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Analysis of Turkish Civil Aviation Accidents Between 2003 and 2017

Erdinç Ercan[1*], Ahmet Uğur Avcı[1]

[1*]University of Health Sciences, Department of Aerospace Medicine, Ankara, Türkiye. (drerdincercan@gmail.com).
[1]University of Health Sciences, Department of Aerospace Medicine, Ankara, Türkiye. (ahmetuguravci@gmail.com).

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Corresponding Author: *Erdinç Ercan*

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Abstract

Aviation accidents are caused by a chain of errors in many steps. Detection and classification of human factors in accidents are critical for taking effective precautions. This study aims to investigate the factors affecting civil aviation accidents in Turkey and increase aviation safety by raising awareness against the contributing factors in the accidents. Final accident reports of Turkish Civil Aviation Accidents, including fatalities or injuries between 2003 and 2017, were analysed retrospectively using the Human Factors Analysis and Classification System (HFACS). 59 aviation accidents were included in this study. Crew Resource Management (CRM) (41.4%), Loss of Situational Awareness (LSA) (39.0%), and meteorology (29.2%) were found to be the most contributing factors in 41 Plane, Helicopter, Glider (PHG) accidents, while meteorology (77.7%) and CRM (61.1%) were found to be the most contributing factors in 18 Balloon accidents. The rate of HFACS levels in the PHG/Balloon accidents were found to be 90.2%/66.6% in Level-1 (Unsafe Acts), 95.1%/100% in Level-2 (Preconditions for Unsafe Acts), 78.0%/94.4% in Level-3 (Unsafe Supervision), and 58.5/83.3% in Level-4 (Organizational Influences). These findings show that human factors are still major contributing factors in aviation accidents. Academic training like CRM, Aviation Meteorology and LSA should be given more frequently to the aviators to prevent accidents. Including Spatial Disorientation, hypoxia, and night vision practical training into the civilian pilot training and integrating HFACS into the "Aviation Safety Management System" might help to reduce aviation accident rates.

1. Introduction

Aircraft are preferred more and more every new year for transportation and are critically important for economic and socio-cultural interaction. Aviation activities in Turkey are improving progressively. While there were 29 general aviation and 12 balloon establishments in 2009, this number increased to 83 for general aviation and 34 for balloon establishments in 2019 (DGCA, 2019). Approximately 34 million passengers and 964 thousand tons of cargo were transported in 2003, 211 million passengers and 3.85 million tons of cargo were transported in 2019 (DHMI, 2020). Safe, fast, and low-cost trips are some of the reasons why air travel is so preferred. A disruption in flight safety will adversely affect air transport despite all its other advantages.

It is accepted that aviation accidents are not caused by a single factor but by a chain of errors in many steps. The most frequently encountered factor in the chain is human-derived errors. Shappell et al.'s (2007) study showed at least one human error in 60-80% of aviation accidents. To reduce human errors in accidents, it is necessary to focus on the causes of the error instead of focusing on those who made it (Dekker, 2001). Many factors such as stress, fatigue, and insufficient training can facilitate human errors during flight (Murray, 1997). The main challenge is the difficulty of tracking the factors that lead to human errors. Reason (1990a, 1990b) named these factors as active and latent factors; he stated that they only occur in the presence of a trigger, and he defined the model, also known as the Swiss Cheese Model, in which he explained that accidents could only occur as a result of the combination of more than one fault that will occur in various layers. Shappell and Wiegmann (2001) developed the Human Factors Analysis and Classification System (HFACS) based on the Swiss cheese model. HFACS gathers human factors at four levels (Figure 1). HFACS has been used in many different fields besides aviation since its development and has been a valuable tool for detecting human factors in accidents (Cohen et al., 2015; Celik & Cebi, 2009). Detection and classification of human factors in aviation accidents have critical importance for taking effective precautions.

This study aims to reveal the contributing factors in the Turkish Civil Aviation Accidents between 2003 and 2017, classify and compare them with other studies in this field, and increase aviation safety in our country by enabling suitable countermeasures against the contributing factors in aviation accidents.

