sufficient? Or, do you have any contribution?

Q6 - Interview-1

Since I don't have any experience such checklist before, I cannot explain the systems additional requirements. However, I can clearly say that it would be quite advantageous for us on board.

Q6 - Interview-2

I do not have any idea about the relation between these systems. It seems applicable on cockpit.

Q6 - Interview-3

There are 23 computers on Airbus aircraft, and one of them is only working for interactive checklist. Communication between FMS and EFB warn pilots not to do any mistake because of the reason checklist usage. Thus, erroneous steps are minimized. Today, the architecture seems satisfactory, however, with respect to the new technology, some minor fallacies would be de updated.

Q6 - Interview-4

FMS and EFB interactions here decrease our workloads in flights. It seems sufficient due to not having experience on this kind of technology in flight operations.

Q6 - Interview-5

Unfortunately, we have not met interactive checklist yet. I cannot say additional system improvements. Thus, pilots would be adapted interactive checklist as soon as possible.

Q6 - Interview-6

According to the given information about the interactive checklist, I would like to say that it will be a terrific idea to use in cockpit. I cannot tell any specific information about the new system since I do not have chance to test a system like interactive checklist yet.

Q6 - Interview-7

Since we do not have an interactive checklist on our planes, I cannot comment on the interaction with the aircraft systems. However, I think that such an application will be very useful for pilots.

Q6 - Interview-8

We have tablets on training aircrafts to provide real-time weather, traffic, pattern, fuel calculation information. But, we don't have any system which can communicate with the aeroplane's systems and pilots. It would be an amazing opportunity for us to teach as well as for our students. I believe that these improvements will be integrated in our aircrafts in very short time period.

Q6 - Interview-9

I would like to share my opinions. We were memorizing the checklists which belonged to our light aircrafts since our instructors were asking us to say the steps of the checklist. For example, we were beginning the steps of the before taxi checklist or after takeoff checklist. Then, with the bigger types, checklist steps were tripled and our responsibilities also increased evenly. Now, we need such technologies to avoid basic mistakes during our flights. To increase the aviation safety, I think, that kind of implementations will be on board soon.

Q6 - Interview-10

I did not hear about interactive checklist before. But I can say that the interactions between cockpit systems seem sufficient initially. According to the test results and feedbacks from the pilots, system can be revised and integrated in our cockpits as a new generation checklist model.

3.8.1.2.3.1. Analysis of “Design of Interactive Checklist”

In terms of interactions between interactive checklist and FMS, EFB and other information systems have taken into account, it has been asked to the pilots to cover interactive checklist. However, 9 of 10 of the interviewees responded as they have never attempted to fly with that kind of interactive model before. So, additional information could not have been received by them. However, all pilots are agog as they waiting such a system on board. Only a pilot, who has Airbus 320 type rating, suggested that minor updates would be sufficient as future improvements of current systems on Airbus aircrafts as an interactive checklist model.

3.8.2. Analysis of the Interviews

Analysis of interviews was discussed separately under the regarding questions. Hence, the total outcomes based on the analyzed answers were covered in this subject to explain the results of the interview. Table 20 summarizes the findings of the interview.

Table 20: Outcomes of the Interviews

Common Checklist Usage Errors	Fatigue, Stress, CRM, Time Pressure, Routine Jobs, Over Confidence, Indiscipline.
Number of Pilots Involved Checklist Usage Errors	7/10
Number of Pilots Preferred Electronic Checklist to Hard Copy Checklist	8/10
Number of Pilots Preferred Interactive Checklist to Minimize Human Errors	10/10

Fatigue, stress, time pressure and CRM issues are indicated as common checklist usage errors as responses of the interview. However, the attributes which are routine jobs, over confidence and indiscipline are also included to the table despite of not being frequent answer but pointing possible outcomes. Second row, “Number of Pilots Involved Checklist Usage Errors”, describes the attendees’ responses if they experienced any checklist miss use or neglected to use events. So, the answer 7/10 clearly shows that more than %50 of the respondents has some checklist failures during their flight operations as explained in face-to-face conversations. In the “Number of Pilots Preferred Electronic Checklist to Hard Copy Checklist” row, 8/10 of the all attendants claimed that electronic checklist has more advantageous in cockpit in terms of time efficiency, quick access to data and paperless cockpit. The last row of the Summary of the Interviews table demonstrates

that 100% of the respondents accept the interactive checklist as a preventative method for accidents and efficient improvement which can decrease the human factors regarding to use of checklist.

3.9. Questionnaire for Pilots

The purpose of this study is to discover the general opinion of the effects of traditional and interactive checklists in terms of aviation safety. To identify a model of checklist which named as interactive checklist, there are 50 surveys applied which includes 10 questions. Respondents have selected by their positions; such as, working as flight instructor pilots, airline pilots and also one examiner. According to the received responses, further analysis also can be found at sections starting from 3.9.1. Same with the interview section, due to sensitivity of the questions number; 1, 2, 3, personal information of respondents were kept confidential.

Basically questions are classified in three parts which are “General Checklist Usage”, “Hard Copy Checklists” and “Interactive Checklists”. Likert scale has been preferred instead of asking a simple yes/no question. “Strongly Disagree” and “Strongly Agree” are represented by 1 and 2 respectively. Survey can be seen in Table 21.

