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Effects of Meteorology Data on Crew Resource Management in Aviation

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Abstract

Risks associated with meteorology must be continuously assessed and carefully managed by the flight crew to ensure the safety of flights. This study aims to examine meteorological events' favorable and unfavorable effects on crew resource management in recent aviation operations. The face-to-face interview technique, one of the qualitative research methods, was used, and data were collected in light of the information obtained from the pilot pool of 50 people. In the study, the opinions of the crews on what kind of flight management and data analysis application they carried out were taken, accompanied by questions directed through meteorology, flight safety, and crew resource management factors. The collected data were analyzed by content analysis method. As a result of the analysis, it was concluded that theoretical knowledge of stress management and a good analysis of meteorology is of vital importance. It has been evaluated that accidents and incidents that occur indirectly in aviation in meteorology can be prevented entirely, and by drawing attention to the importance of the crew resource management factor, it has been concluded that they can be prevented by working together with advanced meteorology systems and an up-to-the-date training.

1. Introduction

The adverse effects of the usual and erratic structure in the air have remained with us since the beginning of the history of air transportation. During its early years in aviation, the use of Crew Resource Management (CRM) for effective teamwork and good communication between the cabin and cockpit was limited to technical and cognitive methods. However, with the emergence of the importance of cognitive thinking, data analysis, and data management processes, its content has been expanded over time to help crews improve their situational awareness. Aircraft systems and resources providing meteorological data must be used effectively for pilots to conduct safe and efficient air operations. Strengthening communication and management skills within the flight crew positively impacts flight safety.

In aviation, the constant scrutinization of meteorology is an essential requirement, and more than any other mode of transport, weather variations need to be analyzed carefully (Anaman, Quaye, and Brown, 2017). It is evident that these changes significantly impact flight safety, and pilots should be prepared to apply risk scenarios in adverse weather conditions under all situations (Howell, 2019).

For a high level of safety to be achieved here, it has to be ensured that updated technological systems and training procedures are implemented to support pilots' data tracking and flight management performance in unfavorable weather conditions (Stahl, 2016).

Humanity has studied weather phenomena for centuries to understand their implications for safe air transportation. During aviation experiments, humanity has attempted, with varying degrees of success, to gain insight into the complex dynamics of weather events. Meteorological changes from the past and their practical results have shown that meteorological reports must remain up-to-date every minute. The adverse effects of meteorology on aircraft in the process of meteorology until today have always produced striking results regarding flight performance (Gultepe and Feltz, 2019).

The following are cited among the main weather events:

• Wind (its effects during landing and take-off of the aircraft)

• Icing conditions (its effects on aircraft fuselage and engine)

• Thunderstorm (abnormal condition of aircraft during all phases of flight)

• Fog (its effect on visibility at all stages of flight)

The factors created by such weather events directly affect the aircraft's flight performance, fuel efficiency, and the economic income and expenses of the companies. Meteorological situations, covering all stages of ground and air operations, play a significant role in the realization of an operation. With up-to-date METAR (routine weather report) reports, pilots perform planned flight operations. The analysis of meteorological data should include the following features;

• Up-to-date weather conditions,

•The information regarding the expected weather conditions on the route and the destination,

• The adverse effects on flight safety, if any,

• The proper management of meteorological data and the goal of a safe flight.

For this reason, the concept of meteorology in aviation aims to ensure that the aircraft's performance is affected at the lowest level on the routes determined as a result of the up-to-date data obtained by the crews and to get the highest efficiency from the operation.

Being aware of the weather during the flight and accurately assessing the other phases of the flight is an important quality to have in flight crews. In particular, pilots are expected to take a correct and practical approach by considering flight safety during the decision-making process by analyzing meteorological data. In a regional study on this issue, 204 pilots' attitudes towards dangerous meteorological events and the management processes between them were examined in the simulation environment. The findings obtained included the following;

• Increase in the percentage of stress in hazardous weather events

• Lack of information on emerging weather events

• Insufficient division of labor among cockpit crews and insufficient data management

The study conducted among pilots serving in commercial aviation revealed that piloting and crew management processes need to be improved in the face of challenging meteorological conditions. (Keebler et all., 2018).

In another review of the same study, participant pilots were asked to interpret a ground-based infrared radar indicator in the test system. Although 32 percent of the pilots were unsuccessful in weather analysis, 8 percent of this rate was observed to have passed the meteorology exam in the FAA exam system. As a result of the system encouraging the rote-based question system, it was found that the pilots could not analyze the visual data. It was stated to the pilots in the study that the radar they viewed transmits data with a delay of 10 to 15 minutes. It was further noted that if a time difference is not noticed in the ground-based radar data arriving in the cockpit, they face a negative situation for flight safety in an aircraft flying 120 miles per hour (Blickensderfer et all., 2017).

