THE ANALYSIS OF CIVIL AVIATION ACCIDENTS AND INCIDENTS WITH CREW RESOURCE MANAGEMENT (CRM) SINCE THE BEGINNING YEAR OF 1979*

1979 YILI BAŞLANGIÇ DÖNEMİNDEN İTİBAREN EKİP KAYNAK YÖNETİMİ (EKY) İLE SİVİL HAVACILIK KAZA VE OLAYLARININ ANALİZİ

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Abstract:

Crew Resource Management (CRM) is one of the key global aviation endeavors to reduce the number of accidents aiming a safe and efficient worldwide air transportation. Knowing that aviation authorities as well as ICAO (International Civil Aviation Organization) have shown numerous efforts in this respect since the 1970s. It is essential to comprehend if those aviators' attempts have been adequate or not. This paper questions the effectiveness of worldwide CRM efforts by making an unbiased comparison between the accident rates within predefined time periods of CRM and naming them as phases of its evolution and the efforts shown for development. The study is aimed to define the CRM concept by dividing into five stages and making the analysis of the accident and incident rates according to these stages. The results of this study indicate that continuous CRM development has improved worldwide air transport safety throughout the years. The main focus should be on better equipped and trained pilots by enhancing their linguistic performance in operational procedures.

Keywords: Crew Resource Management (CRM), Aviation Safety, Flight Training, Human Factors, Commercial Aviation.

Öz:

Ekip Kaynak Yönetimi (EKY), dünya çapında emniyetli ve verimli bir hava taşımacılığını hedefleyen kaza sayısını azaltmaya yönelik kilit küresel havacılık çabalarından biridir. Havacılık otoritelerinin ve ICAO'nun bu konuda 1970'lerden beri sayısız çaba gösterdiği bilindiğinde, bu girişimlerin yeterli olup olmadığını anlamak önemlidir. Bu makale, EKY'nin önceden tanımlanmış zaman periyotları içindeki kaza oranları arasında tarafsız bir karşılaştırma yapmaktadır. Bu karşılaştırma evrim aşamaları ve geliştirme için gösterilen çabalar olarak adlandırarak dünya çapındaki EKY çabalarının etkinliğini sorgulamaktadır. Çalışma, EKY kavramını beş aşamaya ayırarak ve bu aşamalara göre kaza ve olay oranlarının analizini yaparak tanımlamayı amaçlamaktadır. Bu çalışmanın sonuçları, sürekli EKY gelişiminin yıllar boyunca dünya çapında hava taşımacılığı emniyetini arttırdığını gös-

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termektedir. Bu nedenle çalışmanın temel odak noktası daha iyi donanıma sahip ve eğitimli pilotlar yetiştirerek, operasyonel prosedürlerle birlikte dil performansının geliştirilmesi şeklinde ortaya çıkmaktadır.

Anahtar Kelimeler: Ekip Kaynak Yönetimi (EKY), Havacılık Emniyeti, Uçuş Eğitimi, İnsan Faktörleri, Ticari Havacılık.

INTRODUCTION

Crew Resource Management (CRM) is the administration of all resources that are available to the crew, rather than the resources themselves. In other words; it is a management process that enables them to use their cognitive abilities, technical and non-technical skills to effectively display expected behavioral performance by using time, information, human, and equipment effectively (Lauber, 1984: 20). CRM is described by the United Kingdom Civil Aviation Authority as: "A management system which makes optimum use of all available resources (equipment, procedures, and people) to promote safety and enhance the efficiency of flight operations". Different practices were introduced at the Cockpit Resource Management Conference held in 1979 so that flight crews related to the implementation of team resource management thought in civil aviation could exhibit their CRM skills more effectively. Since then, it is seen that CRM has been continuously developed (Helmreich et al, 1999: 21) and expanded from the subject date (Authority, CA., 2014: 62) until the present day (Jimenez et al, 2015: 946). The success of CRM is dependent either on the complex technologies used in the flights with the user-guiding methods for enhancing the working capacity of pilots (Helmreich and Merritt, 2017) or to the effectiveness of the pilots' training in nontechnical skills desired for flight crews for the safe operation of an aircraft" (Jimenez et al, 2015: 947). Airlines follow CRM advances through training for their flight crew, so the authors suggest that airlines operate for the sole purpose of giving CRM an application (Wagener & Ison, 2014) because the capability of controlling and reducing the safety risks unsurprisingly brings a competitive advantage (Salas et al, 2010: 9).

1. PRELIMINARY DISCUSSION: RELATION BETWEEN ACCIDENT RATES AND SAFETY AND CRM

This study claims that efforts for CRM have resulted in lower accident rates in worldwide air transportation. In this paper, the improvement has been recorded regarding some predefined phases in the literature as compared with accident statistics. It is found evidence of a decrease in statistical data on occupational accidents and damage to aircraft in care institutions where human factors (HF) trainings are provided. Defining accident rates as an objective measure for success or fail, a previous study had questioned the contribution of CRM to air transportation. Nonetheless, since the accident rates are too low in air transportation, it is not easy to make a respectable assesment (Helmreich et al, 1999: 22). Another study has also questioned the contribution of CRM to safety level of world wide air transportation in an attempt to offer to

apply "most obvious, objective measure, namely accident data". Unfortunately, these authors abstained from using accident data due to the same reason (Flin et al, 2002). The authors of this study will advocate the use of accident data as an objective measure of continuous efforts to enhance CRM since a lot of lessons could be learnt from them either in the past or in present. Failures in CRM are noted as the most frequent circumstantial factor in accidents occurred in Asian and African airlines. Another previous study where the outcomes of the CRM trainings were discussed (Bennett, 2018: 657), a questionnaire was distributed to flight and cabin crew as participants of the CRM trainings where they were asked about how to improve the effectiveness of the trainings.

