TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ

SOSYAL BİLİMLER ARAŞTIRMALARI DERGİSİ

ISSN:1306-732X (Print)/E-ISSN: 2564-680X (Online)
Kış Sayısı / Winter Issue
Aralık / December 2020
Tüzün Tolga İnan ve Cengiz Mesut Bukeç(2020). "THE RELATIONSHIP BETWEEN THE IMPROVEMENT OF THE SAFETY MANAGEMENT SYSTEM (SMS) WITH THE CIVIL AVIATION ACCIDENT RATES"
Tokat Gaziosmanpaşa Üniversitesi Sosyal Bilimler Araştırmaları Dergisi. Aralık, s.599-610.
Sivil Havacılık-İstatistik Araştırma
Doi Numarası: 10.48145/gopsbad.744724
Geliş Tarihi / Received: 29 Mayıs 2020 *Kabul Tarihi / Accepted: 3 Aralık 2020*

EMNİYET YÖNETİM SİSTEMİNİN (SMS) İYİLEŞTİRİLMESİ İLE SİVİL HAVACILIK KAZA ORANLARI ARASINDAKİ İLİŞKİ[1]

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Öz– *Emniyet yönetmeliği, Aralık 2010'da Emniyet Yönetimi El Kitabı adıyla yayınlanmıştır. 2010 yılından sonra bu doküman sayesinde sivil havacılık kaza oranları önemli ölçüde azalma trendine girmiştir. Çalışmanın amacı, ekip kaynak yönetimi kavramının başlangıç döneminden itibaren 40 yıllık bir zaman diliminde seçilen parametrelere göre segmentlere ayrılarak sivil havacılık kazalarının nedenlerini bulmaktır. Kzaların nedenlerini bulmak için seçilen parametreler yolcu sayısı (milyar), olay tarihi, soruşturma tipi, yaralanma şiddeti, uçak hasarı, amatör yapım, motor tipi, uçuş amacı, hava durumu ve uçuş aşaması olarak belirlenmiştir. Uçuş amacına ilişkin yapılan analizde, genel havacılığın kaza ve olay oranlarının diğer modüllere göre daha yüksek orana sahip olduğu bulunmuştur. Uçuş aşamasında ise iniş safhasının kaza ve olay oranları baz alındığında en tehlikeli aşamayı oluşturduğu ortaya çıkmıştır. Lojistik regresyon analizinde ise motor sayısındaki 1 birimlik değişiklik kaza oranlarına göre olay sayısını 3.817 (OR) birim artırmaktadır. Bu sonuç ışığında uçaklarda motor sayısı arttıkça olayların ölümcüllüğünün azalacağı yorumu yapılabilir.*

Anahtar Kelimeler– *Havacılık Emniyeti, Uçak Kazaları, Uçak Olayları, Emniyet Yönetmelikleri, Soruşturma Türü.*

THE RELATIONSHIP BETWEEN THE IMPROVEMENT OF THE SAFETY MANAGEMENT SYSTEM (SMS) WITH THE CIVIL AVIATION ACCIDENT RATES

Abstract – *The safety regulations were document published in December 2010 with the name of Safety Management Manuel. After this year civil aviation accident rates have decreased dramatically. The purpose of this study is to find the reasons for civil aviation accidents by segmenting into the selected parameters in a 40-year time period starting from the crew resource management concept. These selected parameters are the number of passengers (billion), event date, investigation type, injury severity, aircraft damage, amateur-built, engine type, the purpose of flight, weather condition, and phase of flight. In the analysis, related to the purpose of flight, it is found that general aviation has a higher proportion according to accident and incident rates than other modules. In the phase of flight, it is found that the landing phase is the most frequent one among accident and incident rates. In the logistic regression analysis, the 1 unit change in the number of engines increases incident rates by 3.817 (OR) units according to accident rates. In light of this result, it can be said that when the number of engines is increased, the fatality of the events is decreased.*

Keywords – *Aviation Safety, Aircraft Accidents, Aircraft Incidents, Safety Regulations, Investigation Type.*
Jel Codes: *Y10, Y80, Y90*

[1] Bu makalede yazarların katkı oranları, sorumlu yazar %60, diğer yazar %40'dır.