Table 21: Questionnaire for Pilots

Sections	Opinions
General Checklist Usage	1- According to the statistics of "NTSB, June 2017", it is found that 2% of the accidents and incidents in 2017 were directly caused by misuse of checklists. I have experienced any incident or accident caused by incomplete application of the items identified in the checklists or misuse of the items identified in the checklists.
	2- I have experienced incorrect usage or missing step in checklists.
	3- I warn the flight crew when they apply the checklists without confirmation from the items in the checklists.
Hard Copy Checklists	4- When the environment of the cockpit is taken into consideration, hard copy checklists are limiting the actions of the pilots.
	5- Hard copy checklists are beneficial in terms of contribution to time management and accessing the correct information in the cockpit.
Interactive Checklists	6- Interactive checklists can be beneficial in terms of contribution to time management and accessing the correct information in the cockpit.
	7- I have encountered study/studies about dissemination of usage of the interactive checklist.
	8- I think that the use of interactive checklists can be beneficial to aviation safety effectiveness.
	9- I think the interactions between the interactive checklist and the systems like EFB, FMS are enough.
	10- I think that interactive checklist application should be implemented in a short time.

3.9.1. Analysis of Questionnaires

Questionnaires has been divided into three main subjects that are; questions of general checklist usage, questions of hard copy checklist and questions of interactive checklist.

3.9.1.1. Questions of General Checklist Usage

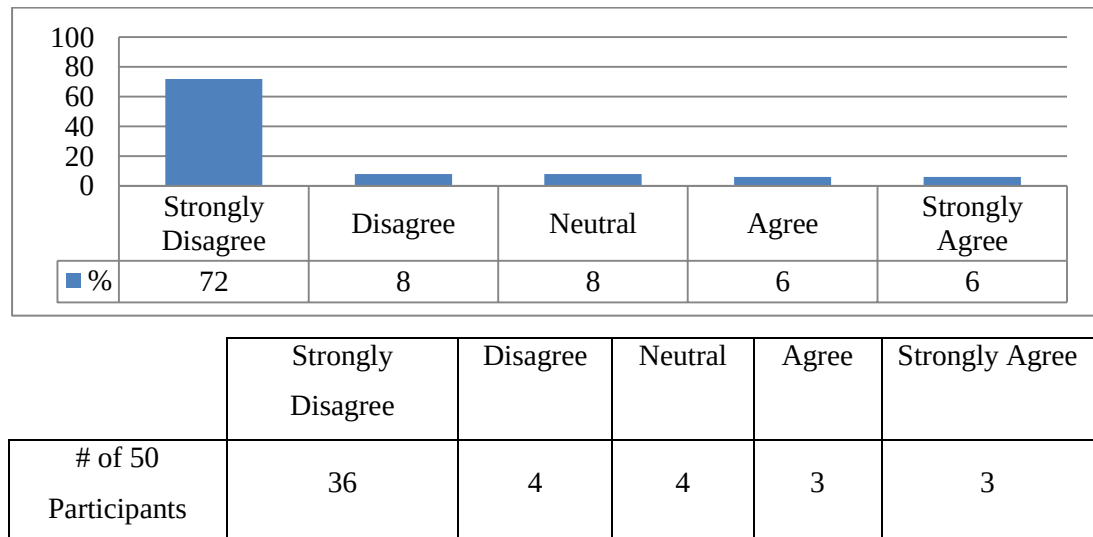
Questions of general checklist usage have been classified in three subjects as accident or incident experience, experience of erroneous checklist usage and CRM in cockpit.

3.9.1.1.1. Accident or Incident Experience

Q1- According to the statistics of "NTSB, June 2017", it is found that 2% of the accidents and incidents in 2017 were directly caused by misuse of checklists.

I have experienced any incident or accident caused by incomplete application of the items identified in the checklists or misuse of the items identified in the checklists.

Figure 10: Accident or Incident Experience Resulting in Checklist Usage



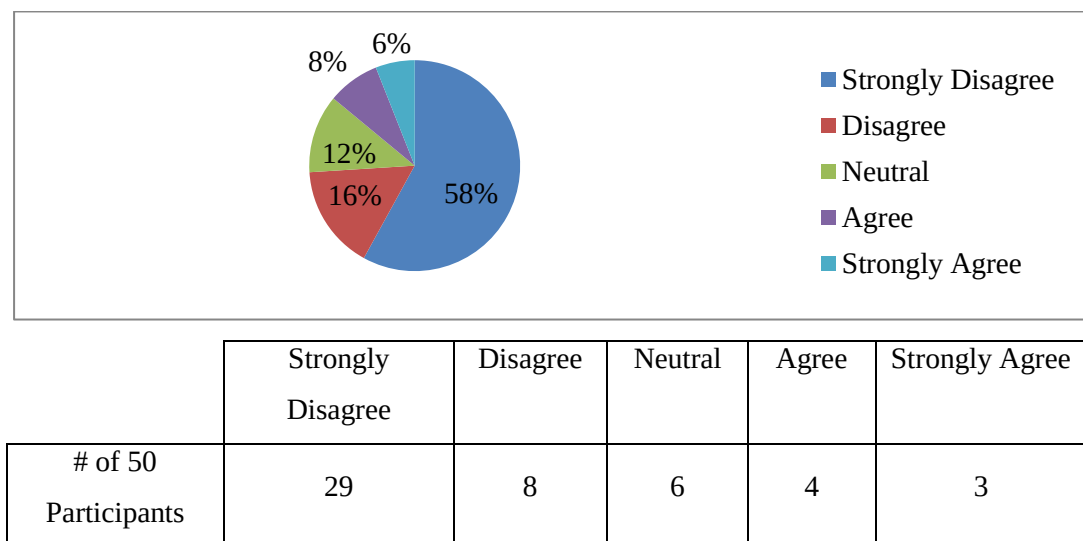
In this question, responses were received explicitly by 92% of the participants. The field of "Neutral" which is representing 8% of total is evaluated

neither agree nor disagree calculations. As per the Figure 10, total of “Strongly Disagree” and “Disagree” is equal to 40 respondents out of 50 which are representing 80% of the all attendants. However, sum of the “Agree” and “Strongly Agree” is equal to 12% of the total. That means they have experienced incident or accident regarding to incomplete application of the items identified in the checklist. To minimize the percentages of human errors, this is the field that we are actually looking for. Hence, the importance of the proper checklist usage is indicated clearly. 12% of the all incidents or accidents were caused by a checklist usage error.

