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DETERMINE THE PROBABILITY OF PASSENGER SURVIVAL IN AN AVIATION INCIDENT WITH FIRE ON THE GROUND

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Conducting the risk level of aviation incident with fire and the impacts of contingence affecting factors on people. Base on statistical data of aviation incident, the model of aircraft fire situation on the ground was offer.

Keywords: *aircraft; aviation incident; statistical model; probability of getting in an aviation incident; probability of survival in an aviation incident.*

1. Introduction

Emergence of every aviation incident usually a consequence not because of individual reason, but because of chain result of the relevant prerequisites. The initiator causal chain in the aviation incident usually because of people mistake with deficiently professional preparedness, refusal of technics and equipment or unauthorized external effects. The predominant role of human factor in the formation of the primary prerequisites according to different sources hesitate from 60–70% in industry, others civilian facilities and 80–90% in aviation [1, 7].

ICAO initiated on determining risk that aimed at improving level of fly safety, which based on operation information of fly safety [4,8]. During the period 2006 to 2010 aviation incident related with safety operation on runway, make up 59% of the total number of incidents, 29% of all incidents fatalities and 19% of it dead. While incidents cause by loss control in flights is only 4%. Fly safety also related with the survival of people during aviation incident that can end without death as well as the presence or absence of fire on the ground.

2. The main reasons and fire situations in aviation incidents of aircrafts

Regardless of the type of aircraft (VS), the main reasons are poor control over the aircraft at low altitude, landing, taxiing, and fire/smoke after hitting the ground. The main factors leading to the death and injury of people in AI are increased shock overload – 80% fatalities and 75% injuries, poisoning from smoke and toxic gases – 16% fatalities and 14% injuries, and other factors – 3% fatalities and 10% injuries.

Obviously, the passenger can survive only if the AI is on the ground (or water). At the same time, eliminating the death toll from aircraft depressurization, shock, or pain because of ill health, the survivors still have to face with the problem of survival in case of fire of aircraft in the open vicinities of aviation incident.

Depending on the combination of these factors in [2] a typical amount ten cases of emergency state is presented. Presented cases are based on the generalization of AI materials that took place in the territory and or in the terminal area, i.e., in the area of accident rescue teams (ART) of airport.

In Table 1, these cases are arranged in order of complexity of firefighting and rescue conditions (evacuation) distressed passengers.

A list of events in case of fire emergencies on the ground [2] (Table 1).

As you can see, the main factors hampering rescue or self-rescue is the condition of the fuselage, the volume of the fire (its intensity, ignition area), and the passengers the ability to perform self-rescue. It should be noted that these factors must be added to the remoteness of the place of accident and rescue services from the airport (ACC) [2].

Table 1.

<table>
<tr><th rowspan="2">№ AI</th><th colspan="3">Factors characterizing AI</th></tr>
<tr><th>The position and condition of the fuselage</th><th>The nature of fire on aircraft</th><th>Status of passengers</th></tr>
<tr><td>1</td><td rowspan="4">Located on the landing gear completely, no damage</td><td>Fire engine</td><td rowspan="4">All or most of the passengers are capable of independent movement and evacuation</td></tr>
<tr><td>2</td><td>Burning parts falling</td></tr>
<tr><td>3</td><td>low-intensity fire outside of the fuselage</td></tr>
<tr><td>4</td><td>Fire under the fuselage of jet fuel spilled</td></tr>
<tr><td>5</td><td>Fuselage (passenger cabin) partially damaged</td><td>Fire spilled jet fuel around the fuselage of medium intensity</td><td>Some of the passengers are not able to self-rescue</td></tr>
<tr><td>6</td><td rowspan="2"></td><td>Fire spilled fuel under the fuselage of medium intensity</td><td rowspan="2"></td></tr>
<tr><td>7</td><td>The fire inside the fuselage</td></tr>
<tr><td>8</td><td>The fuselage is significantly damaged</td><td rowspan="3">Fire spilled under the fuse-lage of jet fuel, the fire inside the fuselage</td><td rowspan="3">Most of the passengers are not capable of independent movement and evacuation</td></tr>
<tr><td>9</td><td>The fuselage is on the ground, the passenger cabin is signifi-cant damage</td></tr>
<tr><td>10</td><td>The fuselage flipped, does considerable damage</td></tr>
</table>

Ensuring the survival conditions of the people and reducing the severity of the consequences of the AI with the fire on the ground can be achieved if follow this requirements [3].

– Extinguishing the fire on the aircraft should begin prior to exceeding the maximum permissible value of fire hazards;
– Localization fire time and fire extinguishing primary combustion area must not exceed the set value;
– Localized fire containment time should be sufficient for the evacuation of the emergency aircraft.

In addition, you must be guided by the principle and building forces and means involved in firefighting in the aircraft.

Mathematical modeling makes it possible to measure that and it is important to compare the relative frequency of occurrence of the danger and the fire situation, the probability of passengers death in a given situation, and to identify the most immediate dangers in terms of fire safety types of aircrafts and airlines.