1. INTRODUCTION

Civil aviation does not forgive mistakes because the results are usually tragic. Renowned worldwide by aviators, Silas Christofferson made many efforts to increase safety in passenger and cargo transportation in 1913. Further efforts have sustained for more than a hundred years since the transportation of a seaplane between San Francisco and Oakland ports (Dodhia and Dismukes, 2009). The concept of safety has evolved from the industrial revolution to the technological developments experienced today and this evolutionary process is expected to continue (ICAO, 2009). When discussing safety at the present day, academic resources, as well as regulations, emphasizing efficient and continuous efforts for a better description of safety risks to lower them for managing effectively (ICAO, 2013). Aiming to assure human health and human life, it is essential for aviation organizations to reduce losses contingent upon accidents as low as reasonably practicable by means of well-coordinated organizational efforts as communicated at all levels (CAA, 2006). The questions arise here: Has safety managed in this way? Has it brought satisfactory results? How safety thinking has evolved since the beginning of civil aviation, and is it in progress or not? It is possible to say that the efforts about ensuring safety have evolved beginning from the early years of civil aviation in which only the technical causes of accidents were investigated to take lessons. Ergonomics has emerged as an independent discipline both in Europe and the US since the 1950s, safety thinking began to receive added value with the contribution of behavioral sciences in defining and generating solutions for human error (Helander, 2005; Moray, 2008). Since then, the human factor has accepted to be the cause of numerous major accidents. Contrary to be the main cause of majority of the accidents, a brief review of safety evolution may naturally point out that the most effective factor in ensuring the continuity of safety is human (Reason, 2002; Shappel and Wiegmann, 2003). As approached to present day while the aircraft and flight technologies develop, human interaction with technology, environment, and other human becomes more complex. Contemporary civil aviation organizations are high integrity socio-technical systems that balance the high reliability and high-performance characteristics (Westrum and Adamsky, 1999). Hence, the concept of safety -mainly focusing on "organizational error"- has turned into a well-coordinated management activity where proactiveness is highly motivated (Authority-CAA, 2002; Shappell and Wiegmann, 2003; ICAO, 2013). In order to ensure safety and increase the level of it, the organization must be aware of all dangers, risks, errors, violations, and solutions at different organizational levels that affect safety (Hale, 2000). The necessities are defined as two parts; the first one is the awareness of the organization about safety at all levels. The second one is a notice requirement to share values, beliefs, attitudes, norms, and behaviors which produced for supporting the safety of civil aviation (Furnham and Gunter, 1993; Glendon and Stanton, 2000). Today a wide range of studies are pointing out the human factor which is seen as the cause in approximately two-thirds of the accidents while it has been reduced to a level that can be considered as "almost perfect". In the following stage, it is seen that the source of errors is defined in processes within the organization such as; technical, procedures, and understanding of doing business that is also known as the period of organizational factors. The definition and adoption of safety as a culture is both a natural result and the final stage of work on organizational factors. It can be seen as the prevention of losses and accidents in the definition of basic function about safety and the development line mentioned above. Prevention of losses and accidents should be considered with the reliability problem in the air transport industry. In addition to economic concerns, the content of this problematic situation also includes the personality, behavioral, characteristics, and cultural texture of the individual that need for modern and socio-technical civil aviation organizations (Reason, 2000). This paper is related to find the causes of civil aviation accidents into five stages which are specified as the periods of crew resource management. The content of this paper included the literature review, methodology, research findings and results, the logistic regression analysis-dependent: investigation type, and the concluding remarks.

2. Literature Review

Safety thinking was too weak in the first decade of the 20th century which accepted as the years beginning of civil aviation. During that time more than 9 million people who dreamed of better lives had migrated to the USA though safety considerations in the work-area were weak (Baines, 2003). Nonetheless, one witnessed Orwell Wright talked about thinking of safety risks and relevant simple but important considerations due to the tough nature of civil aviation even in the beginning (Crick, 1980). The first scheduled air service began in Florida on January 1, 1914 (Petrescu and Petrescu, 2012). Since then, safety thinking merits the value increases in worldwide air transportation. When one reviews the historical developments in civil aviation, one can realize the coincident development of technology, the economy of international transportation, the contribution of scientific developments, and ever-changing methods for safety mesh-like tresses. As the world economy had been awarded great support of air transportation with increased ranges and capacity of the aircraft in the 1970s, the civil aviation industry witnessed a dramatic increase in the number of passengers worldwide (Masefield, 1972). Aviators must accept that before the 1970s, neither human factor nor human error models were in view of the technological developments making safety thinking compulsory. An exceptional model could be Heinrich's pyramid where accident prevention was called for discerning an organizational endeavor (Heinrich, 1941). Expectedly, the safety considerations were limited about the development of aircraft produced with better technology or equipped navigation systems till the 1970s (Lee, et all. 2001). Managers were trying to learn from bloody accidents to solve out ongoing vexing safety problems (ICAO Doc.9859, 2013). Even until 1972 before the Human Factors model applicated by Edwards (1972) that is the ancestor of the SHELL model. This model is developed by Hawkins and aviators whom could not benefit from this model in error management (Helmreich, 1999). So, human Factors began to become popular as an interdisciplinary study area for enhancing aviation safety. After the SHELL model (software, hardware, environment, liveware for one person, and groups) had driven organizations to think about the necessity of human interaction with technology and environment as well as other human success models tried to explain any other reason with different taxonomies for human error within this context (Shorrock and Kirwan, 2002). Following the disastrous accidents, Cockpit Resource Management began to apply as an important constituent of accident prevention (ICAO Doc. 9859, 2013). Since then, aviators apply to these models especially in contemporary CRM trainings in order to prevent from human error accident incessantly (Helmreich, 1999). What changed safety thinking worldwide had been the treasure found in the magic combination of the two words by James Reason (1995) as an organizational error. With that concept, error mitigation became a responsibility of anyone in an organization while faults and troubles at different levels of the organization had to be noticed. Consequently, top management support and safety awareness at all levels with a feeding organizational culture became compulsory about "safety culture". The presence of these was regarded as the only way to detect each safety trouble around every corner (ICAO Doc. 9859, 2013). Consequential error models were generated with an organizational perspective (see Table 1). Thereafter, taking lessons from some other disasters such as Linate in 2001 and Überlingen in 2002, it became more apparent that states need to find solutions to ongoing safety problems at the national level (Brooker, 2008). Thus, it was at the end of the 2000s where one can observe that State Safety Programs (SSP) became prevalent. Unsurprisingly, the ICAO endeavor in 2010 resulted in generating Annex-19 and Doc. 9859 within a couple of years. This significant keystone established an SSP framework and the eight critical elements of a safety oversight system at the national level. Below that level, as interacted with those safety programs, organizations were obliged to show continuous effort with harmony and awareness at all levels.