In addition, in the same study the participants demanded for the CRM trainings to be carried out where the cabin and cockpit crews are participants together. The idea behind was the requirement that the cabin and non-cockpit issues be included in the trainings in order to anticipate situations those could threaten safety. Besides the participants specifically requested the use of innovative training models. The two main objectives of CRM are increasing safety and flight efficiency and it is not easy to determine how much CRM based implementations comply with these objectives. In this respect, it had better try to recognize the fact that CRM trainings do not have the same effect on each participant in every kind of businesses. If it is checked the historical development, it is realized that the belief in the importance and necessity of CRM trainings by the participants developed and increased the impact on operations later than expected. CRM training programs generally include psychology-based topics and aim to strengthen the cognitive and social aspects of the participants. Furthermore, there are criticisms in the literature that these trainings should be enriched in terms of socio-cultural aspects (Helmreich and Merritt, 1999; Hearkens et al, 2015; Wahl & Tongsvik, 2018: 386; Moffatt-Bruce et al, 2017: 7). Although the purpose of an ideal CRM training is certain, there is no compromise how the content should be (Man et al, 2020: 81). When the development of CRM trainings from past to present is evaluated, it can be seen that lessons are learned. adequately. CRM is restructured in accordance with the developing understanding of safety (Helmreich et al, 1999: 23; Bennett, 2018) and more and more it is focused on the non-technical skills of aviators. The content of CRM trainings has evolved to team operations in keeping with the mutual effect of the dynamic environment (Hearkens et al, 2015), though it was limited with individual constraints in the workshop at NASA in 1979 (Man et al, 2020: 82).

2. DEVELOPMENT STAGES OF CREW RESOURCE MANAGEMENT IN AIRLINE BUSINESSES

When the development of aviation for nearly one hundred and twenty years is examined, one could easily see that the impact and importance of human factors were realized only in the last quarter. Moreover, it can be said that the idea of CRM is actually the product of a human-oriented approach and the result of studies based on human factors (Authority-CAA, CA., 2002). The goal of all CRM processes is to prevent accidents and reduce human errors

to a controllable level to achieve this (Jimenez et al, 2015: 948). However, although CRM only envisaged avoiding mistakes in the initial period (Helmreich et al, 1999: 24), it later aimed at the development of non-technical capabilities of the flyers especially under the influence of the paradigm shift in safety thinking (Gerede, 2015: 108) and has a character in concordance with the Safety Management System (SMS) (Bennett, 2019: 1363). CRM based implementations have focused on solutions to the problems faced during the flight such as decision making either solo or with the team, establishing effective communication with the crew members, overcoming present leadership problems, enduring fatigue especially due to underemployment, and other difficulties related to resources since the early days (Shappell et al., 2006).

Considering the technological developments experienced since the 1950s; first of all, accidents due to advancement in turbo-jet engine technology has been reduced, development in avionic systems has contributed significantly to safety (Wiener et al., 2010) especially with the development of CRM trainings (Helmreich & Foushee, 2010: 17) and then focus on people in all activities aiming at preventing accidents became more palpable. In the implementation of the CRM idea in civil aviation; two recorders which developed rapidly from 1950s to 1970s were located in cockpits as required by Apendix-6. The name of the recorders in Apendix-6 are classified as; Flight Data Recorders (FDRs) and Cockpit Voice Recorders (CVRs) (Authority, CA., 2014: 63). The information is taken from these recorders after realized that causes of many accidents are directly with human errors and these problems are concentrated in interpersonal skills, communication, decision-making, and leadership. As a matter of fact when the solutions obtained by using technology combined with modern simulator possibilities, (Helmreich et al, 2010: 495) there was a great decrease in the number of accidents which taken by National Transport Safety Board accident and/or incident reports (www.ntsb.gov). The CRM based implementations ensue from an interdisciplinary area where variety of studies had contributed to behavioral sciences. Parallel to the developments first in ergonomics in UK during 1950s (Helander, 2005) and human factors (HF) in USA in the coming years (Moray, 2008: 413) aviation engineers realized the importance of the human-machine relationship in the 1960s and started to work on the effective use of human skills and necessary resources to fly the aircraft effectively and safely by emphasizing ergonomic designs (Barbé et al, 2012: 11). However, it was understood by the historical events highlighted below that it would not be sufficient to limit the studies to the cockpit design and the machine-human relationship. The efforts continuously improve the HF and the interaction area which affect the continuation of flight uninterruptedly and continuously.

3. PHASES OF DEVELOPMENT IN CRM

There has been an increasing demand for civil aviation and also for the design of aircrafts. Boeing 747-100 the first wide-body aircraft was put into service causing it to change the design of the terminal buildings and the airport capacity was no longer limited to the runway and apron dimensions, but also the terminal building capacity which increased the passenger capacities and occupancy rates. Accordingly, it is seen that scheduled flights

spread rapidly around the world. The tariff brought the imperative to balance "capacity and demand" which brought about feasible global agreements and rules. The introduction of new technologies in aircraft structure and navigation has caused the workload of aviators to undertake operational tasks. In the context of developing new threats and risks this endanger safety, a series of accidents and the development of new generation understandings should be evaluated within this framework. After 1978, liberalization which spread wave by wave from the US center, paved the way for benefiting from Scope Economies and air transportation has reached its current structure step by step thanks to hubs developing in suitable geographical locations. In the beginning of the airline companies' prioritizing and paying special attention to the CRM issue, the location of a series of accidents that occurred in the 1970s caused by flight crew errors (Helmreich et al., 1999: 25) and the lessons learned from these accidents played a role in the rapid development of the CRM training programs (Muñoz-Marrón, 2018: 192). The accidents that took place until 1979 and mentioned above led to the discussion of the competencies and training of the volatiles. However, it can be said that the disaster which took place in Tenerife Airport in 1977 which was realized by the collision of two Boeing 747 passenger aircrafts pushed the airline companies and the responsible authorities to do more than what had been done about CRM. Just a few weeks after the accident, NASA organized a workshop and made the first decision of an innovative education (Cooper & Saunders, 1980: 933). NASA researchers' work on the causes of accidents between 1968 and 1976 in jet air transport has been accepted as the reason for launching the pioneering HF program in aviation safety (Sexton and Helmreich, 2000: 65) and can be considered the beginning of CRM applications (Helmreich et al., 1999: 26).