2. Materials and Methods

2.1. Subjects

Civil aviation accidents, including fatalities or injuries in Turkish airspace or Turkey registered civil aircraft get involved in an accident in foreign airspaces between 2003 and 2017, were included in this study.

2.2. Procedures

The researchers analyzed final accident reports in the Transportation Safety Investigation Centre of Turkey. Turkey and other countries where the accidents took place, are members of ICAO, and it has been observed that accident investigations are carried out according to Annex 13 recommendations. Findings included in the final accident report were evaluated using the HFACS scheme. Findings were used as stated in the original investigation reports without any changes. General-commercial aviation flights were classified as specified in ICAO Annex 6, and accident and injury definitions were used as specified in ICAO Annex 13. Occurrence categories were used as specified in ICAO Accident/Incident Data Reporting.

Although it is a non-motorized aircraft, glider accidents were evaluated under general aviation accidents among plane and helicopter accidents due to its ability to move in 3 axis and the low number of accidents. Balloon accidents were considered as a separate category.

2.3. HFACS model

Data were analyzed using the HFACS model described by Wiegmann and Shappel (2003). Findings in the final reports were evaluated according to the HFACS model presented in Figure 1 and Table 3, considering a total of 140 factors under four main levels, 12 headings and in the first and second level there are12 subheadings. A contributing factor (finding) in an accident was attributed to only one factor listed within the same HFACS Level.

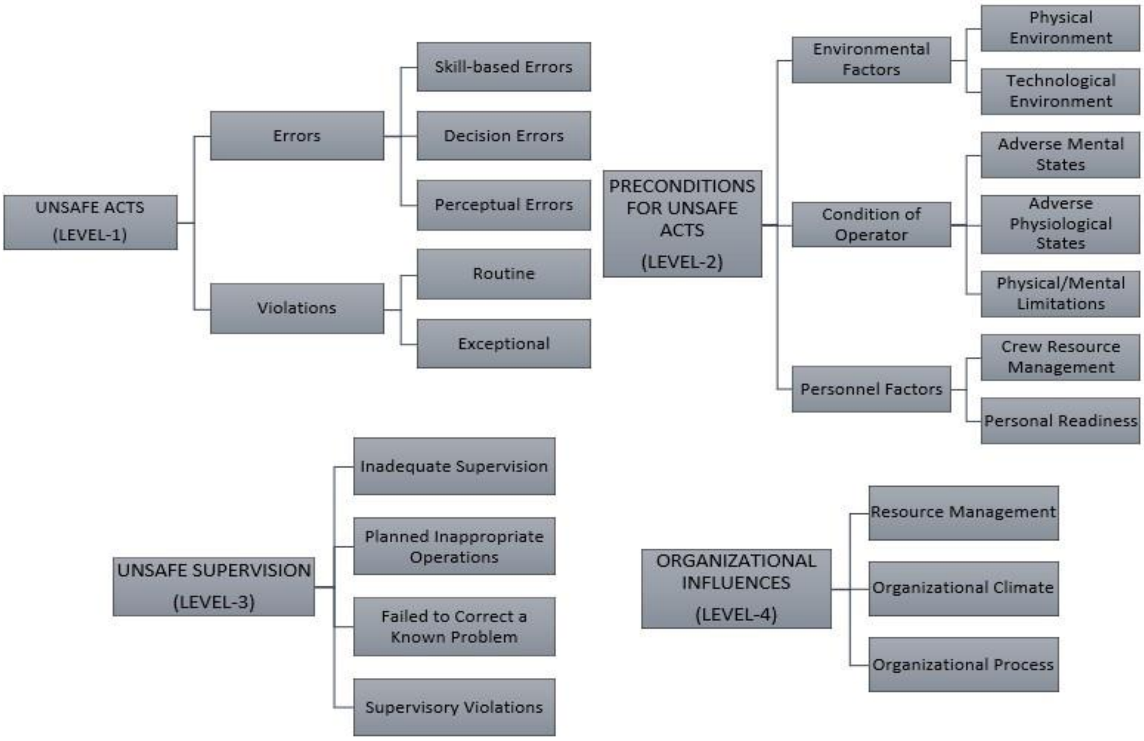

Figure 1. Human Factors Analysis and Classification System (HFACS) scheme

2.4. Researchers

The first researcher completed the Residency in Aerospace Medicine. He completed the 8th Human Factors in Aircraft Accident Investigation certification program held at the US DOT Transportation Safety Institute. He holds a private pilot license (PPL) and an ultralight aircraft pilot license (UPL) and has a bachelor's degree in civil aviation management. The second researcher is a flight surgeon and continues to Residency in Aerospace Medicine and the aviation management undergraduate program.