3.9.1.1.2. Experience of Erroneous Checklist Usage

Q2. I have experienced incorrect usage or missing step in checklists.

Figure 11: Experience of Erroneous Checklist Usage Results



At the Figure 11 is drawn above, total of disagreement indicated as 74% which is represented “Strongly Disagree” in blue color and “Disagree” in red color with the pie chart. Once again, attributes of the number of “Agree” and “Strongly Agree” fields are significant due to aviation safety. 94% of the given responses are satisfying considering on our computations which means “Neutral” answers are neglected. The outcome points that accidents or incidents resulting in incorrect usage or missing step issue of the checklist is 14%.

Regarding to the “Question – 1” and “Question – 2”, correlation between “accidents or incidents occurred due to checklist usage” and “missing step issue or incorrect usage of checklist” shows parallel results as expected. It is explained as consistency of the respondents.

3.9.1.1.3. CRM in Cockpit

Q3. I warn the flight crew when they apply the checklists without confirmation from the items in the checklists.

Figure 12: CRM Results in Cockpit

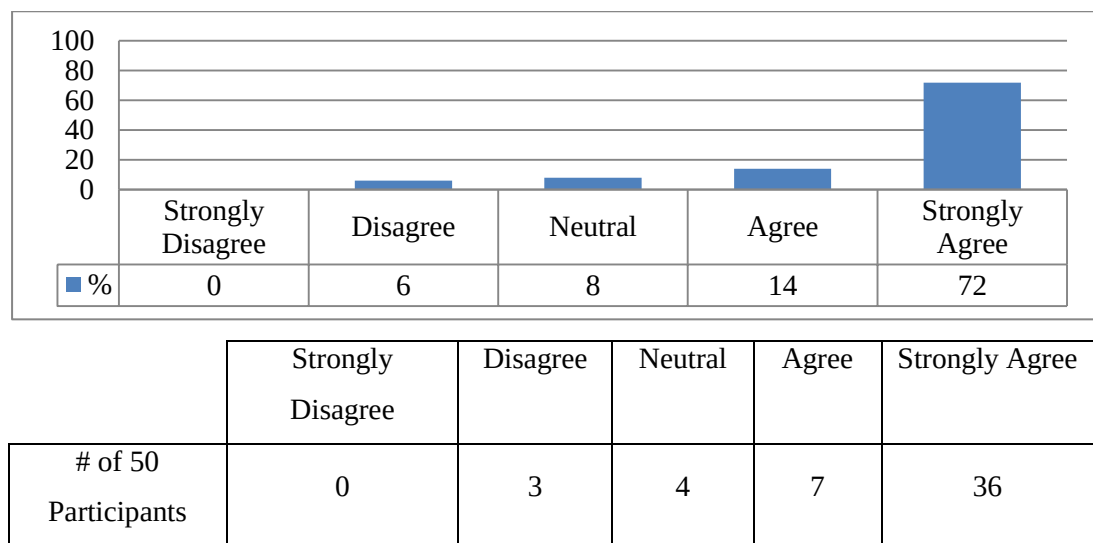


Figure 12 shows a clear trend of CRM in cockpit. As a result of the “Strongly Agree” and “Agree”, 86% of the all attendances replied as they warn flight crew if they apply the checklists erroneously. But distinctly, “Disagree” has a value of 6% which represents lack of CRM conditions during flights. Even if the participants have the opportunity of skipping any question, they marked as “Neutral” instead of leaving blank. In various conditions, some of the captains have full authority in flight deck which causes first officers not to feel comfortable which leads to have communication problems. In our case, it is figured on as a human factor which results incidents or accidents. The percentage of “Strong Disagree” reveals that pilots are aware of the danger of CRM issues but somehow they faced with such situations.

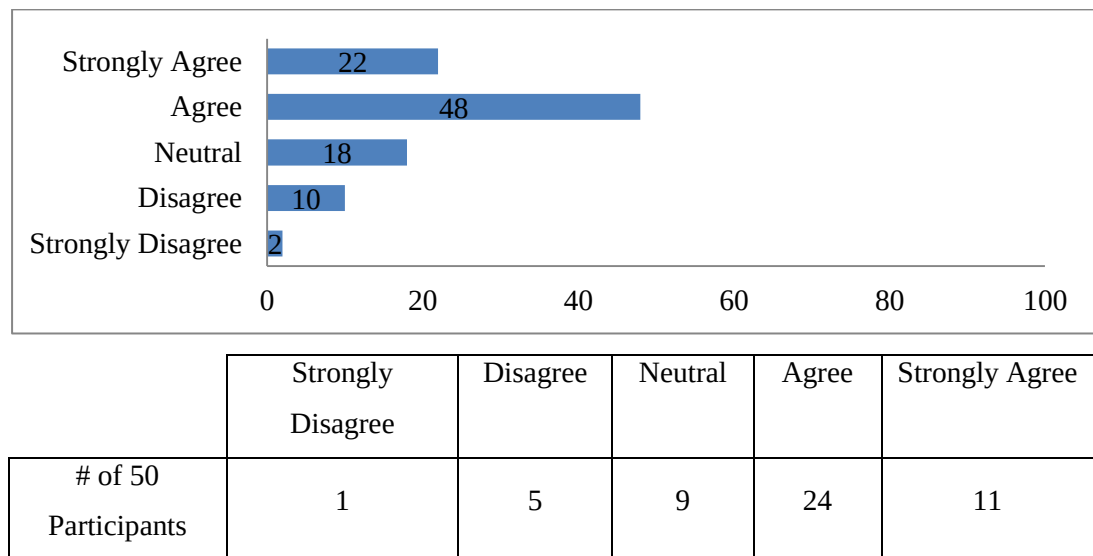
3.9.1.2. Questions of Hard Copy Checklists

Questions of hard copy checklists are divided as limitations of hard copy checklists and evaluation of hard copy checklist into two subjects.