From past to present, the adverse effects of meteorological conditions within the commercial and civil aviation industry have reached all phases of all air operations. The monitoring, analysis, and management of the weather reports to be made here are considered the primary safety factor by the flight crews. Flight safety in poor weather conditions and crew resource management are directly proportional. The opinions and techniques of experienced pilots should be taken into account here.

The negative returns of accidents and flight cancellations caused by meteorological conditions in commercial and general aviation are essential factors that reveal severe economic consequences for companies. In aviation, where the meteorology factor is so important, attention should always be paid to crew resource management based on communication and cooperation regarding the continuity of flight safety.

An in-depth literature review concluded that the relationship between meteorology and crew resource management in the Turkish and English literature still needs to be adequately studied and examined academically. This research will provide significant awareness of flight safety, the training models planned to be developed in aviation companies, and the studies to be carried out in this field in our country, and will support the development of the scheduled training processes.

In light of the above information, the primary purpose of this thesis is to determine the adverse effects of meteorology data on flight safety and to examine and reveal the usual and variable impacts of crew resource management practice on the crew.

2. Theoretical Framework

2.1. Meteorology

The atmosphere and the structural elements that make up the atmosphere, meteorological events that need attention in aviation, the ozone layer and their effects on flight operations, the radiation rates to which the crews are exposed and their effects on the health of the crews, create the dynamics that should be considered at every stage of air operation. In addition, the adverse effects of these radioactive factors on the systems existing on the fuselage structures of the aircraft are among these factors (Firat, 2019).

Meteorology in aviation directly affects all aviation operations covering every stage of flight, from general to commercial aviation. Correct analysis of meteorological data affects all aircraft's flight safety and efficiency, including airport and air traffic operations. The 1948 Chicago Convention's "Annex 3" appendix contains statements by the aviation industry about the practices and significance of providing meteorological data assistance. These remarks refer to the significance of the most comfortable, shortest, and safest transportation (Kucuk Yilmaz, 2007).

The General Directorate of State Meteorology Affairs is the only national organization in Türkiye that provides the information required for commercial and general aviation activities. Due to the importance of meteorological systems' impact on aviation safety, throughout Türkiye, approximately 54 meteorology stations have been established to provide 24/7 service to ground and air personnel. (MGM; Textbook, 2021).

In a region where meteorological events occur rapidly, it is crucial to examine the conditions within the framework of certain conditions (Noyan, 2007). These conditions are;

• Expected meteorological conditions on the flight route

• Instantly developing meteorological conditions on the flight route

The crews must be aware of the meteorological conditions on the flight route at the moments mentioned above. Aircraft can only be expected to perform their operations safely with meteorological information. In a region where sudden weather events occur, pilots should regularly check current weather data, prepare for potential weather events during their flight, adjust their route to ensure safety and analyze data to decide if canceling the flight is necessary (Ozturk et al. 2021).

2.1.1. Meteorological Effects During Flight

Flight crews rely on obtaining accurate and up-to-date weather information, also known as "current weather," in order to plan their flights effectively. Commercial air operations occur in the atmosphere's troposphere layer, frequently affected by meteorological influences caused by humidity, pressure, and temperature changes. In aviation, the meteorological factors that adversely affected flight safety are as follows;

• Fog: Visibility is crucial for aircraft approaching for landing or taking off from an airport. Excessive cloudiness caused by "water vapor" that reduces visibility, such as cloudiness, haze, etc., causes unsafe landing and take-off phases of the flight.

• One of the major problems affecting flight safety has been severe weather, including Cumulonimbus-Oraj clouds, abbreviated CB by pilots, which may cause thunder, lightning, gusty ground wind, turbulence, heavy precipitation, hail, and icing (Ozturk et al., 2021).

• Icing: The accumulation of snow and ice on the airplane's surface, which affects the airplane's weight, increases the frictional force on the aircraft, harms the lifting power, and causes the plane to require more engine performance (Unlu and Hilmioglu, 2017).

• The heights that come from the formation of clouds are known as cloud layers, and they are structures visible from the ground up. Clouds' visual mass of tiny water droplets, ice crystals, and other particles in the Earth's atmosphere have significantly impacted flight operations (Atasoy, 2015).

Due to their proximity to the ground, stratus (St) clouds, one of the lower layer cloud types, pose a severe risk to aircraft during takeoff and landing. Altocumulus (Ac) cloud type, one of the mid-altitude clouds, is a slow-forming cloud type whose base levels start at about 6500 feet above the ground and can reach up to 16,500 feet. Within this cloud type, there is no danger for the aircraft to fly under observation and for a short period. Among the high-altitude cloud structures, Cirrus (Ci) type clouds form similar cloud types in the form of tiny ice crystals, very thin or narrow lines above 16,500 feet (MGM: Textbook, 2021).