2.5. Statistical Analysis

The accident data was obtained from records of original final reports. The study data was edited in Microsoft Excel, and statistical analyses were executed in the IBM SPSS program. $P<0.05$ was considered statistically significant. Descriptive statistics for accidents were presented as frequency and percentage. "Chi-Square Test" and "Fischer's Exact test" were used for testing relationships between categorical variables.

3. Result and Discussion

59 Turkish Civil Aviation Accidents between 2003 and 2017, including fatalities or injuries, were analyzed in this study. All accidents were investigated using scientific methods, and suggested countermeasures based on the findings in the final reports were taken immediately after the accidents.

A total of 62 aircraft were involved in the accident (32 planes, seven helicopters, three gliders, 20 balloons). Two gliders in one accident and four balloons in two separate accidents occurred as mid-air collisions, and the aircrafts and balloons involved in the same accidents were analyzed in the relevant final report. Among 59 accidents, there were 32 (54.2%) plane, 7 (11.9%) helicopters, 2 (3.4%) glider, 18 (30.5%) balloon accidents. The number of deaths and injuries in 59 accidents was 309 and 298, respectively.

3.1. The Plane, Helicopter, Glider (PHG) Accidents

Of the 41 PHG accidents, distribution of accident occurrence categories, flight class and phases, fatalities, and

Table 1. Overall Accidents outcomes of Plane, Helicopter, Glider.

NO	CLASS	D	I	Occurrence Category	Flight Phase	NO	CLASS	D	I	Occurrence Category	Phase
A01*,†,‡	C	75	.	CFIT, NAV	Descent	**A22¶**	C	9	120	SCF-NP, LOC-I	Descent
A02	Gen(t)	2	.	LOC-I	Cruise	**A23**	Gen(t)	.	2	SCF-PP	Landing
A03	Gen	1	.	SCF-PP, LALT	Cruise	**A24**	Gen(t)	.	1	CTOL, RE	Landing
A04*	Gen	1	.	AMAN, LOC-I LALT	Cruise	**A25**	Gen	.	2	ARC	Landing
A05	Gen	1	.	LOC-I	Take-off	**A26¶**	Gen(t)	.	2	LOC-I	Cruise
A06	Gen	1	.	LALT	Cruise	**A27†,¶**	C	.	3	RE	Landing
A07	Gen	2	.	SCF-PP, LOC-I	Cruise	**A28***	Gen(t)	.	1	CFIT, UIMC	Cruise
A08¶	C	1	1	FUEL	Descent	**A29*,¶**	Gen(t)	.	2	CFIT	Cruise
A09	Gen(t)	1	1	CFIT	Cruise	**A30**	Gen(t)	.	1	RE	Take-off
A10*	Gen	2	.	WSTRW, UIMC, LOC-I	Cruise	**A31¶**	Gen	.	2	RI	Taxi
A11	Gen	1	.	LOC-I	Take-off	**A32*,†,‡,¶**	C	37	36	USOS	Landing
A12§	Gen	2	.	AMAN, SCF-NP	Cruise	**H-1*,¶**	C	1	2	CFIT, UIMC	Cruise
A13§,¶	Gen(t)	2	.	SCF-PP, LOC-I	Descent	**H-2¶**	C	1	2	CTOL	Take-off
A14	Gen	1	.	SCF-NP, LOC-I	Take-off	**H-3***	C	2	.	ICE	Cruise
A15¶	Gen(t)	1	1	CFIT	Cruise	**H-4§**	Gen	5	.	SCF-PP	Cruise
A16	Gen(t)	2	.	SCF-PP, FUEL	Take-off	**H-5¶**	Gen	2	.	SCF-PP	Take-off
A17†,¶	C	57	.	CFIT, NAV	Cruise	**H-6***	C	.	1	LOC-I, TURB	Landing
A18*,†,¶	C	75	5	USOS	Landing	**H-7*,¶**	C	6	.	CFIT, UIMC	Cruise
A19	Gen	1	1	LOC-I, LALT	Landing	**G-1¶**	Gen(t)	2	.	MAC	Cruise
A20	Gen(t)	2	.	LOC-I	Take-off	**G-2§,¶**	Gen(t)	2	.	LOC-I	Landing
A21*	Gen	2	.	CFIT, UIMC	Cruise						