Table 1: Types of Detection Sensors and Descriptions

ERA	DATES	MAIN CONCERN	SAMPLE ACCIDENT CAUSATION MODELS USED SINCE THEN	MAIN CONCERN IN LEARNING
Technical Era	1900s - late 1960s	safety deficiencies were related to technical factors and technological failures	No Causation Model Applied	reactive
Human Factors Era	1970s - 1990s	human performance was cited as a recurring factor in accidents	**Human Error Modeling** Software-Hardware-Environment-Liveware - SHELL (Hawkins, 1975) Human Error Assessment and Reduction Technique (Williams 1986) Systematic Human Error Reduction and Prediction Approach (Embrey 1986) SRK (Rasmussen, 1981) Hazard and Operability Analysis - Human Error Guidewords - HAZOP (Whalley 1988)	reactive
Organizational Factors Era	1900s - 2010	safety began to be viewed from a systemic perspective, which was to encompass organizational factors in addition to human and technical factors	**Organizational Error Modeling** Swiss Cheese Model of Causation (Reason, 1990) GEMS (Reason, 1990) HEIST (Kirwan, 1994) CREAM (Hollnagel, 1998), HFACS (Shappell and Wiegmann, 2000)	both reactive and proactive
Post-SMS Era	2010 - today	organizations began considering the impact of organizational culture and policies on the effectiveness of safety risk controls	**Main Concern is Safety Performance** Safety Plannings at all levels, 2010 State Safety Programs, early 2010s Doc 10004 Global Aviation Safety Plan, 2017 Safety II theory is in place	mainly proactive but also reactive

Reference: (Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A. and Wiegmann, D. A., 2007).

Nonetheless; safety management did not simply involve applicable processes or rules where any organization could standardize and apply to them utilizing error management models. Neither a unique document would answer all requirements to manage safety. Therefore, the necessity to define safety culture and to promote it continuously in genuine aviation organizations was expected to fill in all of the potential gaps. Consequently, reporting safety troubles especially voluntarily by all employees was seen as the key progress Hence, Reason's generic model for safety culture gave way to explicit and supporting behavioral patterns for continuous improvement with agile changes at all levels (Reason, 2000).

This research focuses on mainly 3 epochs of safety thinking in civil aviation as described by ICAO (Doc. 9859, 2013) and added the post-SMS era for an extra concentration to determine the changes in accident rates clearly to tie with those epochs. Defining epochs could enable to list and distinguish complex efforts to manage safety. Consequently, this paper aims to find out changes that began from technology, continued with human factors, organizational factors, and still in progress with cultural factors. Matching the efforts with the results of the analysis about accident rates undoubtedly is expected to reveal the rights and the wrongs in the efforts to answer real-world safety management requirements.

Table 2: Support of Disciplines to Safety Management Evolution

ERA	DATES	SUPPORTING DISCIPLINES	MAIN CONCERN OF RESEARCHES
Technical Era	1900s - late 1960s	Engineering Ergonomics and Human Factors	Aircraft Technologies Technical Human capabilities and limitations
Human Factors Era	1970 - 1990s	Engineering Human Factors Behavioral Sciences	Aircraft Technologies Communication Technologies Human capabilities and limitations*
Organizational Factors Era	1900s - 2010	Engineering Human Factors Behavioral Sciences Management Science	Aircraft Technologies Communication Technologies Software Development and Analysis & Computer Technologies Human capabilities and limitations
Post-SMS Era	2010 - today	Engineering Human Factors Behavioral Sciences Strategic Management Cultural Studies Communications Sciences	Aircraft Technologies Communication Technologies Software Development and Analysis & Computer Technologies Human capabilities and limitations Air Law Cultural Diversities Organizational Culture, Safety Culture

Reference: (Human Factors and Ergonomics Society, 2020)

The accident rates according to the predefined epochs as described in this research, may express the efficiency of new implementations to enhance and promote safety management. Nonetheless, the information set may not explain the efficiency of each implementation since each organization could have different safety management considerations or focuses. Another deliberate deficiency in matching has new developments in Safety II since no substantial practice could have been observed yet.

3. Methodology

This section discusses the research framework, approach, tools of measurement, variables, and assumptions used in this article. In this research paper, the causes of air accidents and incidents that happened between 1979-2018 are analyzed. These analyses are examined with; Kruskal Wallis, Mann-Whitney U, Fisher's Exact, and * Chi-Square Tests. These tests are examined in nine classifications as related to aircraft accidents and incidents. These are classified as; event date, investigation type, injury severity, aircraft damage, amateur-built, engine type, the purpose of flight, weather condition, and phase of flight.

Event dates are covered a 40 year period which has 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 a determinant position for directing civil aviation. Because of that, it is examined a 40-year period which started in 1979 and ended in 2018. The investigation type covers two concepts. These are accidents and incidents. At first sight, the incident is more common and the accident is more particular. An incident could deal with any event which is big or little, well or worse and intentional or unintentional, however, an accident is a worse occurrence induced with the mistake and inadvertently. Accidents are generally unintended and they normally ensue in any damage or injury. Injury severity covers four concepts. These are fatal, incident, non-fatal, and unknown events. Fatal events are deadly and create big damage. For instance; fatal accidents are injuries that ensued in death-related to the accident itself either till 30 days following the accident. Non-fatal accidents are injuries that seek upwards of 2 days of hospitalization till 7 days following the accident. Incidents are injuries that seek fewer than 2 days of hospitalization till 7 days following the accident. Aircraft damage covers three concepts. These are destroyed minor and substantial events. Destroyed events are related to the aircraft is not repairable. If the aircraft is repairable, the expenses for fixings overlaps 50% of the expense of the aircraft when it was recent. Substantial events are related to harm or loss which inversely influences constructional force, performance, or flight characteristics about the aircraft and that could ordinarily need grand fix or adjustment related to the smitten component. Minor events are related to damages which neither demolish the aircraft nor accounts for substantial harm.

Amateur built covers two concepts. It is related to the event that is a civil aviation activity or not. If an event is a civil aviation activity like passenger transportation, cargo transportation, general aviation, and flight training it is named as no amateur-built. If an event is a non-civil aviation activity like sportive aviation it is named as amateur-built. Engine type covers four concepts. Turbofan is used in the civil industry related to passenger aircraft, cargo aircraft, and flight training. The turboprop engine is the improved generation of turbofan that used in the civil aviation industry related to passenger aircraft, cargo aircraft, flight training and also in general aviation. Turbojet is the oldest model in the civil aviation industry that used related to only flight training. Turboshaft is used in helicopters related to general aviation.