The occlusion rate, which occurs depending on the cloudiness levels, constitutes an essential meteorological data reporting due to its effects on the operation-oriented activities of the aircraft and flight safety. The terms of view in these data reports created a system divided into 8 equal parts by the experts to express the vertical view. This system, which includes 8 octa measurement units, informs the crews about the cloud cover rate in any region through the Aviation Routine Weather Report (METAR) and various meteorological station data (Gultepe, 2007).

Table 1. Cloud Capacity (octa) rates

Cloud Amount	Ratio/Octas	Abbreviation
Sky Clear	0	SKC
Few	1/8 – 2/8	FEW
Scattered	3/8 – 4/8	SCT
Broken	5/8 – 7/8	BKN
Overcast	8	OVC

Source: Meteorology Textbook, (2018).

• Wind: The most dangerous wind for airplanes was the Low-Level Windshear. In their research, ICAO and the US Federal Aviation Administration (FAA) have found that wind shear plays a vital role in most accidents, especially during the approach and landing phases, which are the most critical phases of flight and is recognized as potential hazard for aircraft (Frost and Bowles, 2012). There are 3 types of wind depending on the direction of travel of the aircraft: 1) Headwind, 2) Crosswind, and 3) Tailwind (Atasoy, 2015).

The crews performing air operations can be divided into 4 main stages. At these stages, flight crews are expected to manage meteorological data correctly and carry out safety management processes for the division of labor within the crew during the pre-flight, take-off, cruise, and landing phases.

2.1.2. Pre-Flight Phase

The weather has often been an influential factor in aviation accidents and air traffic. Researchers have observed that pilots play a critical role in evaluating the latest weather events and current radar data before take-off.

The research by the FAA revealed that, during the pre-flight ground briefings, pilots needed more meteorological information about recent and due-to-occur meteorological events. The research further revealed that, during adverse weather conditions occurring on route or at airports, the Automatic Flight Service Station (AFSS) canceled and changed nearly 70 percent of the plans entered into the flight planning system.

A study on planning within AFSS found that during adverse weather conditions, 78 percent of the pilots flying on that day requested briefing information from the system. The remaining percentage was unaware of the adverse weather conditions on the route and committed rule violations in the face of unanticipated complex management during the flight (FAA, Preflight, 2007).

2.1.3. Take-Off Phase

The weather forecast data provided to flight crews for take-off is usually delivered to the planning and flight crew 2 to 3 hours before the operation. The forecast information during the planned departure period of the aircraft provides the necessary data to the crews regarding the expected surface wind, temperature, atmospheric pressure, and weather conditions on and around the airfield. Careful crew management for the take-off phase is needed; extra information on significant events such as precipitation conditions and strong wind warnings must be analyzed in detail due to their negative impact on flight safety (WMO: Guide, 2003).

With the "Trajectory Options Program (CTOP)" system, which is planned to be implemented for the restrictions of airspaces and the cancellation of aircraft departures, it is aimed that the airline companies will provide safe options to the pilots by making a detailed analysis of the adverse weather conditions occurring on the planned departure and route by artificial intelligence. As a result, it aims to reduce pilots' workload during take-off and to make healthy data management accompanied by safe plans analyzed by artificial intelligence (Arneson et al., 2017).

2.1.4. Cruise Flight Phase

Flight crews must receive detailed, up-to-date data on weather events occurring at every phase of the air operation. In all aircraft fleets used by airlines and private jet crews, the change of meteorological data is carefully monitored to ensure optimum cruise performance. Dangerous weather events on the route can adversely affect the aircraft's outer surface. An aircraft deviating from its current route may result in higher fuel consumption or safety issues. (Chu, Gorinevsky and Boyd, 2010).

During the flight's cruising phase, "storms" have been the most critical weather events that affect flight safety and aircraft performance. Regarding new route calculations, crews are recommended two methods for calculating aircraft mass and performance conditions and ensuring flight safety. These methods can also be applied to examine the distribution functions of the management process (in the case of certain weather events) and fuel consumption (in the case of a specific range) among the pilots and to alleviate the workload among the crews (Vazquez and Rivas, 2013).

2.1.5. Landing Phase

In aviation, the landing phase plays a significant role in the safe flight of an aircraft from point A to point B by correctly analyzing the weather data. Landing planning in lousy weather conditions is an essential problem for the air traffic system. In these conditions, various systems have been implemented to assist pilots, including ILS and Microwave Landing System (MLS), which greatly facilitate the stress management of landing. Although these systems are helpful, they are generally only available in major airports in metropolitan areas due to their high cost.

It has been observed that the landing systems, which provide great convenience to the crews in the data management process, positively affect the intensified air traffic due to weather conditions and reduce the delay times of the flights. In addition to these landing systems aiding pilots, the introduction of the Corridor Integrated Weather System (CIWS) offers up-to-date information on aircraft approach processes for traffic flow management in congested areas (Evans et al., 2016).

2.2. Crew Resource Management

The validity of CRM training in commercial aviation, including the switch from the cockpit to CRM, is still up for debate. There have been modifications and variations of CRM across different cultures, including a lack of cross-cultural generalization.