3.9.1.2.1. Limitations of Hard Copy Checklists

Q4. When the environment of the cockpit is taken into consideration, hard copy checklists are limiting the actions of the pilots.

Figure 13: Limitations of Hard Copy Checklists



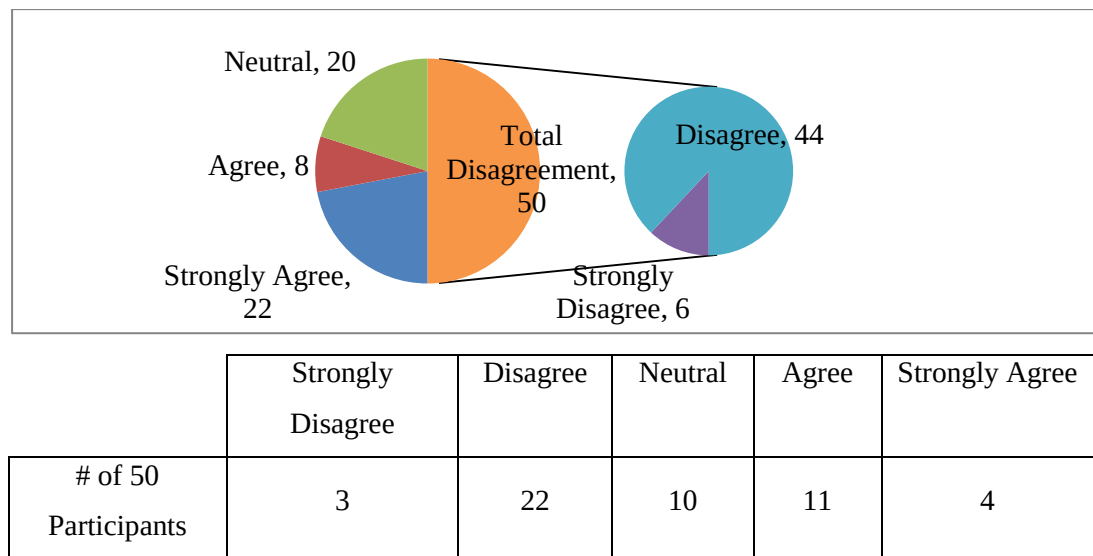
The results of the “Question – 4” are represented by a graph of horizontal bar chart. At first glance, in the Figure 13, the percentages are distributed precisely on the choice of the agreement. It is inferred that hard copy checklist as a traditional checklist method is found that has limiting the actions of the pilots. 70% of participants which includes 22% “Strongly Agree” and 48% “Agree” are represented that they need more ergonomic model of checklist in cockpit. However, 12% of the respondents that contains 10% “Disagree” and 2% “Strongly Disagree” indicates hard copy checklists are not restraining the pilots from flight procedures during flight. “Neutral”, that is counted neither agree nor disagree, which has 18% of total indicates 9 out of 50 participants. This question has not been skipped by any of the participants. To analyze the hard copy checklist, results of the “Question – 5” are

evaluated and shared under regarding question below. To compare hard copy model and interactive checklist model “Question – 6” is also being inspected.

3.9.1.2.2. Evaluation of Hard Copy Checklists

Q5. Hard copy checklists are beneficial in terms of contribution to time management and accessing the correct information in the cockpit.

Figure 14: Accurate Information and Time Efficiency of Hard Copy Checklists



“Question – 5” is demonstrated by Figure 14 with two pie charts. Both charts represent the contribution of the hard copy checklist in terms of time management and accessing the correct information in cockpit. At the first pie chart on the left side, a general view of the collected responses illustrated. Sum of the Agreement choices is 30% which contains 8% “Agree” and 22% “Strongly Agree”. “Neutral” has 20% of total responses which is unexpectedly high.

At the second pie chart which locates on the right side, the distribution of disagreement is indicated as %44 “Disagree” and 6% “Strongly Disagree”. It is obviously seen from the data, 50% of the participants voted that hard copy checklist are not advantageous in cockpit due to time efficiency and correct information topics.

As a comparison of the “Question - 4” and “Question - 5”, results are correlated each other. Participants who respond “hard copy checklists limiting the action of the pilots” also indicate that “hard copy checklist are not time efficient and not easy to access correct information”. So, this outcome is in parallel that we expected according to the hard copy checklist usage in cockpit. Results can be interpreted as a brand new model is anticipated in flight deck in order to minimize human errors that are suffered by hard copy checklists.

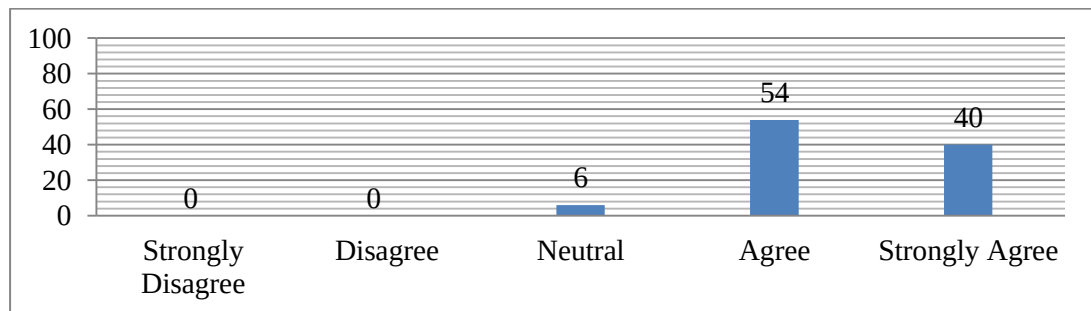
3.9.1.3. Questions of Interactive Checklists

Questions of interactive checklists are inspected in five topics which are evaluation of interactive checklists, literature review of interactive checklist, interactive checklists effectiveness in aviation safety, interactive checklists interaction and implementation of interactive checklists.