The 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 a 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 to 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 incident rates are the highest (ICAO, 2020). Weather condition covers three concepts. These are instrument meteorological conditions, visual meteorological conditions, and unknown conditions. Instrument meteorological conditions (IMC) are meteorological conditions defined about visibility, range from cloud, and ceiling, fewer the minima specified for visual meteorological conditions (VMC). Visual meteorological conditions (VMC) are the meteorological conditions defined in terms of visibility, range from cloud, and ceiling equivalent to or greater than determined minima. Instrument meteorological conditions are much safer than visual meteorological conditions that as stated in table 3 and table 4. The phase of flight covers seven phases. These are approach, cruise, landing, maneuvering and divert, take off, taxi, and unknown phases. The cruise phase means the procedure of the aircraft on the specified route. Approach and landing phases are related to the descending process. Take off phase is related to the ascending process. The maneuvering and divert phase is related to the landing of the aircraft in other designated airports because of technical problems. The taxi phase is related to the transition path from the apron to the runway. When it is examined phase of flight exposure vs. accidents; the percentage of exposure time (per flight) for take-off phase is %16, the cruise phase is %60, approach and landing phase is %24 percentage. In addition, the rates for the percentage of accidents (per phase of flight) are classified as; take off phase %22, cruise phase %17, approach and landing phase %61 percentage. These rates are shown that the approach and landing phase is the most dangerous phase in civil aviation accidents and incidents (ICAO, 2020).

4. Research Findings And Results

The normality test was completed with the Shapiro-Wilk test. Non-parametric statistical methods were used for values with irregular (non-normally dissipated, Shapiro-Wilk p>0.05) distribution. Descriptive statistics are submitted using mean and standard deviation for normally distributed factors and median (and minimum-maximum) for the non-ordinarily dissipated factors. Non-parametric statistical practices were applied for rates with irregular circulation. For the collation of two non-ordinarily dissipated independent groups, the Mann-Whitney U test is applied. For the collation of over two non-normally dissipated independent groups, the Kruskal Wallis test is used. On account of the survey, the influence of parameters on investigation type Logistic Regression is used. The χ^2 test and Fisher's exact test are applied for categorical factors and defined as investigation quantities (and ratios). Statistical importance is admitted when the two-sided p-value is fewer than the value of 0.05. Statistical analysis is applied accessing 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, so 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 designated the "one-way ANOVA on ranks") is a grade-basis nonparametric test which could be applied to adjust if there are statistically substantial distinctions among two or more categories of an independent factor on a steady or ordinal dependent factor. It is noticed that the nonparametric alternative to the one-way ANOVA and an extending of the Mann-Whitney U tests are authorized the crosscheck of more than two independent groups (Laerd Statistics, 2020).

Table 3: Kruskal Wallis Test

		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 a statistically significant difference between event date in terms of the number of passengers (p<0,05).

Table 4: 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 to 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 examining the experiment-wise error percentage (Statistics By Jim Making Statistics Intuative, 2020).

Table 5: Distribution of Parameters

	The Year Period	N	%
Event Date	1979-1986	311	18,5%
	1987-1990	171	10,2%
	1991-2001	494	29,5%
	2002-2010	408	24,3%
	2011-2018	293	17,5%
Investigation Type	Accident	1585	94,5%
	Incident	92	5,5%
Injury Severity	Fatal	354	21,1%
	Incident	92	5,5%
	Non-Fatal	1229	73,3%
	Unavailable	2	0,1%
Aircraft Damage	Destroyed	412	24,6%
	Minor	102	6,1%
	Substantial	1163	69,4%
Amateur Built	No	1662	99,1%
	Yes	15	0,9%
EngineType	Turbo Fan	215	12,8%
	Turbo Jet	108	6,4%
	Turbo Prop	519	30,9%
	Turbo Shaft	835	49,8%
Purpose Of Flight	Passenger Transportation	356	21,2%
	Flight Training	439	26,2%
	General Aviation	816	48,7%
	Cargo Transportation	66	3,9%
Weather Condition	IMC	240	14,3%
	UNK	11	0,7%
	VMC	1426	85,0%
Phase Of Flight	Approach	193	11,5%
	Cruise	236	14,1%
	Landing Phase	502	29,9%
	Maneuvering And Divert Phase	414	24,7%
	Take Off Phase	270	16,1%
	Taxi	49	2,9%
	Unknown	13	0,8%
	Mean ±SD	**Med.(Min-Max)**	
Number Of Engines	1,52±0,57	(1-4)	

Table 6: 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%	
Amateur Built	No	1572	99,2%	90	97,8%	0,197
	Yes	13	0,8%	2	2,2%	
Engine Type	Turbo Fan	180	11,4%	35	38,0%	**<0,001**
	Turbo Jet	100	6,3%	8	8,7%	
	Turbo Prop	480	30,3%	39	42,4%	
	Turbo Shaft	825	52,1%	10	10,9%	
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%	
Weather Condition	IMC	228	14,4%	12	13,0%	0,172
	UNK	9	0,6%	2	2,2%	
	VMC	1348	85,0%	78	84,8%	
Phase Of Flight	Approach	185	11,7%	8	8,7%	**<0,001 ***
	Cruise	225	14,2%	11	12,0%	
	Landing Phase	465	29,3%	37	40,2%	
	Maneuvering And Divert Phase	409	25,8%	5	5,4%	
	Take Off Phase	245	15,5%	25	27,2%	
	Taxi	43	2,7%	6	6,5%	
	Unknown	13	0,8%	0	0,0%	

In this table fisher's exact test is related to independence when there are two numerical 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 (www.biostathandbook.com). Fisher's exact test is used when there are two numerical variables. It should be known whether the proportions for one variable are different among values of the other variable (van Nood et al. 2013). The 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 these counts would anticipate if there were no relationship at all in the population. For instance, it is used how the information collected and which hypothesis is being tested. However, all of the factors use the same idea which crosschecks anticipated originally gathered values (Statistics How To, 2020). There is a statistically significant difference between investigation type and event date, aircraft damage, engine type, the purpose of flight, and the phase of flight ($p<0,05$). The incident rate is higher for the years between 1979-1986. 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. The accident percentage is found higher for Turbo Shaft Engine Type. The accident percentage is found higher for VMC weather conditions. The accident percentage is found higher for General Aviation. The accident percentage is found higher for Landing Phase, Maneuvering, and Divert Phase.