Crew Resource Management training in the United States, one of the pioneers of CRM, has its roots in a NASA-sponsored workshop called "Resource Management on the Flight Deck" in 1979. This conference expanded NASA's research into the causes of air transport accidents and identified the majority of accidents caused by severe weather conditions as failures in poor communication, decision-making, leadership, and inadequate data management due to human error. In order to reduce "pilot error" by better use of human resources and management on the flight deck, Cockpit Resource Management (CRM) was first applied during the crews' training process (Helmreich, Klinect and Wilhelm, 1999). New training programs are always needed to improve the interpersonal aspects of flight operations. In this sense, CRM training programs have found widespread use worldwide to train and prepare pilots under challenging conditions. The CRM training aims to achieve a permanent safety attitude by trying to solve the problems encountered in changing the attitudes and behaviors of flight crews under certain phases.

Over the years, the CRM phases have expanded to include management techniques that can assist pilots, providing a systematic system of procedures in emergencies and integrating them into the cabin crew. In this direction, a simulated flight scenario application between two or more points on threat and data error management training, preventive measures, weather recognition, avoidance and management strategies has been included in the system as a beneficial training program for airlines today. These scenario-based learning tasks involve a combination of conducting flight operating procedures under normal, ordinary, and variable weather conditions. A modern training update for the CRM phases will increase the potential cost of air carriers and prevent possible accidents (Wagener and Ison, 2014).

CRM goals include:

- Awareness of concepts
- Discussing the different philosophies and goals of crew resource management training
- The ability of pilots to use data management correctly and safely in average weather conditions.
- Improving the crew's ability to use data sources

2.2.1. Factors of Crew Resource Management

The factors of CRM allowed the factors for the causes of aircraft crashes to evolve after the introduction of FDR and CVR devices to modern jet aircraft. The information obtained from these devices is not the result of many accidents due to a technical malfunction of the aircraft or systems, a failure in the ability to operate the aircraft in adverse weather conditions, or the lack of technical knowledge of the crew; instead, it appears to be due to the crew's inability to respond appropriately to the situation while they find themselves in it. CRM factors that affect the crew are as follows:

Decision-Making: In flight crews, distinctions between personality traits and decision-making are made. The decision-making process, especially by forming a whole with situational awareness, can only choose the best management form if the flight crews completely understand the situation. Here, the most significant factor affecting the decision-making process is various prejudices, and it can be demonstrated that people's culture and characters have a negative impact on the flight operation process and decision-making (Kearns, 2021).

Leadership management: The enhancement of leadership abilities and ensuring crew members collaborate to accomplish tasks safely in adverse weather conditions are two primary purposes of CRM training. It primarily aims to enable inexperienced co-pilots to learn their leadership roles in variable meteorological conditions and to lead the flight when the captain is inadequate (Sekerli, 2006).

Crew Cooperation: Studies examining the relationship between social culture and CRM in crew cooperation show that subordinates have limited dependency on their superiors and feel more comfortable defending different opinions in cultural environments with low power distance. In cultural environments where power distance is high, on the contrary, it is stated that subordinates are overly dependent on their superiors. In such environments, they need to be at the desired level of questioning their superiors, approaching them comfortably, and defending different ideas (Set, 2019).

Situational Awareness: Situational awareness refers to the process by which flight crews can follow and analyze the weather conditions in their environment. Situational awareness has several critical factors for the crew:

- Perception of ongoing environment and weather conditions throughout the flight

• Understanding the current variable weather pattern
• Forecasting the impact of meteorological data on flight safety.

When these behavioral attitudes are adopted during the flight, the desired level of contribution to flight safety and ECM practices can be achieved. Through accurate and up-to-date data sharing, crew members can always keep their situational awareness fresh. As a result, the decision-making process is supported more effectively (Set, 2019).

2.3. The Relationship between Meteorology Data and Crew Resource Management in Aviation

Due to its structure, aviation has been an important industry where dangers and risks have arisen intensively. This sector should have understood the concept of safety compared to other sectors and should have adopted a top-level management approach to prevent hazards. Even if all safety precautions are taken, the occurrence of human-induced errors cannot be eliminated entirely. Regarding safety, it is vital that the workload and intensity of the crews can be controlled, regardless of the type of meteorological situation (Kurnaz, 2018). Meteorology data plays a crucial role in aviation safety, particularly in the area of CRM. CRM is a set of procedures and skills that pilots and crew members use to manage and mitigate the risks of flying an aircraft. Meteorology data provides critical information to pilots and crew members, allowing them to make informed decisions regarding flight safety. This information includes current and forecast weather conditions, such as wind speed and direction, visibility, cloud cover, and precipitation. With this information, pilots can decide the best route, whether to delay or cancel a flight due to adverse weather conditions and what precautions to take in flight. Crew members can also use meteorology data to prepare the aircraft for takeoff and landing, such as ensuring that the runway is clear of debris and that the aircraft is adequately de-iced.