D: Deaths, I: Injuries
H: Helicopter, G: Glider, C: Commercial Aviation, Gen: General Aviation, Gen(t): General Aviation – Training Flight
CFIT: Controlled Flight Into or Toward Terrain, NAV: Navigation Errors, LOC-I: Loss of Control-Inflight, SCF-PP: System/Component Failure Or Malfunction (Powerplant), LALT: Low Altitude Operations, SCF-NP: System/Component Failure Or Malfunction (Non-Powerplant), USOS: Undershoot / Overshoot, AMAN: Abrupt Maneuver, FUEL: Fuel Related, WSTRW: Wind Shear or Thunderstorm, UIMC: Unintended Flight in IMC, CTOL: Collision with Obstacle(s) During Take-off and Landing, RE: Runway Excursion, RI: Runway Incursion, ARC: Abnormal Runway Contact, ICE: Icing, TURB: Turbulence Encounter, MAC: Midair Collisions
** Meteorology is a contributing factor, † Occurred During Dark Hours, ‡ Dysrhythmia or Fatigue, § Intoxication, ¶ CRM.*

injuries, were presented in Table 1. Twenty-nine of PHG accidents (70.7%) were general aviation accidents and 12 (29.3%) of PHG accidents were commercial aviation accidents and 12 (37.5%) of 32 plane accidents and 2 (100%) of 2 glider crashes were in training flights. There were no training flights among helicopter accidents (Table 1).

3.2. Balloon Accidents

Table 2 presented the causes of balloon accidents, death and injury statistics, and flight phases of the accidents. All balloon flights were commercial flights, and there were no training flights among balloon accidents.

3.3. HFACS classification

The frequency and percentages of HFACS in all subcategories of the accidents are summarized in Table 3. When the accidents were grouped according to aircraft categories and compared between aircraft groups, the rate of HFACS Level-1 findings detected in PG accidents (n=32, 94.1%), were higher than helicopter accidents (n=5, 71.4%) and balloon accidents (n=12, 66.7%) and the difference was statistically significant (Chi-Square Test; p=0.029). The rates of HFACS Level-2 findings were similar in both aircraft (PG, n=32, 94.1%; helicopters, n=7, 100% and balloons, n=18, 100%), and the differences between aircraft categories were not statistically significant (Chi-Square Test; p=0.467). Rate of HFACS Level-3 findings detected in helicopters (n=7, 100%) and balloons (n=17, 94.4%), were higher than PG (n=25, 73.5%) but the difference was not statistically significant (Chi-Square Test; p =0.071). HFACS Level-4 findings detected in PG (n=21, 61.8%) and balloons (n=15, 83.3%), were higher than helicopters (n=3, 42.9%) but the difference was not statistically significant (Chi-Square Test; p =0.113).

3.4. Meteorological Events

Meteorology contributed to 29.2% of the PHG accidents (Table 1). It was determined that the accident occurred due to Unintended Flight into the IMC (Instrument Meteorological Conditions) in 12.1% (n=5) of the PHG accidents. In 14 (77.7%) balloon accidents, meteorology was one of the contributing factors (Table 2). When the accidents were grouped according to aircraft categories, the effects of meteorological factors were found to be higher in balloons (n=14, 77.7%) and helicopters (n=4, 57.1%) compared to PG (n=8, 23.5%), and the difference was statistically significant (Chi-Square Test; p=0.001).