At last, almost all acccidents are happened in no amateur built stage. This situation is shown that sportive aviation has a minimum level of accident and incident rate. To sum up, in this paper all the figures and tables are taken from (NTSB, 2020 and (Plane Crash Info Accident Database, 2020) websites.

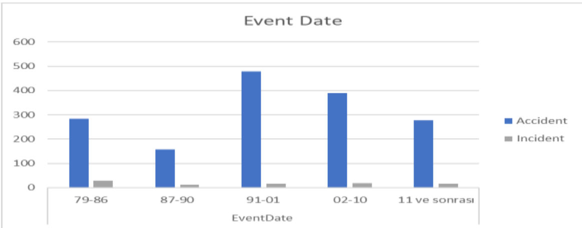

Figure 1: Event Dates

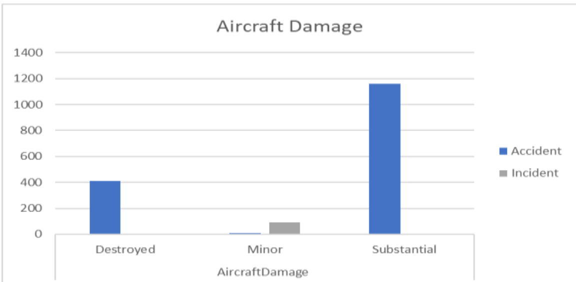

Figure 2: Aircraft Damage

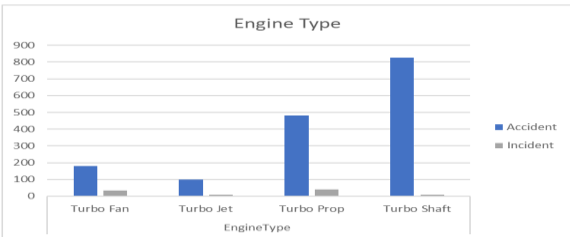

Figure 3: Engine Type

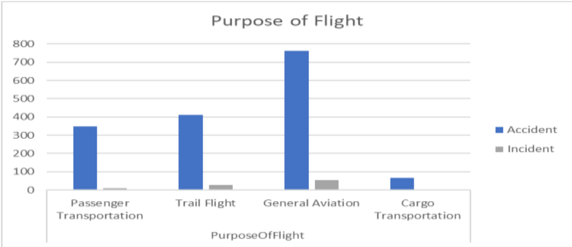

Figure 4: Purpose of Flight

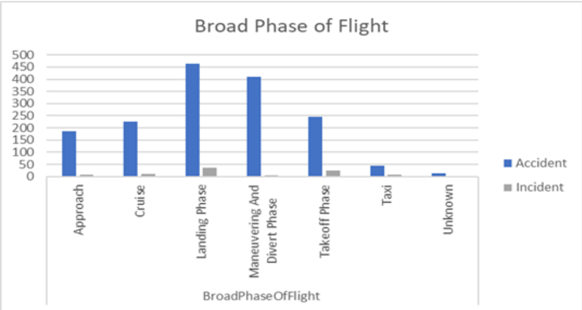

Figure 5: Phase of Flight

Table 7: Mann-Whitney U test

	Accident	Incident	
	Mean ±SD Med.(Min-Max)	Mean ±SD Med.(Min-Max)	p
Number Of Engines	1,49±0,55 1 (1-4)	2,01±0,54 2 (1-4)	**<0,001**

There is a statistically significant difference between investigation accident and incident, in terms of the number of engines (p<0,05). The average of accidents is found lower than incidents.

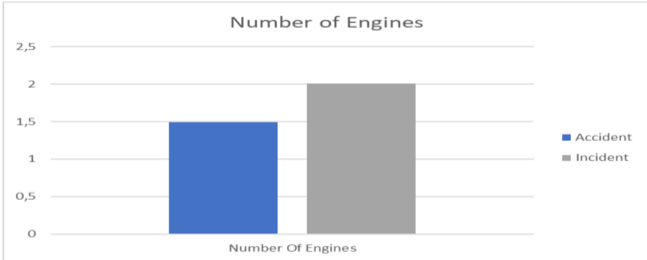

Figure 6: Number of Engines

Table 8: Fisher's Exact Test, *Chi-Square test - Comparison Parameters According to Aircraft Damage