Effective CRM requires pilots and crew members to work together to ensure the safety of the flight. This includes effective communication, such as sharing information about weather conditions and making decisions as a crew. Using meteorology data, pilots and crew members can make informed decisions about flight safety and work together to ensure a safe and successful flight.

The crew readily recognized that resource management, flight safety, and meteorology concepts and training could improve aviation safety. CRM now includes the entire flight operations crew, including pilots, cabin crew, dispatchers, air traffic controllers, and maintenance. Specific crew resource management between meteorology and flight safety should avoid complacency in all circumstances and continually evaluate our CRM programs to ensure that the flight safety objective is met as the current data analysis and management environment changes (Kolander, 2019).

3. Methodology

3.1. Research Method

The qualitative research model was used because it allows for an objective evaluation and in-depth investigation of experienced pilots who are knowledgeable and responsive to crew resource management and meteorology issues in the face of phenomena such as how pilots balance their stress levels under adverse and abruptly changing weather conditions, which phases of the flight create more challenging conditions, how to gain experience under these conditions and what training equipment should be used.

3.2. Population and Sample of the Research

The population of this study consists of pilots employed by private capital and public-based airline companies within the scope of Turkish civil aviation who have professional experience and are fleet members and teachers and those who have objective views and information about meteorology, CRM, and flight safety. The maximum diversity sampling strategy was used to reveal different perspectives, analyses, and management examples on the same subject due to the specific competencies and characteristics of the flight crews that could represent the phenomenon involving this research.

3.3. Data Collection Tools

The interview method, one of the qualitative research methods, was used to obtain detailed information on meteorology, crew resource management, and flight safety by asking questions that would reveal detailed, confidential information and methods from pilots with high flight hours and seniority levels related to the research subject.

The interview questions were generated from a thorough literature review since there is no example research in the literature. Below are the research questions that have been used in the interview to accomplish the study's primary goal:

1. What data do you think is one of our resources regarding crew resource management during the flight?
2. Do you think meteorological data is one of our resources in terms of crew resource management? Why?
3. What do you think about the relationship between meteorology, safety, and crew management?
4. Which phases of flight, in particular, require an effective data management process?
5. Which conditions in the METAR reports affect long-term flight safety, and do they have any effects?
6. Which meteorological conditions can become so severe during the landing phase of the flight that they often cause concern for flight crews?
7. What is the attitude of the crews towards meteorological reports that abruptly change? Are stress-induced, hasty, and erroneous data evaluations experienced in these sudden situations?
8. Is it possible to have a practical skill aspect that every pilot should have in adverse weather conditions? If possible, what skills and competencies are essential?
9. What kind of training and evaluation process should the airline companies that will serve within the scope of commercial aviation include in the training and evaluation process of the pilots in the face of meteorological conditions?
10. What is the benefit of simulating difficult meteorological conditions in simulation or training flights?
11. What countermeasures should be provided regarding flight safety to detect mistakes made by pilots and reduce their consequences?

3.4. Data Analysis

This research gathered data by conducting a thorough content analysis of the interview-based answers, a qualitative data-gathering technique. With the semi-structured interview technique performed here, the data acquisition and analysis processes could be explored in more detail, and all the data values were observed. Participants in the research were asked questions within the framework of four main problems: Meteorology, CRM, flight safety, and flight phases. Based on the data obtained, with the aim of an in-depth examination, information showing similar characteristics was coded and classified within themselves, allowing the emergence of structures related to the research purpose. Tables were created and transferred by analyzing the frequent use of these structures that emerged here.

4. Result and Discussion

4.1. Demographic Information on Participating Pilots

Tables 2 and 3 provide information about the participating pilots, including their demographic characteristics.