3.9.1.3.1. Evaluation of Interactive Checklists

Q6. Interactive checklists can be beneficial in terms of contribution to time management and accessing the correct information in the cockpit.

Figure 15: Accurate Information and Time Efficiency of Interactive Checklists



	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
# of 50 Participants	0	0	3	27	20

Figure 15 illustrates by the bar chart that the percentages of the “Strongly Disagree” and “Disagree” are 0%. The uneven distribution of the responses is observed. Quantile of the “Question – 6” is only shows positively which means right side distributed. 94% of the participants certainly voted as they have agreed on the advantages of the interactive checklists in terms of time management and accessing correct information in cockpit. Outstandingly, 47 out of the 50 respondents are expecting that interactive checklists are sufficient for flight decks instead of using traditional methods. 6% of the given answers which belong to “Neutral” are not evaluated for any aspects.

Comparison between the “Question – 5” and “Question – 6” overwhelmingly resulted with choice of the interactive checklist in order to overcome with the difficulties in cockpit. For instance, time usage, easy access and ergonomics are fundamentally considered as reasons of the human factors that have an impact on accidents or incidents during flight.

3.9.1.3.2. Literature Review of Interactive Checklists

Q7. I have encountered study/studies about dissemination of usage of the interactive checklists.

Figure 16: Literature Review of Interactive Checklists

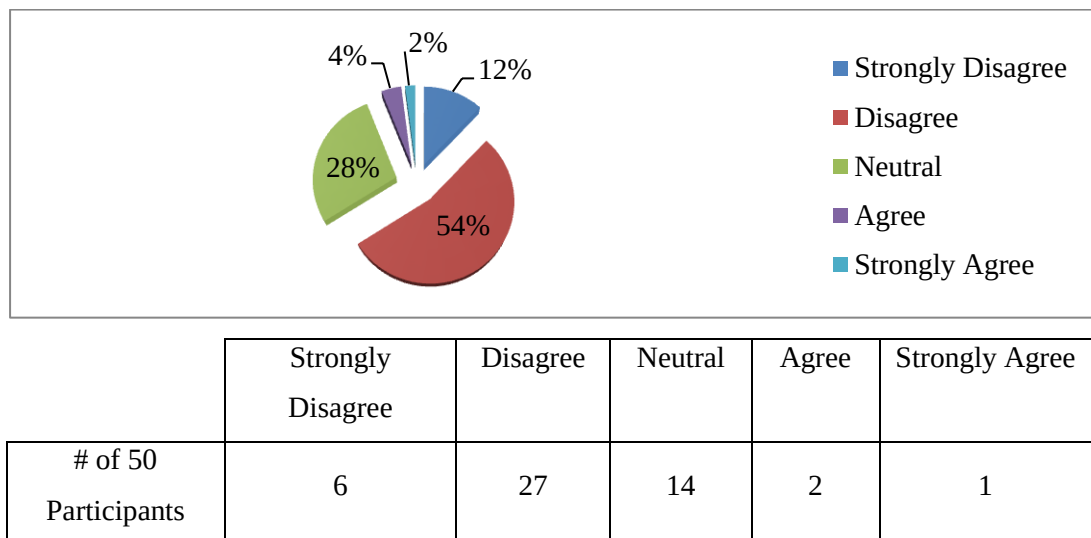
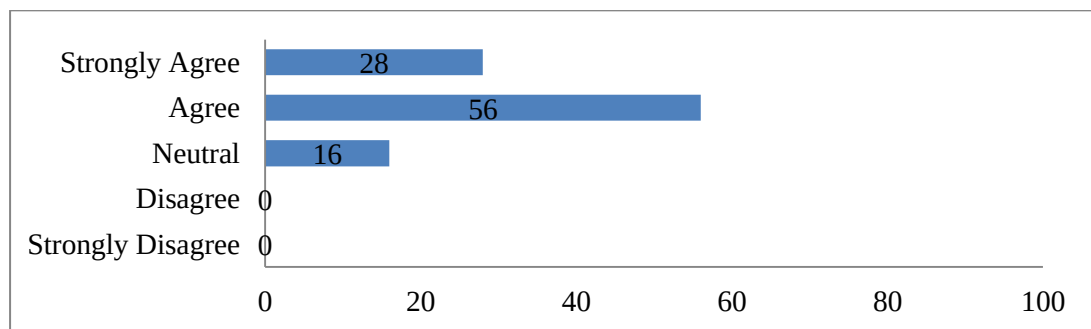


Figure 16 which is shown by pie chart demonstrates percentile of the interactive checklists whether such studies have already been represented in any conferences or researches. Summation of the disagreement is indicated as 66% which contains 12% “Strongly Disagree” in dark blue color and 54% “Disagree” in red color. In contrary, agreement choices indicated in purple and light blue color, 4% “Agree” and 2% “Strongly Agree” respectively. Green color illustrates “Neutral” responses as 28% which means 14 participants. “Neutral” respondents evaluated as if they have do not feel certain considering on any studies that are initiated in this field before. Agreement percentiles can be explained as some Airbus type rated pilots according to the received information from the previous “interviews” conducted by Airbus Captains.

3.9.1.3.3. Interactive Checklists Effectiveness in Aviation Safety

Q8. I think that the use of interactive checklists can be beneficial to aviation safety effectiveness.