3.1. Phase-1: Cockpit Resource Management (1979-1986)

It is seen that NASA is a leading institution for CRM in 1973 by providing HF trainings in aeronautics and astronautics (Helmreich et al, 1999: 27). Among the causes of the Tenerife accident, which was widely discussed at the beginning of CRM applications, it was observed that there was a combination of low assertiveness, leadership, fatigue, decision making and communication problems. In addition, the data obtained from CVR devices which were started to be used in the same period revealed that crews could not fulfill their responsibilities in Flight Deck in accidents (Flin et al, 2002). Lauber (1984: 21) defines the purpose of the initial period CRM trainings as "using the all available resources - information, equipment, and people - to achieve safe and efficient flight operations". The courses included a few topics based on psychology and one of the most prominent topics such as psychological tests and the concept of leadership and generally took place in the classroom setting (Helmreich et al, 1999: 28). Employees were able to discuss their practices in their business during a series of seminars (Muñoz-Marrón, 2018: 193). When it is focused on introducing airlines to CRM training, it is seen that the first comprehensive CRM training was carried out by United Airlines in 1981. This pioneering training developed by psychologists Robert Blake and Jane Mouton and modeled similarly to the management system (Merritt and Helmreich, 1996: 22) focuses on the assertiveness of the team. On the

other hand, the National Transportation Safety Board (NTSB) cited the captain's failure to consider the cockpit warnings about the accident assessment in 1978 (Helmreich et al, 1999: 29). In the USA United Airlines was followed CRM applications first. After that in Europe KLM (Flin et al, 2002) and in Australia Ansett Airline were followed these applications too (Muñoz-Marrón, 2018: 194).

3.2. Phase-2: Cockpit and Cabin Resource Management (1987-1990)

Another seminar held by NASA in 1986 said, "…if CRM courses remain an ordinary part of the airline companies' training programs, it will disappear over time" (Helmreich et al, 1999: 29). However, on the same date it was seen that CRM trainings were adopted and expanded by airline companies. With the influence of the feedback received in the trainings, the word in the abbreviation “cockpit” was started to be replaced with “crew” then in a process that started with Delta Airlines. CRM focused trainings were started to get rid of the individual focus. Focus was on breaking the chain of errors leading to decision processes and disaster (Muñoz-Marrón, 2018: 195). In this period, the introduction of digital recording devices instead of first generation FDR devices brought the opportunity to increase the variety and amount of information to be obtained from accidents. Another remarkable issue in this period was the fact that it was called “it was further concluded that the management failed to recognize the human performance factors of inspection”. After the Aloha Accident in 1988, CRM issues started to be recorded for maintenance technicians other than cockpit and cabin personnel (Flin et al., 2002). In Phase-2 due to the important and rapid technological developments in the aeronautical industry, the reliability of the aircraft had increased (Alkov, 1989: 487) and therefore efforts perceptibly focused on HF.

3.3. Phase-3: Error Management Oriented CRM (1991-2001)

In this period, the basic understanding is to combine CRM trainings with technical trainings in order to have a content based on the new aircraft and navigation technologies (Salas et al., 2001: 651). Aviation unfortunately have been dictating some developments regarding CRM in aftermath of accidents. An appropriate example can be the accident in Kegworth, UK. Although the cabin crew knew which engine was burned at England in 1989, the cockpit team regrettably stopped the wrong engine. Thus, it is understood that CRM trainings started to be given to the cabin crew after the crash where the main topics are “personality awareness, human error, information acquisition and processing, situtional awareness, workload management, stress, fatigue and assertiveness” (Flin et al., 2002). More importantly, the concept of "organizational error" introduced by James Reason into the literature since the early 1990s has been the driving force of the development of a new understanding in safety and CRM trainings. CRM trainings have been expanded on the basis of concepts such as organizational errors and safety culture. On the one hand, leadership training is increasingly given to pilots, while CRM training has become widespread for flight attendants, dispatchers, and maintenance personnel. In this period, some airline companies have added HF training which also includes automation in the cabin and has developed

technologically in the content of CRM trainings (Helmreich et al, 1999: 29) because the troubles that may occur in the use of high technology in the cockpit have brought new threats (Muñoz-Marrón, 2018: 196). When it is reviewed the CRM syllabus of some airlines in the mid-nineties, it is seen that the topics in CRM training appeared to have expanded in the branches of; communication, leadership, teamwork, decision making, error management, situational awareness, fatigue, and automation. In 1997, the Dirty Dozen model developed by Dupont was started to be used in the CRM course for aircraft maintenance technicians in Canada to be used for root cause analysis of maintenance errors. Again during this period, "vigilance, communication and situational awareness" problems were identified as a result of the Canadian Aviation Safety Board (CASB) conducting a research on air traffic controllers towards the end of 1998. After that, "Air Traffic Team Work Enhancement - ATTE" course, which basically includes "understanding air traffic teamwork, communicating with others, being a resource and managing conflict and stress", was added to the FAA catalog. It is recently seen that in Europe, EUROCONTROL started a 3-day CRM training under the name of "Team Resource Management" where "situational awareness, decision making, communication, teamwork, leadership, and stress management" were noticeably the main topics (Flin et al, 2002). These developments should be interpreted as an indication that Reason's organizational error understanding has become effective in activities and training in air transportation. Reason's (2002: 41) model also caused extensive updates in the content of the trainings, as it also includes topics such as defense culture as a subculture of defense culture and organizational culture (Muñoz-Marrón, 2018: 196). Moreover, CRM has become common for all groups that interact during the operation area (Salas et al, 1999: 330). It is known that pilots regarded as "charm school" due to their low belief in CRM courses in Phase-1 and Phase-2, they could not position their relevance to their jobs and called them "psycho-bable". In the third term, CRM courses started to expand and to some extent dispersed in the area and the main purpose of "reducing human error" was diluted (Helmreich et al, 1999: 30). It is also known that some of the pilots defined their CRM trainings as "brainwashing by management" due to the spread in this period and the widening and dispersal in the content (Wagener & Ison, 2014).