3.5. Night Flight

5 (12.1%) of PHG accidents occurred between sunset and sunrise (Table 1). In the night flight accidents, 244 people died, and 44 were injured. Statistical analysis of the effects of

darkness was compared between helicopter and plane crashes, as balloon and glider flights were performed only between sunrise and sunset. The effects of darkness were found to be higher on planes (n=5, 15.6%) compared to helicopters (n=0, 0%), but the difference was not statistically significant (Fischer's Exact Test; p=0.56)

3.6. Biorhythm Disruptions (Dysrhythmia) or Fatigue

In 2 (4.8%) PHG accidents, dysrhythmia or fatigue affected the accidents (Table 1). Fatigue or dysrhythmia was not found in helicopter and balloon accidents. The effects of dysrhythmia and fatigue were found to be higher in PG (n=2, 5.9%), compared to balloons (n=0, 0%) and helicopters (n=0, 0%), but the difference was not statistically significant (Chi-Square Test; p=0.47).

3.7. Aircrew Intoxication

Intoxication was a factor in 4 (9.7%) of 41 PHG accidents. Alcohol (46 mg/dl, 15mg/dl) use was detected in 2 (4.8%) plane accidents, and psychoactive substance use was detected in 1 (2.4%) glider accident as a contributing factor. In 1 (2.4%) helicopter firefighting flight, carbon monoxide (CO) intoxication is considered to have contributed to the accident (Table 1). No intoxication was found among balloon accidents. The effects of intoxication were found to be higher in helicopters (n=1, 14.3%) and PG (n=3, 8.8%) compared to balloons (n=0, 0%), but the difference was not statistically significant (Chi-Square Test; p=0.34).

3.8. Crew Resource Management (CRM)

CRM was found as one of the causal factors in 41.4% (n=17) of 41 PHG accidents (Table 1). CRM was found as one of the causal factors in 61.1% (n=11) of the balloon accidents (Table 2). CRM effects were found to be higher in balloons (n=11, 61.1%) and helicopters (n=4, 57.1%) than PG (n=13, 38.2%), but the difference was not statistically significant (Chi-Square Test; p= 0.25).

Table 2. Overall Causal Factors and Flight Phases of Balloon Accidents.

No	D	I	Cause of Accident	Phase of Flight
*1**, †	1	10	Air collision	Cruise
*2**, †	.	1	Contact with a power line	Landing
*3**, †	.	1	Hard landing	Landing
4†	.	2	Hard landing	Landing
*5**	.	7	Hard landing	Landing
*6**, †	.	3	Contact with a base station	Descent
7†	.	12	Hard landing	Landing
*8**, †	.	18	Fire after hard landing	Landing
*9**, †	.	3	Hard landing	Landing
*10**, †	.	3	Contact with a power line	Cruise
*11**, †	1	7	Hard landing	Landing
*12**, †	1	1	Hard landing	Landing
*13**	3	22	Air collision	Cruise
*14**	1	7	Contact with a power line	Cruise
*15**	1	.	Hard landing	Landing
16	1	.	Falling from the basket (Ground personnel)	Landing
*17**	.	9	Hard landing	Landing
18	.	6	Hard landing	Landing

D: Deaths, I: Injuries

***** *Meteorology is a contributing factor, † CRM is a contributing factor.*

3.9. Loss of Situational Awareness (LSA)

LSA was a contributing factor in 16 (39.0%) of 41 PHG accidents (Table 4). 14 (87.5%) were plane accidents and 2 (12.5%) were helicopter accidents (Fischer's Exact Test; p=0.685). 9 (56.25%) of the LSA accidents were commercial, and 7 (43.75%) were general aviation accidents (Fischer's Exact Test; p=0.004). 4 (25.0%) of LSA accidents were training flight accidents (Fisher's Exact Test; p=0.501). 5 (31.3%) of the accidents, including LSA, occurred in night-time (Fischer's Exact Test; p=0.006).