Investigation Type		Destroyed		Minor		Substantial		p[1]
		Number	%	Number	%	Number	%	
Event Date	**1979-1986**	107	26,0%	29	28,4%	175	15,0%	**<0,001***
	1987-1990	56	13,6%	13	12,7%	102	8,8%	
	1991-2001	146	35,4%	21	20,6%	327	28,1%	
	2002-2010	63	15,3%	21	20,6%	324	27,9%	
	2011-2018	40	9,7%	18	17,6%	235	20,2%	
Injury Severity	**Fatal**	304	73,8%	2	2,0%	48	4,1%	**<0,001**
	Incident	0	0,0%	91	89,2%	1	0,1%	
	Non-Fatal	107	26,0%	9	8,8%	1113	95,7%	
	Unavailable	1	0,2%	0	0,0%	1	0,1%	
Amateur Built	**No**	408	99,0%	100	98,0%	1154	99,2%	0,323
	Yes	4	1,0%	2	2,0%	9	0,8%	
Engine Type	**Turbo Fan**	45	10,9%	40	39,2%	130	11,2%	**<0,001**
	Turbo Jet	33	8,0%	9	8,8%	66	5,7%	
	Turbo Prop	159	38,6%	40	39,2%	320	27,5%	
	Turbo Shaft	175	42,5%	13	12,7%	647	55,6%	
Purpose Of Flight	**Passenger Transportation**	91	22,1%	9	8,8%	256	22,0%	**<0,001***
	Flight Training	102	24,8%	30	29,4%	307	26,4%	
	General Aviation	214	51,9%	63	61,8%	539	46,3%	
	Cargo Transportation	5	1,2%	0	0,0%	61	5,2%	
Weather Condition	**IMC**	105	25,5%	12	11,8%	123	10,6%	**<0,001**
	UNK	5	1,2%	2	2,0%	4	0,3%	
	VMC	302	73,3%	88	86,3%	1036	89,1%	
Phase Of Flight	**Approach**	82	19,9%	8	7,8%	103	8,9%	**<0,001***
	Cruise	84	20,4%	12	11,8%	140	12,0%	
	Landing Phase	42	10,2%	38	37,3%	422	36,3%	
	Maneuvering And Divert Phase	117	28,4%	8	7,8%	289	24,8%	
	Take Off Phase	81	19,7%	26	25,5%	163	14,0%	
	Taxi	2	0,5%	10	9,8%	37	3,2%	
	Unknown	4	1,0%	0	0,0%	9	0,8%	

There is a statistically significant difference between aircraft damage and event date, engine type, the purpose of flight, phase of flight, weather conditions (p<0,05). The destroyed percentage is found higher between the years 1991-2001. A substantial percentage is found higher for non-fatal severity. A substantial percentage is found higher for Turbo Shaft Engine Type. The accident percentage is found higher for Turbo Shaft Engine Type. The minor percentage is found higher for general aviation. A substantial percentage is found higher for VMC conditions. The destroyed percentage is found higher for Maneuvering and Divert Phase. The minor percentage is found higher for Landing Phase.