3.4. Phase-4: Systematic CRM (2002-2010)

The first of igniters of the fourth period is shown as the Advanced Qualification Program (AQP) introduced by the FAA since the early 1990s. Thus, CRM and Line-Oriented Flight Training (LOFT) are now provided for flight crews and the CRM concept is integrated with other technical trainings (Helmreich et al, 1999: 30; Muñoz-Marrón, 2018: 197). The AQP enabled each company to create its own "customized" CRM training, appropriate with the requirements of each operator in order to fulfill them. AQP could match up to real-world requirements as specific response to the particular problems related to human factors was needed (Salas et al., 2001: 652). Thus, trainings to react as a team and achieve cooperation in different situations were provided by playing realistic scenarios (Helmreich et al, 1999: 30; Salas et al, 2001: 653). Accordingly, standard operating procedures (SOP) were better

determined about what to do in an emergency. Moreover, checklists that functioned healthy at the individual level could now be created and developed (Wiener et al, 2010). As a matter of fact, it has been observed that in 2000s SOP has become an increasingly important tool in safety management. The importance and benefit of SOPs is now understood in this period for the teams to have a cognitive model for each task and the performance of the teams that can act together (Wagener and Ison, 2014). Now, the foundation of CRM is to reveal all the deficiencies of the human factor and to reduce and / or prevent the errors that may arise due to positive inputs (Helmreich, 2000: 784; Reason, 2000: 769). In particular, there are findings and opinions that cultural values, insights and practices may have a widespread effect on the flight crew's attitudes and behaviors (Helmreich and Merritt, 1998: 137). In this respect, it is necessary to be aware of cultural trends at the social and organizational level in order to reveal the ESR practices that may be effective according to the environment (Helmreich and Merritt, 1998: 126; Merritt and Helmreich, 1996: 23). Following the September 11 terrorist attacks in the USA, the safety and security measures led by the FAA and their trainings have become much more systematic in national and international level. The establishment of the European Union Aviation Safety Agency (EASA) in 2002 to replace the Joint Aviation Authority (JAA) which was established in 1999 by the European Union, enabled all member countries of the union to quickly determine common procedures applicable in aviation activities (Authority-CAA, CA., 2002). In addition thanks to the Annual Safety Review published by EASA in accordance with the AP decision since 2008, it has been possible to evaluate the safety performances comparatively by looking at the accident rates of the member countries and other countries. As a result of the EU's investment in Single European Sky (SES) integration, the same and valid air traffic procedures have been developed throughout the Union. It is clear that this also reduces the risks related to air traffic (https://ec.europa.eu/). It is understood that pilot mistakes were inevitable in this period and the assumption that complete pilotage was not possible became widespread. Therefore, in CRM trainings, the focus is on increasing the error management skills of flight crews in order to reduce the impact of the factors that endanger the safety. FAA also made these trainings compulsory and strengthened its contents with recommendations. While CRM trainings are given in two types as initial and recurrent trainings in the mentioned period, it is also aimed to develop the safety culture in aviation organizations (Wagener & Ison, 2014).

3.5. Phase-5: Worldwide CRM (2011 and Beyond)

What differs Phase-5 mainly from previous phases particularly is the “normalization” of human error thus, the organizations now are able to produce new error management strategies (Helmreich et al, 1999: 31). Emerging “integrated safety management at all levels by all actors with finding and preventing from the organizational errors” has been the main idea and directly effected the content of CRM trainings as well as the success during Phase-5. It has seen the impulsion behind as the development of State Safety Programs as a consequence of the voluntary efforts since 2008 and the decision given to bring out Annex-19 at the high level Safety Conference at ICAO in 2010 (ICAO, 2020). After the