Impacts of fire hazards at the AI can be determined based on the results of available statistical data relating to similar incidents. To determine the probability of survival in a fire because of the AI offers a simple probabilistic model of survival for passengers caught in AI. To determine the parameters of such a model it is necessary to analyze and process the statistical data on the AI with a fire on the ground. The most common indicators used to assess the static level of flight safety are the number of AI and the number of casualties in them. Therefore, to identify the main factors of AI, it is necessary that we use the statistical data on incidents registered during a sufficiently long time. Obviously, for a correct assessment of the model, parameters should strive to handle a more uniform data on the class and type of aircraft, be excluded from the statistical data sampling, instances of terrorist attacks, military operations, fire in the air, aircraft mid-air collision and etc. [1].

3. Probabilistic model situations of fire in aircraft in aviation incidents

The probability of survival for the passengers in case of fire in aircraft on the ground depends on:

- The number of passengers and evacuation (depending on the type of aircraft and flight qualification of the personnel);
- Proximity of the airport to the place of the AI;
- The value of the ground breaking the fuselage and especially the passenger cabin;
- The ability of passengers to self-rescue;
- The nature and intensity of the fire (fuel spill, fire, power plant, the fire inside the passenger cabin, etc.).

These parameters determining the survival of the passengers in case of fire in aircraft on the ground should be assessed in the analysis of statistical data and the organization of their collection. It is obvious that the proposed model will consist of a matrix of an emergency event and the probability of survival of the passengers.

Then the matrix event of emergencies (Table 2) will be as follows:

Table 2.

Emergency events Matrix

State of emergency (i)	1	2	…	…	i	i+1	…	…	n-1	n
P_i – the likelihood of passenger survival in the i-th situation	P_1	P_2	…	…	P_i	P_{i+1}	..	…	P_{n-1}	P_n
N_i – probability of i-th situation	N_1	N_2	…	…	N_i	N_{i+1}	..	..	N_{n-1}	N_n

The number of states n, generally can be taken from Table 1, where n = 10. Suppose that the event matrix (Table 2) is focused on the most favorable situations (i = 1). AI made almost within the precincts of the airport runway, the destruction of the passenger cabin is virtually absent, almost all the passengers are able to self-rescue, fuel spilled is minimal to catastrophic (i = n). AI occurred in a remote area of the airport, substantial damage to the passenger cabin, the majority of passengers struggled to self-rescue, extensive spilled fuel.

Obviously, the probability of survival of passengers Pi in favorable situation is the greatest, and catastrophic – the smallest, ie:

$$P1> P2> ... Pi-> Pi ....> Pn$$

where $\sum_{i=1}^{n} P_I = 1.0$ (1) is the probability of falling into a particular situation N_i. Logically it can be assumed that the most common situation is close to catastrophic and beneficial. The intermediate situation is likely to occur much less frequently:

$$N_{(1.2.3\ ...)} > N_i\ ...\ <..N_{(n-1,\ n)}$$

Just as in (1) $\sum_{i=1}^{n} N_I = 1.0$ (2)

In this setting of full matrix emergency events will have a minimum of 16 – 24 cases; 4 situation, with two extreme values:

– Close to airport – far from the airport;
– Fuselage lightly broken – badly damaged fuselage;
– Little spilled fuel – fuel spilled and ignited extensively;
– Passengers can evacuate on their own – passengers require help evacuating.

Such statistics are not present in the media – although in principle the organization collecting such statistics would be of some benefit, and given the opportunity to apply the methods of multivariate statistical analysis.

Therefore, assuming that the ability of passengers to self-rescue and degree of fuel spill directly correlated with the degree of destruction of the fuselage, simplify the array of events to nine states:

– AI degree of proximity to the airport, "airport" – "near the airport" – "at a distance from the airport."

– The degree of destruction of the fuselage with the AI: "low" – "medium" – "significant"

Matrix events (Table 2) will become as follows (Table 3).

Table 3.

Grouped alarm events Event matrix

Degree of destruction	Distance from the airport		
	In an Aeroport, i = 1	Near the airporti = 2	Far from the airporti = 3
Small, j =1	$\mathbf{P}_{11}$	$\mathbf{P}_{12}$	$\mathbf{P}_{13}$
Central, j = 2	$\mathbf{P}_{21}$	$\mathbf{P}_{22}$	$\mathbf{P}_{23}$
Much, j=3	$\mathbf{P}_{31}$	$\mathbf{P}_{32}$	$\mathbf{P}_{33}$

We continue further simplification of the model associated with the necessity of treating the available statistical data. Let us assume that the state of emergency situations are divided into I – «favorable» – with a high degree of probability of survival, and II – «adverse» – with a moderate degree of probability of survival. III – «catastrophic» – unlikely to survive in these situations. These groups are respectively highlighted in green, yellow, and red in Table 3. The probability falling into a dangerous situation of danger I, II or III (Table 3) denote respectively N_I, N_{II} and N_{III}. In this case, the source table alarms statuses event matrix (Table 3) takes the following form:

Table 4.