Figure 17: Interactive Checklist Effectiveness in Aviation Safety



	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
# of 50 Participants	0	0	8	28	14

From the Figure 17 we can obviously note that interactive checklist is found beneficial to aviation safety as total percentage of 84% which includes 28% “Strongly Agree” and 56% “Agree”. “Neutral” responses are calculated by the answer of the 8 participants which is represented as 16% of total. There is no any “Disagree” or “Strongly Disagree” choices. Hence, due to the percentile of the disagreement, interactive checklists are accepted as a necessity in cockpit to empower the aviation safety.

By comparison with “Question – 8” and “Question – 6”, both queries consist of without disagreement responses. Also, the outcomes corresponds to each other which represents participants have been positively affected by the concept of interactive checklists.

3.9.1.3.4. Interactive Checklists Interactions

Q9. I think the interactions between the interactive checklist and the systems like EFB, FMS are enough.

Figure 18: Results of Interactive Checklist Interactions

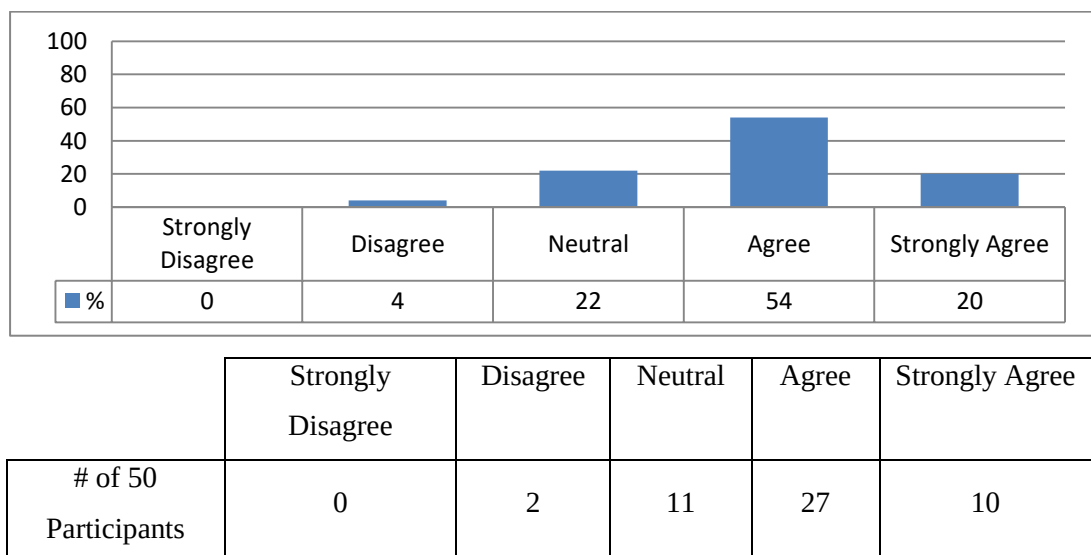


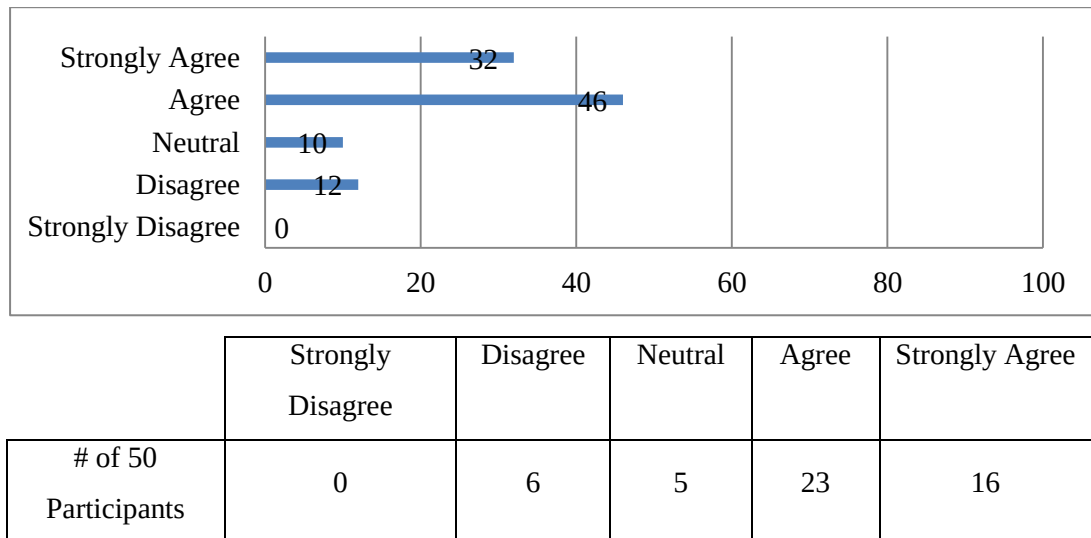
Figure 18 details the data of the interactions between cockpit information systems and interactive checklist with using bar chart. Results show that 74% of the

agreements contain 54% “Agree” and 20% “Strongly Agree”. As disagreement, it is only indicated by 4% which is belongs to “Disagree”. There is no “Strongly Disagree” opinion which is chosen by participants. “Neutral” is represented by 11 attendants as 22% of total. “Neutral” can be assessed as respondents do not ensure in the matter of the interactive checklist structure. Present attendants found the dynamic interactions between EFB and FMS systems as a new concept sufficient to initiate interactive checklist project. In addition to this, integration of interactive checklist should be implemented with basic features to analyze its impacts on flight safety initially. However, participants choosing “Disagree” should be taken into account in order to improve the drawbacks of the system.

3.9.1.3.5. Implementation of Interactive Checklists

Q10. I think that interactive checklist application should be implemented in a short time.