subjected Conference recommended a new Annex dedicated to States, safety management responsibilities and processes framed under the State Safety Programme (SSP). After the first edition of Annex 19 Safety Management was published in 2013, businesses that have to fulfill the requirements of Doc 9859 SMS Manual have taken important steps in the dissemination and adoption of both Reporting Culture and Just Culture. It is now seen that legal regulations supporting Just Culture have been made in many countries. FAA's Aviation Safety Action Program aims to develop a safety culture that supports and assists the necessity of reporting, just as Just Culture aims. In the reporting processes which are carried out on the basis of confidentiality and volunteering of the faults that may endanger the safety. Reporting processes provide convenience to the management of the organization (Helmreich et al, 1999: 31). As well as the aviators making errors were normalized, CRM is defined as a series of measures to stop this error with three basic lines of defense. The first one avoid the occurrence of the error, the second is forecasting or searching for beginners before starting, the third and last one is to mitigate the consequences related with the errors that occurred and that it could not avoid. Thus, CRM becomes a methodology that includes a series of effective countermeasures or strategies to successfully solve situations where an aircraft can cause disaster. The difference in the way of use lies at the moment when the error is detected (Muñoz-Marrón, 2018: 197). In parallel, CRM trainings are aimed at breaking the beliefs that aviators and especially pilots are very ready and always able to cope with difficult conditions (Helmreich et al, 1999: 31). Crew resource management gives pilots and cabin crew the skills and confidence necessary for marshal resources for safe and efficient flight. CRM expresses Langer's "theory of awareness" in many ways. CRM improves listening, observation, planning, coordination, leadership and teamwork skills. It encourages the flight crew to mine for ideas, ask questions and modify with assisting methodical and constructive criticism (Bennett, 2018: 660). CRM continues to provide basic guidance on current training, effective communication, task sharing, team building and teamwork. Threat and Error Management (TEM) training approves preventive strategies for threat recognition, avoidance and management. Both CRM and TEM requires data from accidents and incidents resulting from Flight Operations Quality Assurance (FOQA) programs and Line Operational Safety Audits (LOSA). The most effective training platform for airlines today is LOFT where the crew must fly a simulated flight scenario between two or more points. These scenario-based learning tasks include a combination of modern, adherence simulators and the application of normal flight operation procedures. LOFT provides the most realistic setting that crew performance can be measured according to the operating environment (Wagener & Ison, 2014). In the fifth period depending on the above understanding after the CRM was sent off. Muñoz-Marrón (2018: 198) stated that another sixth period came to the fore. The main feature of this phase is greater awareness of the contextual risks that needs to be managed. Flight crews should now also deal with threats to flight safety from the working environment as a whole. Filght crews should now also deal with threats to flight safety from the working environment as a whole. The differentiation process marked by Muñoz-Marrón could be seen as the precursor of the post-2010 period

of Troika Model. This model was determined by Helmreich in 2006 and considered early to define a sixth period in the literature.

4. METHODOLOGY

In this paper Kruskal Wallis test is used for civil aviation commercial passenger numbers. Mann-Whitney u test is used for the average number of passengers. Fisher's Exact and *Chi-Square tests are used for comparison parameters according to investigation type. In table 1 event dates are examined with the number of passengers (billion), in table 2 post-hoc pairwise comparisons (p) are done related with number of pasengers, in table 3 investigation type is examined with accident and incident rates as segmentating event date, injury severity, aircraft damage and purpose of flight. In table 4 and 5, Hosmer-Lemeshow test is used for event date and purpose of flight dependent of investigation types. In figures; event date and the stages of total number (billion) accidents/incidents rates, aircraft damages rates and purpose of flight are shown as incident and accident rates. Solely, injury severity rates are shown as destroyed, minor and substantial. In addition, the normality test was done with Shapiro-Wilk test. Non-parametric statistical methods were used for values with inclined (non-normally distributed, Shapiro-Wilk $p>0.05$) distribution. Descriptive statistics were existed using mean and standard deflection for normally distributed variables and median (and minimum-maximum) for the non-normally distributed factors. Non-parametric statistical methods were used for values with inclined distribution. For comparison of two non-normally distributed independent groups, Mann-Whitney U test was used. For comparison of more than two non-normally distributed independent groups, Kruskal Wallis test was used. In order to investigate the effect of parameters on investigation type, Logistic Regression was used. The χ^2 test and Fisher's exact test were used for categorical factors and defined as observation amounts (and percentages). Statistical significance was accepted when two-sided p value was lower than the value of 0.05. Statistical analysis was performed using the MedCalc Statistical Software version 12.7.7 (MEDCALC, 2013). The Shapiro-Wilk test is a way to assert if a random sample comes from a normal circulation. The test delivers a W value, by the way small values state the sample is not normally circulated. It can reject the null hypothesis that the population is normally disseminated, if the values are below a specific verge (Statistics How To, 2020). The Kruskal-Wallis H test (sometimes also called the "one-way ANOVA on ranks") is a rank-based nonparametric test that can be used to adjust, if there are statistically significant distinctions among two or more groups of an independent factor on a continuous or ordinal dependent factor. It is noticed the nonparametric alternate to the one-way ANOVA and an extending of the Mann-Whitney U test to authorize the crosscheck of more than two independent groups (Laerd Statistics, 2020). All of the variables which are used for the tables are taken from (NTSB, 2020) and (Plane Crash Info, 2020) web sites.

Table 1: Kruskal wallis test for total civil aviation commercial passenger numbers

		Number of Passengers (Billion)
		Mean±SD Med. (Min-Max)
Event Date	**1979-1986**	0.71±0.07 0.68 (0.64-0.84)
	1987-1990	1.02±0.15 0.97 (0.91-1.25)
	1991-2001	1.38±0.20 1.39 (1.13-1.67)
	2002-2010	2.06±0.31 2.07 (1.63-2.63)
	2011-2018	3.42±0.52 3.34 (2.79-4.23)
	p	<0.001

There is statistically significant difference between event date in terms of number of passengers (billion) ($p<0.05$).

Table 2: Mann-whitney u test

Post-Hoc Pairwise Comparisons (p)	**Number of Passengers (Billion)**
1979-1986 vs. 1987-1990	0.004
1979-1986 vs. 1991-2001	<0.001
1979-1986 vs. 2002-2010	<0.001
1979-1986 vs. 2011-2018	<0.001
1987-1990 vs. 1991-2001	0.018
1987-1990 vs. 2002-2010	0.003
1987-1990 vs. 2011-2018	0.004
1991-2001 vs. 2002-2010	<0.001
1991-2001 vs. 2011-2018	<0.001
2002-2010 vs. 2011-2018	<0.001

According post-hoc pairwise comparisons, the average number of passengers between 2011-2018 is found higher ($p<0.005$ Bonferroni correction). Post hoc tests are a complementary part of ANOVA. When it is used ANOVA to test the equivalence of at least three group means, statistically considerable results indicate that not all of the group means are equivalent. However, ANOVA results do not adjust that specific distinctions among couples of means are considerable. It is used post hoc tests to work out variations among plural group means while examiningthe experiment-wise error percentage (Statistics By Jim Making Statistics Intuative, 2020).