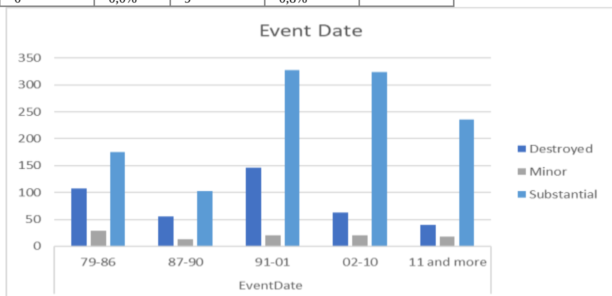

Figure 7: Event Date

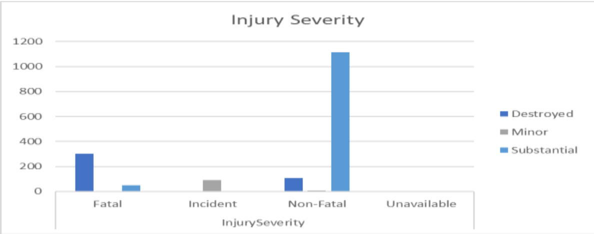

Figure 8: Injury Severity

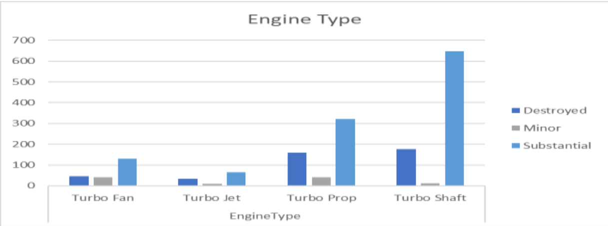

Figure 9: Engine Type

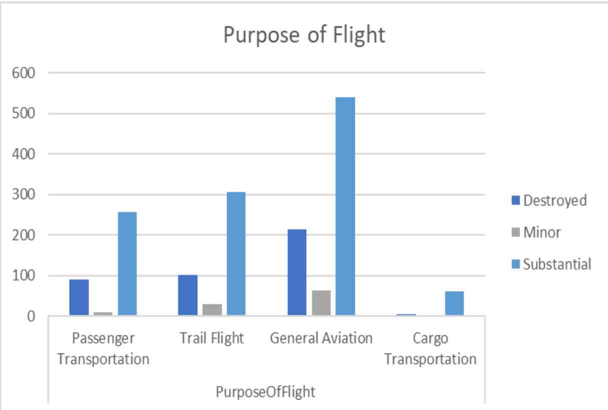

Figure 10: Purpose of Flight

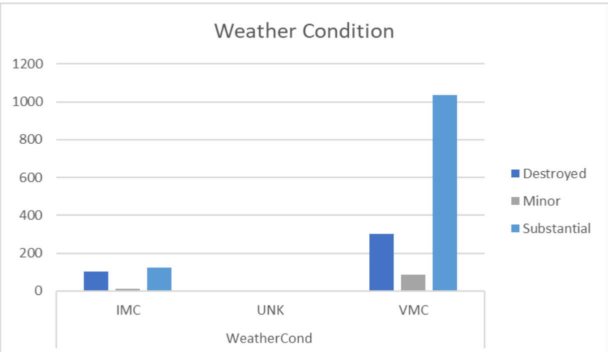

Figure 11: Weather Condition

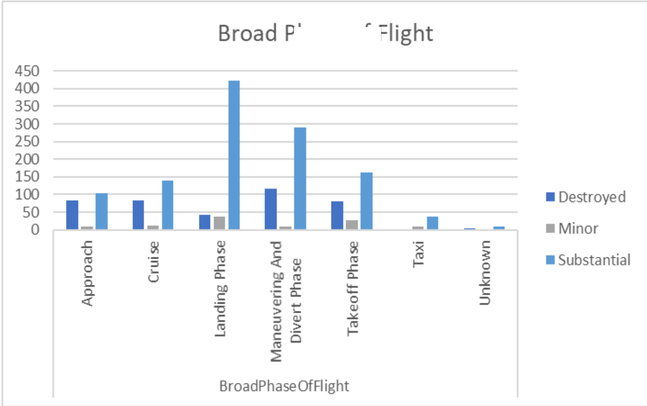

Figure 12: Phase of Flight

Table 9: Kruskal Wallis Test

	Destroyed	Minor	Substantial	
	Mean ±SD Med.(Min-Max)	**Mean ±SD Med.(Min-Max)**	**Mean ±SD Med.(Min-Max)**	**p**
Number Of Engines	1,64±0,59 2 (1-4)	2,01±0,55 2 (1-4)	1,43±0,53 1 (1-4)	**<0,001**

There is a statistically significant difference between aircraft damages in terms of the number of engines (p<0,05).

Table 10: Mann-Whitney U test

Post-Hoc Pairwise Comparisons (p)	Destroyed vd. Minor	Destroyed vd. Substantial	Minor vd. Substantial
Number Of Engines	<0,001	<0,001	<0,001

According to posthoc pairwise comparisons, the average of minor events is found higher than destroyed, and substantial events. The average of destroyed events is found higher than the substantial events (p<0,016 Bonferroni correction).

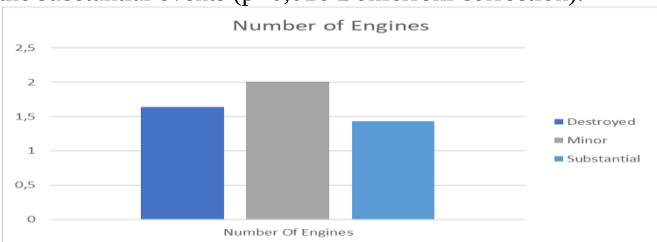

Figure 13: Number of Engines

Like tables and figures, all these statistics are taken from (NTSB, 2020) and (Plane Crash Info Accident Database, 2020) websites.

5. Logistic Regression Analysis-Dependent: Investigation Type

Table 11: 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

The 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 and since the Hosmer-Lemeshow with a value of p = 1,000> 0.05, 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 as 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 12: Engine Type - Dependent: Investigation Type

	p	OR	%95 CI Lower	%95 CI Upper
Turbo Jet	**0,031**	0,411	0,184	0,921
Turbo Prop	**<0,001**	0,418	0,257	0,680
Turbo Shaft	**<0,001**	0,062	0,030	0,128

The engine type is modeled as independent variables. When the significance of the model was examined with a value of p <0.001 was found and since the Hosmer-Lemeshow with a value of p = 1,000> 0.05, the model is suitable for interpretation. Turbo Jet, Turbo Prop, and Turbo Shaft are found as significant as risk factors (p<0.05). Turbo Fan is the selected reference category. Turbo Jet decrease the incident by 1 / 0,411 = 2,43 times compared to those Turbo Fan. Turbo Prop decrease the incident by 1 / 0,418 = 2,39 times compared to Turbo Fan. Turbo Shaft decrease the incident by 1 / 0,062 = 16,12 times compared to Turbo Fan.

Table 13: 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	-

The purpose of the flight is modeled as independent variables. When the significance of the model was examined with a value of p<0.001 was found and since the Hosmer-Lemeshow with a value of p = 1,000>0.05 the model is suitable for interpretation. Flight training and general aviation are found as significant as risk factors (p<0.05). Passenger transportation is the 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.

Table 14: The Phase of Flight - Dependent: Investigation Type

	p	OR	%95 Lower	CI	%95 CI Upper
Cruise	0,796	1,131	0,446		2,869
Landing Phase	0,127	1,840	0,841		4,026
Maneuvering And Divert Phase	**0,029**	0,283	0,091		0,876
Take Off Phase	**0,040**	2,360	1,041		5,351
Taxi	**0,038**	3,227	1,064		9,784
Unknown	0,999	0	0		.

The phase of flight is modeled as independent variables. When the significance of the model was examined with a value of p <0.001 was found and since the Hosmer-Lemeshow with a value of p = 1,000> 0.05, the model is suitable for interpretation. Maneuvering and Divert Phase, Take Off Phase and Taxi Phases are found significant as risk factors (p<0.05). The approach is selected reference category. Maneuvering and Divert Phase decrease the incident by 1/0,283=3,533 times compared to Approach. Take Off Phase increase the incident by 2,360 times compared to Approach Phase. Taxi Phase increases the incident by 3,277 times compared to Approach Phase.

Table 15: Number of Engine - Dependent: Investigation Type

	p	OR	%95 CI Lower	%95 CI Upper
Number of Engine	**<0,001**	3,817	2,733	5,332

The number of engines is modeled as independent variables. When the significance of the model was examined with a value of p <0.001 was found and since the Hosmer-Lemeshow with a value of p = 1,000> 0.05, the model is suitable for interpretation. The number of engines is found significant as a risk factor (p<0.05). 1-unit change in the number of engines increases the incident 3,817 times.