Figure 19: Implementation of Interactive Checklist



As demonstrated at Figure 19 with horizontal bar chart, summation of the agreements is 78% which includes 32% “Strongly Agree” and 46% “Agree”. It can be explained as 39 of the 50 participants mentioned that interactive checklist application should be integrated soon. Disagreement is represented by 12% of total which contains only 12% “Disagree”. There is no “Strongly Disagree” chosen by the

attendants. However, participants who select “Neutral” which may be evaluated as skipped question, indicate 10% of them.

In accordance with the shared information from the graphs, results can be compared with the other interactive checklist questions. Thus, distribution of the agreement percentages of those questions is found to be consistent.

FINDINGS

In this chapter gives all the outcomes obtained from chapter three of this dissertation. Methods which are listed as:

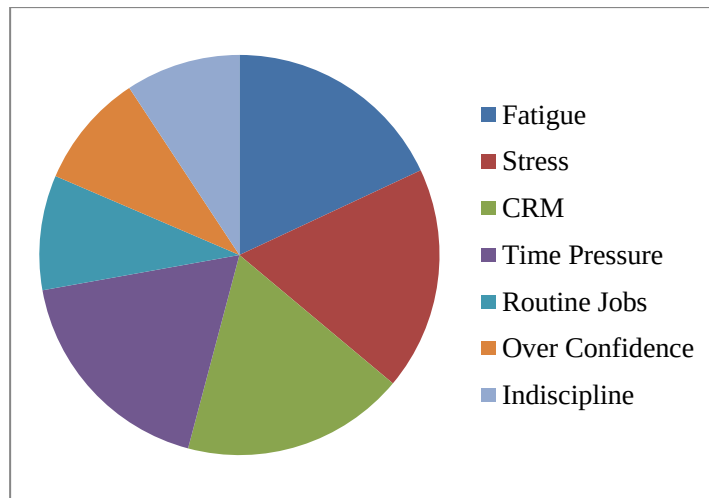
- Investigating the accidents or incidents in 2017,
- Analysis of sample global accidents in interactive checklist perspective,
- Interviews and
- Surveys with the pilots.

Information is inferred from the accidents or incidents inspections in 2017 which are involved in checklist issues. It also shows that 2% of the all events pointing checklist usage issue according to the NTSB database. Based on the table 11 and 12, these two records are only involved in checklist issues which are accident numbers “GAA17CA197” and “ERA17LA151” respectively.

Four sample global accidents reports can be evaluated as each of them could be prevented by implementing new generation checklists model inside the cockpit. As a first thought, it was not expected from the checklist usage to have a vital role to avoid accidents or incidents. However, a closer inspection revealed that checklists usage has a direct effect of the aviation safety. Accidents which are Singapore Airlines SQ006, Spanair JK5002, Gulfstream GIV-SP Private Jet and Turkish Airlines TK-1951 examined as interactive checklist perspective. These accidents were investigated based on the information of section “1.2.3.Incident” and “1.2.4.Accident”. Also, Swiss Cheese Model on section 1.4 provides another point of view to analyze accidents in interactive checklist usage.

As a result of the interviews, the first finding indicates the reasons of common checklist usage errors which are illustrated in Figure 20 as fatigue, stress, CRM, time pressure, routine jobs, over confidence, indiscipline. These factors are also evaluated as risk as explained in section 1.2.2. To deal with the fatigue, fatigue risk management system is defined by Gander et al. (2011), Williamson et al. (2011), Lerman S. E. (2012), Drew D. et al (2012), Cabon P. et al. (2012).

Figure 20: Checklist Usage Errors



Other outcomes of the interviews, 70% of the participants have involved checklist usage errors during their flights. 80% of the pilots prefers electronic checklist to hard copy checklist in cockpit. The most striking consequence of this interview is 100% of the interviewees accept that interactive checklist reduces the human errors in flight deck. The results show that 12% of accidents is occurred by the lack of checklist usage which is shown in section 3.9.1.1.1. in detail. It is vigorous percentage for aviation safety.

The survey results shows that 94% of the respondents feel interactive checklists are beneficial to aviation safety. Additionally, 84% of the participants mention that interactive checklists are advantageous in order to time efficiency and accessing to accurate information. The interactive checklist is designed as a fail-safing and it is better than hard-copy checklist format. Thereby, it eliminates the human factors. Also, 78% of the attendances mentioned that a preventative system like interactive checklist can be applicable in cockpit in short time period.

Comparing with interviews and surveys, it is inferred that objective responses are inquired by face-to-face conversations. For instance, the interview question -2 inquires if they experienced any checklist issue. 70% of all participants replied as “yes” and there is no accident occurred. However, combining with the factors an incident may be observed due to Swiss Cheese Model (James Reason, 1990). In

contrary, given answers of the questionnaire on the same question indicates 7% of the respondents have checklist issue. All the pilots requested to hide their names in case of prevention any negative feedback from CAA. Outcomes of the interviews are not corresponding to surveys in such sensitive situations. The reason of this inconsistency can be evaluated as fear of losing job and trust issues that sourced by questionnaires.

CONCLUSIONS

In this research it is found that 2% of the accidents and incidents in 2017 which recorded in NTSB database are involved erroneous checklist usage. The reason of the common checklist usage errors are sourced by human errors which are fatigue, stress, CRM, time pressure. According to the information are received by interviews, 70% of all participants have been experienced checklist usage errors. 80% of them points that electronic checklists are better than hard copy checklists in usage. The most conspicuous outcome is 100% of the participants mentioned that interactive checklist model may eliminate the human factors and beneficial for the aviation safety. Similar results are observed from the questionnaires, 94% of the respondents found interactive checklist as a preventative model for accidents or incidents. Also 84% of the attendants think interactive checklist is more advantageous in terms of time efficiency and accessing accurate information in emergency conditions.