Table 2. Information on Participants

Participants Codes	Gender	Age	Level of Education	Experience Years
P1	Male	63	Bachelor’s	43
P2	Male	43	Bachelor’s	5
P3	Male	40	Bachelor’s	5
P4	Male	46	Bachelor’s	28
P5	Female	39	Bachelor’s	15
P6	Male	39	Bachelor’s	12
P7	Male	39	Bachelor’s	7
P8	Male	44	Master’s	19
P9	Male	28	Bachelor’s	6
P10	Male	47	Master’s	25
P11	Female	35	Bachelor’s	4
P12	Male	39	Bachelor’s	12
P13	Male	45	Bachelor’s	20
P14	Male	39	Bachelor’s	10
P15	Male	60	Bachelor’s	25
P16	Male	60	Bachelor’s	20
P17	Male	59	Bachelor’s	20
P18	Male	40	Bachelor’s	14
P19	Male	45	Master’s	10
P20	Male	45	Bachelor’s	15
P21	Male	45	Bachelor’s	10
P22	Male	60	Master’s	25
P23	Male	56	Bachelor’s	20
P24	Male	60	Bachelor’s	15
P25	Male	60	Bachelor’s	25
P26	Male	55	Bachelor’s	15
P27	Male	38	Master’s	8
P28	Male	55	Bachelor’s	15
P29	Male	38	Bachelor’s	10
P30	Male	40	Bachelor’s	15
P31	Male	39	Bachelor’s	10
P32	Male	55	Bachelor’s	15
P33	Male	38	Bachelor’s	10
P34	Male	50	Bachelor’s	25
P35	Male	46	Bachelor’s	20
P36	Male	43	Bachelor’s	10
P37	Male	55	Bachelor’s	25
P38	Male	40	Bachelor’s	20
P39	Male	45	Bachelor’s	15
P40	Male	60	Bachelor’s	30
P41	Male	37	Bachelor’s	8
P42	Male	45	Bachelor’s	20
P43	Male	47	Bachelor’s	20
P44	Male	60	Bachelor’s	30
P45	Male	37	Bachelor’s	10
P46	Male	42	Master’s	10
P47	Male	60	Bachelor’s	40
P48	Male	39	Bachelor’s	10
P49	Male	39	Bachelor’s	7
P50	Male	48	Bachelor’s	10

Participants were coded as P1, P2, P3, P4, P5, P6,.............P50 based on the interview's order. To understand crew resource management components, it is aimed to get more efficiency from the participants.

Table 3. Information on Participants

Seniority	Flight Hours	Aircraft Type	Company Business Model
Cpt.	25000	A350	Full Service
F/o	3000	A320	Low Cost
F/o	3500	A320	Low Cost
Cpt.	7500	A320	Low Cost
Cpt.	12000	A320	Full Service
Cpt.	8800	B737	Low Cost
F/o	3800	B737	Low Cost
Cpt	20000	A330	Full Service
F/o	2900	A320	Full Service
Cpt	25000	B737	Regional
F/o	2000	A320	Full Service
Cpt	10000	B737	Full Service
Cpt	20000	B777	Full Service
Cpt	8000	A320	Regional
Cpt	30000	A320	Regional
Cpt	25000	A330	Full Service
Cpt	30000	B777	Full Service
Cpt	15000	A320	Low Cost
Cpt	10000	B737	Low Cost
Cpt	12000	A320	Full Service
Cpt	10000	A320	Full Service
Cpt	25000	B737	Low Cost
Cpt	25000	B737	Low Cost
Cpt	30000	B777	Full Service
Cpt	30000	B737	Regional
Cpt	20000	B737	Low Cost
Cpt	55000	B737	Full Service
Cpt	20000	A350	Full Service
Cpt	6500	G550	Business
Cpt	8000	CN235	General
Cpt	9000	G450	Business
Cpt	20000	B737	Regional
Cpt	7500	CN235	General
Cpt	10000	B737	Full Service
Cpt	12000	B737	Low Cost
Cpt	10000	B737	Low Cost
Cpt	15000	B737	Low Cost
Cpt	10000	B737	Low Cost
Cpt	12000	A320	Full Service
Cpt	20000	B737	Full Service
Cpt	7000	B737	Full Service
Cpt	15000	B737	Full Service
Cpt	15000	B737	Full Service
Cpt	25000	B737	Low Cost
Cpt	6500	A320	Low Cost
Cpt	8000	A320	Regional
Cpt	30000	A350	Full Service
Cpt	7500	G550	Business
F/o	4500	LJ45	Business
Cpt	15000	LJ45	Business

Face-to-face interviews were conducted with the above-mentioned pilots of Turkish Civil Aviation with sufficient professional experience and knowledge about the research topic and questions. The features of the 50 pilots who participated in the interviews are as follows;

- 4% female, 96% male
- 38% are 40 years old and under, 62% are over 40.

• 14% graduate, 86% undergraduate

• 60% have 15 years or less of professional experience, 40% have more than 15 years of professional experience

• 12% co-pilot, 88% captain pilot

• 66% of them have 15 thousand hours and fewer flight times, 34% have more than 15 thousand hours of flight time

• 16% fly in wide body, 84% fly in narrow body aircraft type

Pilots with different features were involved in the research.

4.2. Crew Resource Management and Flight Safety Phases

Full-service airlines, which outperform many low-cost airlines in terms of flight frequency worldwide, can provide us with precise insights into the use of crew resource management factors that affect various aspects of the aviation industry. It can provide sensitive information about the flight operations of most participants across several continents and the various flight phases they have experienced under diverse meteorological conditions. In Table 4, themes will be created through coding in five main problems, and the views and frequency of use of these themes will be analyzed by grouping them according to specific characteristics.