3.10. Spatial Disorientation (SD)

Spatial Disorientation (SD) was found as one of the causal factors affecting the accident in 4 (9.7%) of 41 accidents (Table 4). There were three plane and one helicopter accidents (Fischer's Exact Test; p=0.563). 2 (50%) of them were training flight accidents (Fisher's Exact Test; p=0.573). 1 (25%) was commercial, and 3 (75%) were general aviation accidents (Fischer's Exact Test; p=1.0). Meteorology was the causal factor in 4 (100%) SD accidents (Fischer's Exact Test; p=0.033). All the SD accidents (100%) occurred during daylight hours (Fischer’s Exact Test; p=1.0).

3.11. Engine Malfunctions and Non-Engine System Malfunctions

In 10 (39.0%) of the 39 PH accidents, engine malfunctions and/or non-motor system malfunctions were determined as one of the causal factors (Table-1). Engine malfunctions and/or non-engine system malfunctions were detected in 25% (n=8) of planes and 28.6% (n=2) in helicopters, but the difference was not statistically significant (Fischer's Exact Test; p=1.0).

In our study, it was seen that the first two levels of HFACS were more dominant in the PHG accidents. Li et al. (2008) reported similar HFACS distribution (85.4% Level-1, 82.9% Level-2, 75.6% Level 3, 68.3% Level-4) in 41 civil aircraft accidents and this might be since the findings at first two levels can be obtained more easily in accident investigations. In the Kilic’s (2020) study, Level-1 (51.1%), Level-2 (44.61%), Level-3 (1.94%), Level-4 (%) 2.30) were reported in balloon accidents. It was seen that our results were higher than Kilic’s study, especially in level 3 and level 4 rates. The differences might occur since our study included balloon accidents in Turkey with all contributing factors, while Kilic’s study was conducted on US balloon accidents with only probable cause. It was also considered that especially with a detailed assessment of the 3rd and 4th level findings in the final accident reports to prevent balloon accidents, might lead to these high rates of level -3 and level -4 findings in our study.

Most fatal civil aviation accidents (94%) were general aviation accidents (Boyd and Hinkelbein 2017). Similarly, in our study, the plane, helicopter, and glider (PHG) accidents mainly occurred in general aviation (70.7%).

According to the literature, environmental factors, especially meteorology, seem effective in aviation accidents. Capobianco and Lee (2001) reported that meteorology was a factor in 27% of fatal general aviation accidents. Hasham et al. (2004) stated that adverse weather conditions were detected in a significant part of the balloon accidents. In the study of Goh and Wiegmann (2001), approximately 19% fatality rate was found in other types of general aviation accidents, while this rate was reported to be approximately 80% in VFR flight into IMC accidents. In our study, five accidents were VFR flights into IMC, and 4 (80%) of these accidents were fatal. In our study, following the literature, meteorology contributed 29.2% of PHG accidents, while 77.7% of the balloon accidents.

Although only 11% of aviation accidents occurred during dark times, these accidents were mainly fatal (Capobianco and Lee, 2001). The rate of fatigue has been reported to be at least 4-8% in aviation accidents (Caldwell, 2005). Kilic and Gumus's study (2020) showed that 63,33% of the nighttime accidents and incidents are associated with physical environment (such as severe turbulence, clear air turbulence, and wake turbulence). Our study determined that 12.1% of PHG accidents occurred during dark hours, and circadian dysrhythmia or fatigue affected the accident in 4.8% of the accidents. Pilots need to learn about bad weather, darkness, and physiological vision restrictions in reducing accidents.

Table 3. Frequency and Percentages of HFACS Categories for All Accidents.