As phenomena in the aviation history, aviation accidents or incidents are associated with the utilization of new technologies, functionalities or complexities and also mostly caused by human factors. As stated in the Introduction, the research was undertaken in order to enable aviation safety approaches with information systems and analyzing checklist usage in flight crew perspective. It is clearly shown on this research, the relation between information systems and cockpit has positive effects on concept of aviation safety which can lead to minimize human factors on aircraft accidents or incidents.

The interactive checklist plays an important part in aviation safety. In fact, the thesis is probed the accidents/incidents reports of the NTSB databases, which are recorded in 2017. These 2017 NTSB's accident's reports are lightened the primary reasons of accidents. The reports are including checklist failures are also investigated in details to reach any supportive findings regarding to interactive checklists. It is obtained by the interviews and questionnaires, by interacting information systems in cockpit. To err is human; human inheritances have limitation abilities that human prone to make mistakes. The accident reports attempt to highlight human frailty

which may have led to fatal outcomes. On the basis of evidence, it is postulated that the accidents mostly occurred because the pilot's loss of consideration or not neatly follow the checklist items during the flight. The results of this research obviously indicate that the 12% accidents are caused by the lack of checklist usage which is not an underestimate percentile in aviation industry.

This dissertation asked the pilots to express their opinions about the importance of interactive checklists. Surveys and questionnaires are beat a path to understand the interactive checklist effects from the professional point of view. It is clear that the checklist's real utilization can be purely, completely more understandable with aviation employees' experiences and their considerations. That is the reason why, the interactive checklist usage needs to be covered. The result of this survey and questionnaires could be admissible that the interactive checklist is fundamental for aviation safety.

Most important of all, the interactive checklist usage is confirmed as an appropriate to hoist the pilot's performance. This current research endeavor reinvigorates the checklist usage's benefits. Interactive checklist utilization makes easy to increase pilot's performance, quality of flight and aviation safety. Finally, the thesis is expressed that the interactive checklist dissolves the poor concentration with automatization and annihilate many of the paper checklist errors.

RECOMMENDATIONS

Recent findings regarding interactive checklist have led to comprehend the significance. Inevitably, this research has raised many questions in need of further investigations. As a complement to this study, researchers could address the qualitative gap that might provide the findings of the survey and context to many of the aforementioned statistical findings. Further research will help to understand the strength of checklist usage.

Future studies related to aviation interactive checklist could look in a variety of areas; such as, the interactive checklist cannot be programmed for all non-normal situations and it occurs the accidents and incidents in many situations. We can understand that the future studies need in-depth investigation of programming for all non-normal situations which the automation system can up to doing flight continuity. Within the next few years, the interactive checklist is set to become an incontrovertible component and adaptation effects also need to be researched in future researches.

The current system of Airbus A320 suggests pilots to do manoeuvres in case of emergency situations: such as; PACK malfunctions. Although there are some mechanisms to check flight systems, there are no any automatic flaps position control system in Airbus A320 series. Implementation of the interactive checklist seems more suitable for the Airbus A320-321 than Boeing 737 series.

Checklists are also considered on business companies' perspective. Periodic checks can be preventative action for a company from the occupational accidents: such as, every three or six months, weekly or daily checks. For instance, log off user account while not working around the computer is a must for some companies to avoid unauthorized logging on events. Checklists increase labour safety in working environment and rise up the incomes. Automatization of routine works also minimizes human errors in corporations. Thus, contributions to companies' productivity and profitability are scaled up either with the checklist usage in business.

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APPENDICES

APPENDIX 1 Questionnaire with the Pilots

This study is conducted through the flight crew and flight instructors who are in active duty in aviation industry. This questionnaire asks about your personal opinion of how the traditional and interactive checklists affect aviation safety. Your responses will be anonymous. Thank you for your cooperation. Survey is shown in Table below.

1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree

Opinions	1	2	3	4	5
1- According to the statistics of "National Transport Safety Board (NTSB), June 2017", it is found that 2% of the accidents and incidents in 2017 were directly caused by misuse of checklists. I have experienced any incident or accident caused by incomplete application of the items identified in the checklists or misuse of the items identified in the checklists.					
2- I have experienced incorrect usage or missing step in checklists.					
3- I warn the flight crew when they apply the checklists without confirmation from the items in the checklists.					
4- When the environment of the cockpit is taken into consideration, hard copy checklists are limiting the actions of the pilots.					
5- Hard copy checklists are beneficial in terms of contribution to time management and accessing the correct information in the cockpit.					

Opinions	1	2	3	4	5
6- Interactive checklists can be beneficial in terms of contribution to time management and accessing the correct information in the cockpit.					
7- I have encountered study/studies about dissemination of usage of the interactive checklist.					
8- I think that the use of interactive checklists can be beneficial to aviation safety effectiveness.					
9- I think the interactions between the interactive checklist and the systems like EFB, FMS are enough.					
10- I think that interactive checklist application should be implemented in a short time.					

APPENDIX 2 Interviews with the Pilots

1	In 2017, 2 of the 10 total accidents/incidents filtered out on the checklist according to the National Transport Safety Board (NTSB) were resulting in direct checklist usage error. For which reason, a pilot does not apply or complete partially the checklist?
2	Have you ever encountered with any checklist issue (missing step, incorrect checklist)? And, have you ever experienced an incident or accident about the use of a missing steps, or incorrect checklist?
3	Would you compare the Electronic Checklist and Hard Copy Checklist in terms of time, practicality, correct data, mistakes, safety on board?
4	How does the interactive checklist affect you? What are your thoughts on contributing in terms of aviation safety?
5	Could the use of an interactive checklist be a method to prevent accidents and incidents originating from the checklist in the world?
6	In this design, do you think the interactions between interactive checklist, FMS, EFB and such cockpit information systems are sufficient? Or, do you have any contribution?