CONCLUSION AND SUGGESTIONS

The safety concept is related to all rules, and regulations to protect the civil aviation industry from intentional sabotage events. In this study, the concept and ensuring of safety as an overview discussed in the introduction part, then at the literature review it was introduced the four phases of safety about the support of disciplines to safety management evolution. These are classified as; technical, human, organizational factors, and post-SMS eras. In addition to these eras, civil aviation accidents which are triggered by the lack of support about safety disciplines factors are examined. These factors are classified as; event date that included the last 40 years also with the beginning of crew resource management concept, investigation type related to incident and accident rates by giving their definitions, and the injury severity which is related to the levels of disastrous effects. Aircraft damage like injury severity classified as a minor, substantial, and destroyed effect. Amateur built is about an event that is a civil aviation activity or not. The other variables are named as; engine type, the purpose of flight, weather condition, and phase of flight. When it is examined the investigation type of the selected variables, the number of destroyed events mostly happened in the 1991-2001 period. The injury severity percentage is %77.5 for non-fatality, however, the outcomes are %73.3 percentage with substantial effect. This situation shows that high percentage of incidents have substantial damage though they are not fatal. %99.2 accidents happened in amateur-built which also means as training flights. %52.1 accidents happened with turbo shaft engines that are used by helicopters. General aviation is related to training flight, VMC (visual meteorological conditions) is also related to general aviation. In addition to this information, for all types of flights; landing, maneuvering, and divert phases are the most dangerous time period. They are also described in the methodology part with the reason why they are chosen. In conclusion, it is understood that safety is a concept that includes disciplines such as; human error modeling, organization error modeling, and performance level. These disciplines are contributed to the areas of engineering, ergonomics, human factors, behavioral sciences, management science, strategic management, cultural studies, and communications sciences in civil aviation activities. Finally, this study is examined the selected variables in the safety concept related to incidents and accidents. This study has a contribution to the literature by segmenting and analyzing the causes of civil aviation incidents-accidents for giving knowledge to civil aviation researchers. In future studies in order to prevent accidents and incidents, precautions that can be taken proactively can be discussed.

Acknowledgement
The authors thank the previous researchers who work in civil aviation safety. With this researches, we got inspired to compare this concept with civil aviation accidents and we wish to contribute to the social sciences in this way. 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.

Disclosure Statement
All of the variables are taken from websites, so there is no need for ethical permission.

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EXTENDED ABSTRACT

Background: In the literature part this paper is related to two general concepts. The first one is the types of detection sensors and descriptions such as; technical era human factors era, organizational factors era, and Post-SMS Era. The second one is the support of disciplines to safety management evolution with the same eras. This paper is also related to find the causes of civil aviation accidents into five stages which are specified as the periods of crew resource management. The content of this paper included the literature review, methodology, research findings and results, the logistic regression analysis-dependent: investigation type, and the concluding remarks.

Research Purpose: The purpose of this study is to find the reasons for civil aviation accidents by segmenting into the selected parameters in a 40-year time period starting from the crew resource management concept. This research focuses on mainly 3 epochs of safety thinking in civil aviation as described by ICAO (Doc. 9859, 2013) and added the post-SMS era for an extra concentration to determine the changes in accident rates clearly to tie with those epochs. Defining epochs could enable to list and distinguish complex efforts to manage safety. Consequently, this paper aims to find out changes that began from technology, continued with human factors, organizational factors, and still in progress with cultural factors. Matching the efforts with the results of the analysis about accident rates undoubtedly is expected to reveal the rights and the wrongs in the efforts to answer real-world safety management requirements.

Methodology: This section discusses the research framework, approach, tools of measurement, variables, and assumptions used in this article. In this research paper, the causes of air accidents and incidents that happened between 1979-2018 are analyzed. These analyses are examined with; Kruskal Wallis, Mann-Whitney U, Fisher's Exact, and * Chi-Square Tests. These tests are examined in nine classifications as related to aircraft accidents and incidents. These are classified as; event date, investigation type, injury severity, aircraft damage, amateur-built, engine type, the purpose of flight, weather condition, and phase of flight.

Research Findings and Results: The normality test was completed with the Shapiro-Wilk test. Non-parametric statistical methods were used for values with irregular (non-normally dissipated, Shapiro-Wilk p>0.05) distribution. Descriptive statistics are submitted using mean and standard deviation for normally distributed factors and median (and minimum-maximum) for the non-ordinarily dissipated factors. Non-parametric statistical practices were applied for rates with irregular circulation. For the collation of two non-ordinarily dissipated independent groups, the Mann-Whitney U test is applied. For the collation of over two non-normally dissipated independent groups, the Kruskal Wallis test is used. On account of the survey, the influence of parameters on investigation type Logistic Regression is used. The χ^2 test and Fisher's exact test are applied for categorical factors and defined as investigation quantities (and ratios). Statistical importance is admitted when the two-sided p-value is fewer than the value of 0.05. Statistical analysis is applied accessing the MedCalc Statistical Software version 12.7.7. The Shapiro-Wilk test is a way to assert if a random sample comes from a normal circulation. The test delivers a W value, so 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. The Kruskal-Wallis H test (sometimes also designated the "one-way ANOVA on ranks") is a grade-basis nonparametric test which could be applied to adjust if there are statistically substantial distinctions among two or more categories of an independent factor on a steady or ordinal dependent factor. It is noticed that the nonparametric alternative to the one-way ANOVA and an extending of the Mann-Whitney U tests are authorized the crosscheck of more than two independent groups.

Conclusion: In conclusion, it is understood that safety is a concept that includes disciplines such as; human error modeling, organization error modeling, and performance level. These disciplines are contributed to the areas of engineering, ergonomics, human factors, behavioral sciences, management science, strategic management, cultural studies, and communications sciences in civil aviation activities. Finally, this study is examined the selected variables in the safety concept related to incidents and accidents. This study has a contribution to the literature by segmenting and analyzing the causes of civil aviation incidents-accidents for giving knowledge to civil aviation researchers. In future studies in order to prevent accidents and incidents, precautions that can be taken proactively can be discussed.