Table 3: Fisher's Exact test,*Chi-Square test - Comparison Parameters According to Investigation Type

Investigation Type		Accident		Incident		p[1]
		Number	%	Number	%	
Event Date	1979-1986	283	17.9	28	30.4	0.007
	1987-1990	158	10.0	13	14.1	
	1991-2001	478	30.2	16	17.4	
	2002-2010	389	24.5	19	20.7	
	2011-2018	277	17.5	16	17.4	
Injury Severity	Fatal	354	22.3	0	0.0	-
	Incident	0	0.0	92	100.0	
	Non-Fatal	1229	77.5	0	0.0	
	Unavailable	2	0.1	0	0.0	
Aircraft Damage	Destroyed	412	26.0	0	0.0	<0.001
	Minor	11	0.7	91	98.9	
	Substantial	1162	73.3	1	1.1	
Purpose Of Flight	Passenger Transportation	347	21.9	9	9.8	0.002
	Flight Training	411	25.9	28	30.4	
	General Aviation	761	48.0	55	59.8	
	Cargo Transportation	66	4.2	0	0.0	

In this table fisher's exact test is related with independence when there are two nominal variables and it is aimed to see whether the percentages of one factor are different depending on the value of the other factor. This test is suitable when the sample size is small (Biostat Handbook, 2020). Fisher's exact test is usable when there are two nominal variables. It should be known whether the proportions for one variable are different among values of the other variable (van Nood et al., 2013: 411). Chi-square test is one way to show a relationship between two categorical factors. In statistics, there are two factors: numerical (countable) factors and non-numerical (categorical) factors. The chi-squared test explains how much distinction exists among the observed counts and how this counts would anticipate if there were no relationship at all in the population. For instance, it is used how the data collected and which hypothesis is being tested. However, all of the factors use the same idea which crosschecks anticipated originally gathered values (www.statisticshowto.com). There is statistically significant difference between investigation type and event date, aircraft damage and purpose of flight ($p<0,05$). The incident rate is higher for the years between 1979-1986 and the

accident percentage is found higher in the years between 1991-2001. The accident percentage is found higher for Substantial Damage, the injury severity is higher for Non-Fatal accidents and the accident percentage is found higher for General Aviation. Investigation type covers two dimensions. These are accident and incident. At first sight, incident is more general and accident is more specific. Incident can refer to any event which is big or small, good or bad and intentional or unintentional. On the other hand, an accident is a bad event caused by error or unfortunate coincidence. Accidents are always unintentional and they usually result in some damage or injury. Event dates have covered a 40-year period which had started from the last phase of civil aviation history (deregulation period 1978 to nowadays) and the origin of Crew Resource Management Concept (early name Cockpit Resource Management). These phases are in a determining position for directing civil aviation. Because of that authors decided to examine 40-year period which started from 1979 and ended in 2018. Injury severity covers four concepts. These are fatal, incident, non-fatal and unknown events. Fatal events are deadly and creates big damage. For instance; fatal accidents are injuries that results in death in the accident itself or up to 30 days after the accident. Non-fatal accidents are injuries that requires more than 2 days of hospitalization up to 7 days after the accident. Incidents are injuries that requires less than 2 days of hospitalization up to 7 days after the accident. Aircraft damage covers three concepts. These are destroyed, minor and substantial events. Destroyed events is related with the aircraft is not repairable. If the aircraft is repairable, the cost of repairs exceeds 50% of the cost of the aircraft when it was new. Substantial events is related with damage or failure that adversely affects the structural strength, performance or flight characteristics of the aircraft and which would normally require major repair or replacement of the affected component. Minor events is related with damages that neither destroys the aircraft nor causes substantial damage. Purpose of flight covers four concepts which are mentioned above. Passenger transportation is the most used module in civil aviation that carrying passengers commercially with ticket. General aviation is the second used module in civil aviation that carrying passengers commercially and uncommercially with specific purposes. Flight training is the third used module related with the purpose of pilot candidate practice. The last one is cargo transportation that used for carrying mail and cargo (usually special cargoes like organs, perishable, valuable and dangerous goods). When the rates are examined general aviation is the second most used but the accident and incidents rates are the highest (ICAO, 2020).