	Plane, Helicopter, Glider Accidents						**Balloon Accidents**	
HFACS Category	All PHG Accidents (**N=41**)		General Aviation (**N=29**)		Commercial Aviation (**N=12**)		Balloon (**N=18**)	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Level-1 Unsafe Acts	**37**	**90.2**	**25**	**86.2**	**12**	**100**	**12**	**66.7**
Skill-Based Error	23	56.0	15	51.7	8	66.6	8	44.4
Perceptual Error	11	26.8	6	20.6	5	41.6	-	-
Decision Error	18	43.9	11	37.9	7	58.3	4	22.2
Routine Violations	31	75.6	20	68.9	11	91.6	7	38.8
Exceptional Violations	21	51.2	13	44.8	8	66.6	7	38.8
Level-2 Preconditions for Unsafe Acts	**39**	**95.1**	**27**	**93.1**	**12**	**100**	**18**	**100**
Physical Environment	24	58.5	13	44.8	11	91.6	15	83.3
Technological Environment	3	7.3	-	-	3	25.0	1	5.5
Adverse Mental States	21	51.2	12	41.3	9	75.0	2	11.1
Adverse Physiological States	6	14.6	4	13.7	2	16.6	-	-
Physical/Mental Limitations	17	41.4	11	37.9	6	50.0	-	-
Crew Resource Management	17	41.4	8	27.5	9	75.0	11	61.1
Personal Readiness	14	34.1	8	27.5	6	50.0	7	38.8
Level-3 Unsafe Supervision	**32**	**78.0**	**21**	**72.4**	**11**	**91.6**	**17**	**94.4**
Inadequate Supervision	22	53.6	12	41.3	10	83.3	16	88.8
Planned inappropriate operations	5	12.1	1	3.4	4	33.3	2	11.1
Failed to correct a known problem	6	14.6	5	17.2	1	8.3	-	-
Supervisory violation	9	21.9	8	27.5	1	8.3	2	11.1
Level-4 Organizational Influences	**24**	**58.5**	**14**	**48.2**	**10**	**83.3**	**15**	**83.3**
Resource management	7	17.0	2	6.8	5	41.6	10	55.5
Organizational climate	4	9.7	1	3.4	3	25.0	-	-
Organizational process	22	53.6	13	44.8	9	75.0	12	66.6

Since more than one causal factor was found to be associated in each accident, the sum of the rates within the same main group is not equal to 100%.

A comprehensive study in the USA found a history of driving-while-intoxicated (DWI) in 3.4% of the pilots, and a history of DWI was associated with a 43% increase in accident risk (Li et al., 2005). Another study conducted in the USA between 2000 and 2008 found that 10.6% of pilots involved in a fatal accident and had a previous history of alcohol or substance use had consumed alcohol before the accident (Botch and Johnson, 2009). Canfield et al. (2012) reported that alcohol above the limits was detected in 7% of the samples taken from pilots who lost their lives in civil aviation accidents between 2004 and 2008. In Mitchell and Lilywhite's (2013) study, 31 medical-related accidents were detected, and the majority (n=24, 77%) were psychiatric causes, including illicit/psychoactive substance or alcohol use. In our study, intoxication was a factor in 9.7% of 41 PHG accidents. Alcohol consumption was detected in 2 (4.8%) plane accidents, and psychoactive substance use was detected in 1 (2.4%) glider accidents. In aviation, carbon monoxide (CO) exposure can be in the form of a fire in the cockpit, mixing the exhaust into the cabin ventilation system, and causes intoxication (Dehart and Davis, 2002). Busch (2015) stated that CO exposure can cause clinical symptoms in rescue helicopter pilots. In our study, CO intoxication contributed to 1 (2.4%) firefighter helicopter accidents.

Crew Resource Management (CRM) is one of the prominent factors in PHG accidents. Li et al. (2008) found the effect of CRM to be 68.3% in their study. The CRM rate in accidents in Australia was found as 5.3% by Lenne et al. (2008) and it has been reported that it is mainly associated with violations, and its relationship with the upper levels in the HFACS could not be established. CRM was a factor in 41.4% of all accidents in our study.