Table 4. Crew Resource Management and Flight Safety Phases

Theme	Coding	Frequency of Codes
Meteorological Factors and Flight Safety Phases	Briefing phase	12
	Take off phase	17
	Cruise phase	10
	Landing phase	30
	All phases	11

Table 4 shows the participant pilots' evaluation of meteorological conditions on flight safety phenomena. According to the assessment of some participants, weather conditions affect all phases of the flight, adversely affecting flight safety. When the effect of the briefing phase on the planning is examined according to Table 3, few participants stated that the flight planning could affect the cancellation process. It was determined that the decision to cancel the flight according to the weather conditions while the flight personnel was on the ground did not have an effect in terms of stress but negatively affected the service quality.

According to some responses to the research questions, there is a risk that weather conditions will impact the aircraft up to a particular altitude during takeoff. On the other hand, it is seen that going to a different airport in a wide area can be managed more calmly and comfortably in terms of planning. According to the pilots’ statements, the landing phase reduces the safety of the participant pilots under wind shear and heavy rain conditions and puts them into challenging conditions.

The participants drew attention to some facts regarding the flight phases of adverse weather conditions. Here are a few examples:

• “Especially the deterioration of adverse weather conditions is the first factor for flight cancellations during landing and take-off. The impact of meteorological information and the pre-departure briefing is high, as an indirect factor in forcing the geographical conditions in the airport area and in the case of out-of-limits. The plan’s content to be implemented is revealed by examining the topographic geography and creating the resources for safety and crew management (P1).

• “If we have enough time to analyze the threats and risks that may occur during the briefing, especially during the cruising phase, we will be ready for an effective data management process in the decision-making phase (P4).”

• “METAR reports are critical in landing and take-off. If there is a wind shear at take-off and crosswind limits are very high on approach, the possibility of diverting and holding may cause disruptions in service quality (P34).

Table 4 reveals that pilots mentioned the impact of meteorology on aviation and its detrimental effects on all aspects of flight operations. The participating pilots have firsthand knowledge of the need to understand the fundamentals of METAR data, the importance of solid communication between flight crews in the event of abrupt changes in the weather, and the need to take swift action to deal with challenging weather conditions. Since air-related problems may occur at these levels, stress and workload on the cockpit crew may adversely affect flight safety. For the flight crew to maintain their competence during the flight, conducting more thorough training on the necessary weather report data related to these situations is essential. One of the issues stressed by the pilots is the importance of simulator training planning for such extraordinary situations. The pilots’ awareness of sudden speed loss and altitude changes likely to occur indirectly during the flight is another crucial point that requires practice and self-confidence. Pilots need to be aware that these sudden illusions can occur at every phase of the flight, and in such circumstances, the pilots need to know what steps they need to take toward the flight instruments. When the pilots’ opinions are examined in general, it is seen that flight operations are adversely affected by the various meteorological formations created by the weather conditions. In addition, according to the participants, it turns out that this phenomenon has a negative impact on both material and passenger comfort by causing more fuel consumption economically.

4.3. Accident Events and Factors

The meteorology factor is very high in aviation accidents and crashes. Against this natural structure that can change and disrupt the global flight network every minute, companies should be able to correctly integrate the primary crew management model into their systems and create an auxiliary system that can be followed with technology.

The pilots’ opinions regarding the situations where specific requirements cannot be met in the accident factors are reflected in Table 5.

Table 5. Accident & Incident Factors

Theme	Coding	Frequency of Codes
Team Resource Management Factors	Decision making	10
	Leadership	15
	Crew Cooperation	17
	Situational awareness	10
	Performance under stress	20
	Skill and competence	19
Meteorological Data	Data tracking	14
	Data sharing	16
	Data analysis	10
	Data management	17
Safety Management	Identifying risks	10
	Analysis of risks	12
	Risk management	9
Documentation	Education	39
	Check-list usage	6
	Experience	32

In particular, the reflected results of the lack of certification and the factors affecting the economic, service, and future developments of airline companies in line with the opinions expressed by the participants were created and reflected in the table. More than half of the pilot's state that inadequacy of training and experience negatively affects the industry and that the communication and management in the cockpit are of poor quality.

• "Commercial airlines should not reduce the number of pilots with over 20 years of experience below 50 percent. The best way to pass on knowledge is to retain highly experienced pilots and officially train them in a master-apprentice relationship. (P27).

• "Meteorology education, which will start in flight schools in particular, may enable commercial airline companies to train candidates with quality information and a certain level of competence in data analysis more efficiently (P40)."

It is necessary to record data management errors of airline companies. The participants stated that it is essential to provide support to the pilots by sharing the questions about which CRM factor was used for the mistake made, how it was reacted, and what should have been done with all the pilots within the company and by analyzing with experience when the same situation is encountered in the future stages. Regarding Table 5, the participants reaffirmed that the simulation training included in the training content supported improving skills, competence, stress management, decision-making authority, and pilotage characteristics under challenging conditions. As much situational awareness as possible can be used in effective data management for the existing cockpit crew, and it is seen as a high factor in making important decisions in emergencies.