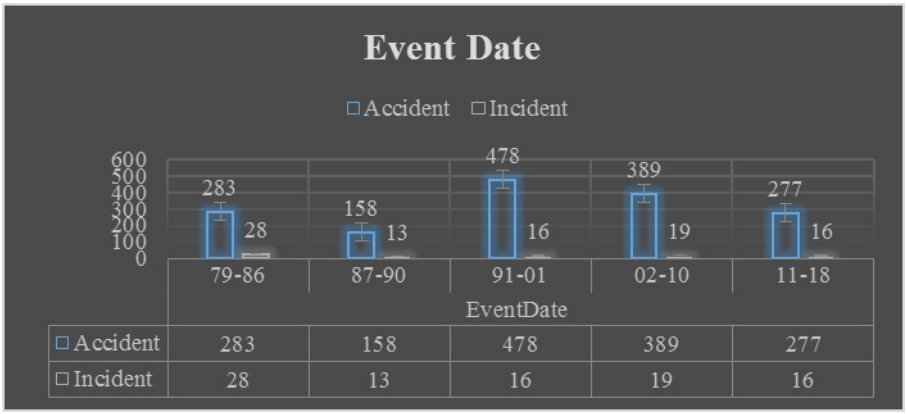

Figure 1: Event Date

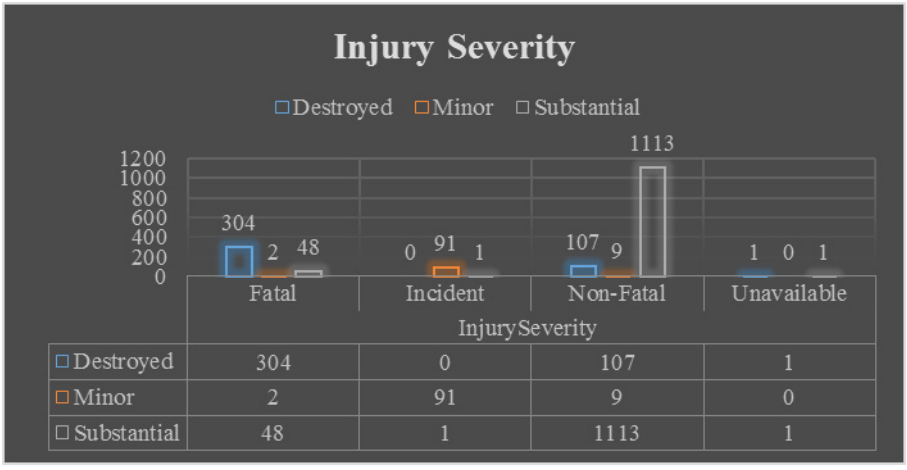

Figure 2: Injury Severity Rates

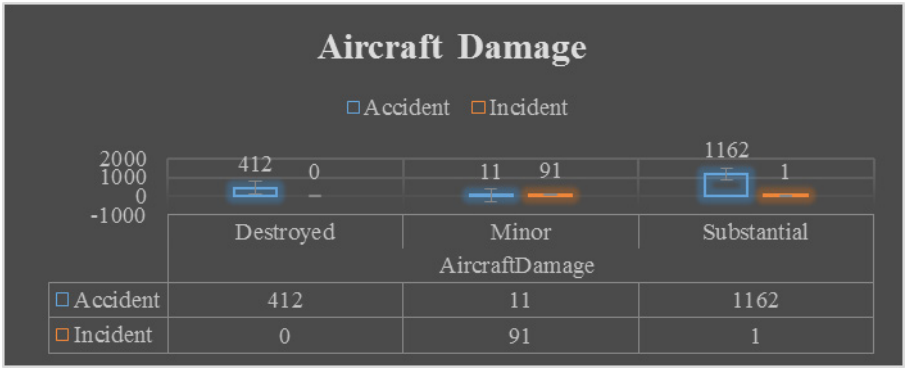

Figure 3: Aircraft Damages Rates

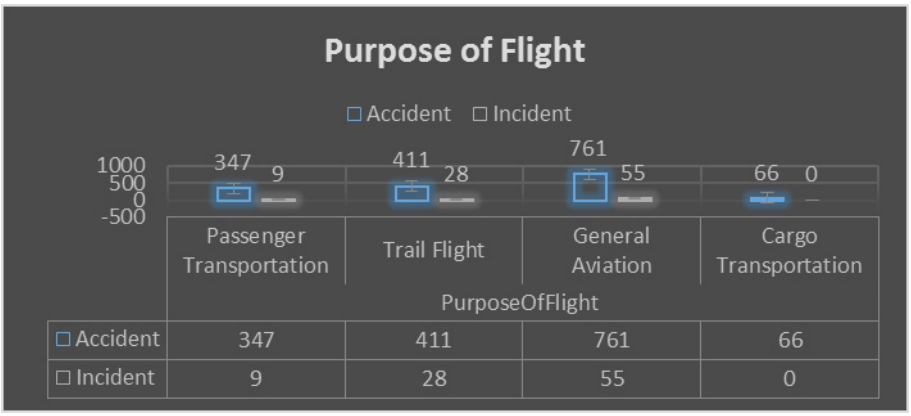

Figure 4: Purpose of Flight

Like the tables, all these statistics used for figures are taken from (NTSB, 2020) and (Plane Crash Info, 2020) web sites.

5. FINDINGS - LOGICTIC REGRESSION ANALYSIS

To show the factors affecting investigation type (accident vs. incident) binary logistic regression model is conducted. The odds ratio (OR) is calculated to reveal the event dates and purpose of the flight's impact.

Table 4: Event Date - Dependent: Investigation Type

	p	OR	%95 CI Lower	%95 CI Upper
1987-1990	0.598	0.832	0.419	1.651
1991-2001	**0.001**	0.338	0.180	0.636
2002-2010	**0.022**	0.494	0.270	0.902
2011-2018	0.097	0.584	0.309	0.103

Event date is modeled as independent variables. When the significance of the model was examined, with a value of $p = 0.008 < 0.05$ was found. The Hosmer-Lemeshow test value is $p = 1.000 > 0.05$, so the model is suitable for interpretation. The years between 1979-1986 is selected reference category. The years between 1991-2001 and 2002-2010 are found significant as risk factors ($p<0.05$). Those between the years 1991-2001 decrease the incident by $1 / 0.338 = 2.958$ times compared to those between the years 1979-1986. Those between the years 2002-2010 decrease the incident by $1 / 0.494 = 2.024$ times compared to those between the years 1979-1986.

Table 5: Purpose of Flight - Dependent: Investigation Type

	p	OR	%95 CI Lower	%95 CI Upper
Flight Training	**0.013**	2.627	1.223	5.642
General Aviation	**0.005**	2.787	1.362	5.702
Cargo Transportation	0.997	0.000	0.000	-

Purpose of flight is modeled as independent variables. When the significance of the model was examined, with a value of $p<0.001$ was found. The Hosmer-Lemeshow test value is $p = 1.000>0.05$, so the model is suitable for interpretation. Flight training and general aviation are found significant as risk factors ($p<0.05$). Passenger transportation is selected reference category. Flight training increases the incident by 2.627 times compared to Passenger Transportation. General aviation increases the incident by 2.787 times compared to Passenger Transportation.