Loss of Situational Awareness (LSA) and Spatial Disorientation (SD) have been significant problems for aviation safety. In Kirkham et al. (1978) study, it was reported that SD was detected in 2.5% of general aviation accidents, these accidents resulted in 90% fatalities. It is reported that 90-100% of pilots experience SD once in their career, and 6-32% result in an accident (Newman, 2007). Newman and Rupert (2020) reported the rate of SD as a primary cause or contributing factor in 549 Loss of Control accidents as 17.1% and stated that the annual number of SD accidents is increasing, and current pilot training may not be sufficient to prevent SD. SD-specific simulators in SD training help pilots better understand SD and perform escape maneuvers more effective (Gibb et al., 2011). In our study, it has been determined that LSA and SD were factors in 39% and 9.7% of PHG accidents, respectively, and these accidents have quite devastating results (268 deaths, 173 injuries in 16 LSA accidents and 8 deaths, 3 injuries in 4 SD accidents). Flight experience and adequate training are needed to prevent SD and LSA accidents. SD practical training is given periodically to military pilots as an effective countermeasure. For these reasons, we strongly recommend that incorporating SD practical training in the flight training of civilian pilots would be very beneficial as a countermeasure against SD accidents.

Engine malfunctions and/or aircraft system malfunctions other than engine faults were rare in aviation accidents. The rate of malfunction-related accidents in the NTSB data was reported as 14.3% in aircraft manufactured between 1970-1984, and the rate decreased to 12.2% in aircraft manufactured between 2000 and 2014 (Boyd and Hinkelbein, 2017). Głowacki and Balicki (2017) found that engine and/or non-engine system malfunctions were 40.6% for airplanes with a maximum take-off weight (MTOW) lower than 5700 kg, while 30.6% for airplanes with MTOW higher than 5700kg. In our study, following the literature, engine and/or non-engine system malfunctions were determined as contributing factors in 39% of the PH accidents.

Table 4. Overall Causes and Factors of SD and LSA Accidents

No	Class	D	I	Occurrence Category	Phase
A01†,‡	C	75	.	CFIT, NAV	Descent
A08	C	1	1	FUEL	Descent
A09	Gen(t)	1	1	CFIT	Cruise
A10*,†	Gen	2	.	WSTRW, UIMC, LOC-I	Cruise
A15	Gen(t)	1	1	CFIT	Cruise
A17‡	C	57	.	CFIT, NAV	Cruise
A18†,‡	C	75	5	USOS	Landing
A19	Gen	1	1	LOC-I, LALT	Landing
A21†	Gen	2	.	CFIT, UIMC	Cruise
A22	C	9	120	SCF-NP, LOC-I	Descent
A27‡	C	.	3	RE	Landing
A28*,†	Gen(t)	.	1	CFIT, UIMC	Cruise
A29*,†	Gen(t)	.	2	CFIT	Cruise
A32†,‡	C	37	36	USOS	Landing
H1†	C	1	2	CFIT, UIMC	Cruise
H7*,†	C	6	.	CFIT, UIMC	Cruise

D: Deaths, I: Injuries
H: Helicopter, C: Commercial Aviation, Gen: General Aviation, Gen(t): General Aviation – Training Flight
*CFIT: Controlled Flight into or Toward Terrain, NAV: Navigation Errors, LOC-I: Loss of Control-Inflight, LALT: Low Altitude Operations, SCF-NP: System/Component Failure or Malfunction (Non-Powerplant), USOS: Undershoot / Overshoot, FUEL: Fuel Related, WSTRW: Windshear or Thunderstorm, UIMC: Unintended Flight in IMC, RE: Runway Excursion, *Accidents Involving Spatial Disorientation, † Meteorology is a contributing factor, ‡Occurred During Dark Hours.*

4. Conclusion

This is the first study using official final accident reports analyzing "Turkish Civil Aviation Accidents" with the authors' best knowledge. This study showed that human factors still have a significant rate in civil aviation accidents. We think that academic training like CRM, LSA, SD, fatigue in aviation, aviation meteorology, etc., should be given more frequently to the aviators to prevent aviation accidents. In addition, it is considered that integrating Spatial Disorientation, Hypoxia, and Night Vision practical training, which are given periodically to military aircrews in many countries, into the civilian flight training and integrating HFACS factors into the "Aviation Safety Management System" might help to reduce aviation accidents' rates.

Ethical approval

Permission was obtained from the Republic of Turkey Ministry of Transport and Infrastructure to analyze the accident investigation reports. Each stage of the research was carried out based on the Declaration of Helsinki, and the University of Health Sciences Turkey, Gulhane Ethics Board approved the study (2019: 19/360).

Conflicts of Interest

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

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