5. Conclusion

Crew resource management has laid the foundation for the first research since the early days of commercial aviation due to the demands for flight safety from meteorological indirect incidents and accidents and the rapid improvements in aviation technology. The failure to properly apply the decision-making mechanism and the lack of communication in the human aspect led to the events and accidents that began to happen due to meteorology. Research has shown that pilots could not perform rescue maneuvers in most aircraft crashes brought on by wind shear occurrences that pushed the aircraft's aerodynamic properties too far. This was due to their inexperience and lack of training. The crew resource management component, which has been steadily introduced and is now one of the primary factors reducing the error rate in the decision-making phase, has been added to the communication, coordination, and data management procedures in the cockpit of piloting errors. With a better grasp of resource management and the ability to analyze and handle meteorological data more successfully, the crew was able to play an essential role in improving flight safety due to these studies.

The study's use of the CRM discussions included the sub-dimensions of CRM, the consequences of bad weather, the idea of flight safety, and the connections between them. Numerous studies conducted in the past have determined the significance of meteorology in the service industry and civil aviation. In the same way, several studies have backed up the importance of the CRM concept for flight safety in aviation, as shown in this study's literature review section. But in terms of flight safety and flight operations, this study discusses the value of crew communication for better management of pilots' CRM skills in adverse weather.

Within the scope of this study, data were collected by face-to-face interview method applied to pilots working in private and public-based commercial airline companies within the range of Turkish civil aviation. The study's findings can be categorized as follows according to the research questions it generated:

- Experience and practical gain in adverse weather conditions positively affect CRM skills; positive use of communication in the cockpit is more successful in managing CRM.
- Pilot skills, especially in ensuring flight safety; It has been observed that flight crews with better self-awareness, social awareness, self-management, and relationship management skills are more likely to comply with the rules of the airline they work for and successfully maintain their composure.

The failure to properly apply the decision-making mechanism and the lack of communication in the human aspect led to the incidents and accidents that started occurring due to meteorology. In the research, it has been seen that the pilots could not perform the rescue maneuvers due to the lack of experience and training, especially due to the wind shear event pushing the aerodynamic properties of the aircraft excessively in most aircraft crashes.

The crew resource management component, which has been steadily introduced and is now one of the primary factors in reducing the error rate in the decision-making phase, has been added to the cockpit's communication, coordination, and data management procedures that reduce piloting errors. As a result of this research, the crew started to play an influential role in flight safety with an understanding of resource management. It enabled the analysis and management of meteorological data more effectively.

Pilots are obliged to monitor flight safety in the cockpit continuously. When we examine the universe of research in this direction, it is a research that focuses on diversity and aims to collect data from a sizable sample by interviewing 50 participants who are knowledgeable in the positive and negative effects of meteorological data on crew resource management in terms of flight safety and who also have strong views and firsthand knowledge of these phenomena.

As a result, the high level of communication and awareness in the cockpit will lead to increased business data tracking. Thus, the success of airline companies consisting of individuals with sufficient theoretical knowledge and high communication skills will be sustainable. Although only a few studies have been conducted in the literature on the importance of crew resource management to prevent or minimize accidents, it has been observed that the training provided needs to be improved in management and theory and that the pilots have difficulties during sudden adverse weather conditions. For this reason, the airline company should give importance to and develop experienced captains' skills. Thus, they can achieve their goals of attaining a higher flight safety rate.

Limitation & Further Research

The study has some limitations. Data were collected only from pilots flying in Türkiye. The relationship between CRM skills and emotional intelligence can be examined with different measurement scales. The application can be expanded to a larger sample, including cockpit crews and other fields of activity in the aviation industry. Emotional intelligence education ought to be a part of the school curriculum since those with high emotional intelligence are successful and can maintain this success in practically every area of life.

Practical Implementations

To prevent accidents in aviation, meteorology, and communication-based procedures should be adapted to the Crew Resource Management Training of pilots who continue their flight activities. Experience during adverse weather conditions positively affects flight safety culture. In this sense, managers must integrate CRM workshops into pilot simulation training programs to develop teamwork, stress management, communication, meteorology data management, and decision-making skills in aviation. However, in the recruitment process of new pilots, it should be essential to measure whether they have positive attitudes toward crew resource management and crew resource management skills, and some tools should be developed to make these measurements.

Organizing stress management workshops or training sessions in the cockpit environment is necessary to teach pilots techniques for managing work-related stress. So much so that "Individual Stress Awareness" positively affects the flight safety culture. For this reason, it is essential to be aware of personal concerns like stress, risking flight safety, taking into account the human factor, experience, and exhaustion in accidents that take place in adverse weather conditions. This cognitive safety mechanism, which reveals the individual mistakes of the person, will positively affect flight safety by encouraging the transfer of corporate failures as learning opportunities and experiences rather than as a punishment method.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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