All tables are analyzed below with the segmentation of five phases:

Before 2011, organizational and technical factors are formed the highest rate of civil aviation incidents and/or accidents. In the last phase of CRM with the participation of SMS concept, organizational and technical factors' percentages have decreased. So, human factors' percentage has the highest rate and the subjects in subsidiary discussion are related with minimizing human factor related incidents and/or accidents (www.planecrashinfo.com).

The first phase includes the years between 1979-1986. In this eight-year period an average of 708,000,000 passengers (total number 5,664,000,000 passengers) used civil air transportation on an annual basis, while the average number of accidents per year is 38.75 (total number 311). When the accident average is taken on an annual basis, the rate of reveals as 0.0000000549%. This rate appears as a number of accident and/or incident statistics per 18.27 million passengers.

The second phase includes the years between 1987-1990. In this four-year period an average of 1,023,000,000 passengers (total number 4,092,000,000 passengers) used civil air transportation on an annual basis, while the average number of accidents per year is 42.75 (total number 171). When the accident average is taken on an annual basis, the rate reveals as 0.0000000417%. This rate appears as a number of accident and/or incident statistics per 23.92 million passengers.

The third phase includes the years between 1991-2001. In this eleven-year period an average of 1,378,000,000 passengers (total number 15,160,000,000 passengers) used civil air transportation on an annual basis, while the average number of accidents per year is 44,909 (total number 494). When the accident average is taken on an annual basis, the rate reveals as 0.0000000326%. This rate appears as a number of accident and/or incident statistics per 30.68 million passengers.

The fourth phase includes the years between 2002-2010. In this nine-year period an average of 2,057,000,000 passengers (total number 18,518,000,000 passengers) used civil air transportation on an annual basis, while the average number of accidents per year is 45,333 (total number 408). When the accident average is taken on an annual basis, the rate reveals as 0.0000000220%. This rate appears as a number of accident and/or incident statistics per 45.375 million passengers.

The fifth phase includes the years between 2011-2018. In this eight-year period an average of 3,416,000,000 passengers (total number 27,334,000,000 passengers) used civil air transportation on an annual basis, while the average number of accidents per year is 36,625 (total number 293). When the accident average is taken on an annual basis, the rate reveals as 0.0000000107%. This rate appears as a number of accident and/or incident statistics per 93.269 million passengers.

6. SUBSIDIARY DISCUSSION

All of the aviation organizations established their safety management systems and this systematic and integrated functioning enabled management of safety at all levels. SMS Manual required the management of safety at a national level via SSP, organizational level via SMS corporate manuals, and the individual level via advanced SMS and CRM training in place. Secondly, better equipped and well-trained pilots are employed. Auxiliary software and equipment make life easier for pilots that give more time for a reaction when critical action is required. Besides, simulators are highly developed. They have a very critical role to make pilots prepared for difficult cases. Furthermore, simulators help pilots to test their skills and reactions in cases like Controlled Flight Into Terrain (CFIT).

Thirdly, enhanced linguistic performance for operational procedures can be observed since aviation English is much widely used. Aviation organizations employ aviators from different nations with better English skills with a better adaptation to socio technic environment where many players interact with each other. Fourthly, scientific studies related to the necessities and achievements of the CRM concept arouse. Many airline companies take benefits of the results of these studies. Interdisciplinary studies have helped a lot to civil aviation in means of safety thinking since the beginning and it will undoubtedly continue to do so with further endeavors.

CONCLUSIONS and RECOMMENDATIONS

In this paper, the aircraft crashes and incidents between the years of 1979 and 2018 were listed and analyzed by using different techniques in order to make a comparison between the accident and incident rates with predefined phases of CRM development. Such an analysis revealed the relationship between the accident rates and the development of the concept as well as an increase in relevant efforts. Although the amount of decrease has been observed vividly in the perio of 2001-2010, the biggest decreasing trend in incidents and/or accidents

has been observed after 2011, namely in the fifth and the last phase. Free from any doubt, the reason for the success rate has a link with the implementation of the Safety Management Manual (SMM) Document 9859 since December 2010. SMM document paved the way for just culture, human error was normalized and no-blame culture began to contribute to accident mitigation. Consequently, the flight crews supported and advocated CRM increasingly. This paper also presents a detailed analysis of key accident rates' by exploring the link between substantial success and the evolution of CRM thinking. Therefore, continuous development in CRM aids for worldwide air transport safety effectively. It must be known that the main focus should be in Phase-5 where mitigation of organizational errors enabled within a just-culture dominated aviation environment with better equipped and trained better pilots enhanced linguistic performance for operational procedures. In conclusion, being a preliminary study, this paper may call attention to further researches to give more value to and enhance CRM training. Scientific studies could help CRM to achieve better accident mitigation particularly on the issues of software development in simulations. For instance, aeronautical information includes assessment of safety data, further safety culture studies, and take results about error model experiences. So, the safety II concept replaced the Safety I concept for enhancing CRM and also SMS. Finally, as supported by interdisciplinary studies, it has been up to date CRM as the main tool to mitigate accidents putting human performance into centering. Therefore, aviators have made progress in enhancing the CRM concept for providing better achievements related to reducing accident rates. It is seen from the analysis that in the 2002-2010 period the civil aviation accident and incident rates were decreased by approximately %50 compared with the 1991-2001 period. This decreasing trend was continued with a high percentage in the 2011-2018 period with a ratio of more than %100. So, it can be said that the implementation of SMM Document 9859 with the practice of CRM training was decreased the accident and incident rates revealing a good performance. In future studies, the researchers can evaluate the subjects related to the Safety Management Concept by segmenting the types of incidents, and accidents.

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Disclosure Statement

In this manuscript, it is declared that there is no conflict of interest related to not have any competing financial, professional, or personal interests from other parties. In this study, all of the data were taken from websites, so there is no need for ethical permission.

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