Matrix grouped emergencies

State of emergencies (•)	I	II	III
The probability of N (•) of an emergency (•)	N_I	N_{II}	N_{III}
passenger survival probability P (•) if it enters the emergency (•)	P_I	P_{II}	P_{III}

Thus, the total probability of survival of passengers in contact with the ground in a situation with a fire on the ground can be calculated using the formula:

$$P_{alive} = \sum_{I=1}^{I=3} P_I N_I \qquad (3)$$

or the average estimate of the probability to survive a passenger, got into the AI with fire.

Of course, to formulate a probabilistic conditions of an emergency N (•) is very difficult and not so important in principle. But, the probability of survival, P (•) can be calculated by an adaptation for flight accidents methods of calculation of survival in fires in civil and industrial buildings [5].

4. Analysis of statistical data to assess the probability of survival of passengers in an emergency with fire

Let us try to evaluate the given parameters of the proposed model (3) according to the available statistical data [4,8]. Consider the data conditionally accepting state groups, depending on the distance (group I to III) AI from the airport.

Table 5.

Statistical data on the AI to fire depending on the distance from the airport

Group states j	I	II	III	Total
N_{fire}	69	31	47	147
N_{deaths}	301	614	937	1852
N_{alive}	4041	456	688	5185
$N_{passangers}$	4342	1070	1625	7037

where

N_{fire} – number of fires;

N_{deaths} – who died in a fire on the ground

N_{alive} – surviving a fire on the aircraft

$N_{passengers}$ – the total number of passengers who find themselves in a situation with a fire on the aircraft.

We estimate the probability of occupant survival *Pj,* who turned in AI group – *j*

group I $\boldsymbol{P = \frac{N^{alive.}}{Npass} = \frac{4041}{4342} = 0.93}$

group II$P = \frac{N^{alive.}}{Npass} = \frac{456}{1070} = 0.42$

group III$\boldsymbol{P = \frac{N^{alive.}}{Npass} = \frac{688}{1625} = 0.42}$

Rate N_j hit passengers trapped in the AI group – *j*

Group I: $\boldsymbol{N = \frac{N^{fire}}{\sum n^{fire}} = \frac{69}{147} = 0.47}$

Group II:$\boldsymbol{N = \frac{N^{fire}}{\sum n^{fire}} = \frac{31}{147} = 0.21}$

Group III: N=$\boldsymbol{\frac{N^{fire}}{\sum n^{fire}} = \frac{47}{147} = 0.32}$

The data show that all AI with fire is likely to occur at the airport (or near) – Group I situations, or away from it (Group III situations), see (2). In addition, the possibility of passenger survival is greatest in the case of situations of group I, the compositions according to the model (3) matrix states and survival, we get:

Table 6.

The initial matrix event of emergencies

Group states - j	I	II	III
$P_{i\ alive}$	0.93	0.42	0.42
$N_{i\ situation}$	0.47	0.21	0.32

Based on the data, the average (full) probability of survival of passengers (3) is equal to

$$P_{alive} = \sum_{I=1}^{I=3} P_I N_I = 0.660 \tag{4}$$

Despite that when the data was taken into account only the distance AI from the airport received a full passenger survival probability based on the probability that in a particular situation is equal to 0.660, while the calculation of the probability of survival without regard to conditions hit probability in an emergency situation (arithmetic mean) we have:

$$P_{\text{survivors.} = \text{N is alive.} / \text{N passengers}} = 5185/7037 = 0.737 \sim 0.74 \tag{5}$$

which is almost 15% overstates the estimate of survival.

5. Determine the probability of passenger survival rate in an emergency per year

Determine the probability can be obtained based on one of three approaches:

1) Direct determine based on statistical data processing;

2) Analysis the model that relates to the likelihood of the considering event with probabilities of other events;

3) In the analysis, based on expert judgment

Let's conduct an analysis of statistical data on the ratio of the amount of aircraft emergencies per year for the group companies in the US [4.8].

Table 7.

Initial data for the AI with a fire in the period of 1995–2004

Index	AI with fire
Number of accidents	112
Number of passengers involved in fire	7017
Amount of deaths	1917

It is evident that the number of passengers caught in a fire in AI equaling 7017, during the same period as passengers that died in 1917, averaging 112.

Simple range probability of survival according to the formula:

$$P_{alive} = \frac{N^{pass}}{N^{fire}} = \frac{7017-1917}{7017} = 0.73 \tag{6}$$

Presented probability of survival for a group of companies under consideration almost equal to the arithmetic mean of the probability of survival for all US airlines [4.8]. Statistics examined airlines presents data on the hit rate of aircraft in different emergencies (see. Table 1), which is shown in Table 8.

Table 8.

Table initiating event of emergencies

The reason for the AP (situation i) see Table 1	Number of AP in a situation i Ni
i = 1	15
i = 2	14
i = 8	12
i = 10	10

Then estimate the probability of contact with AI event group *j,* (I = 1,2,3) for the consideration of the airlines.

Table 9.

Table probability event of emergencies

Group states - j (Table 1)	I group		II group	III group		Total
Status - i	1	2	-	8	10	-
number of accidents	15	14	-	12	10	51
Probability situatsii - i	0,294	0,275		0,235	0,196	
Ni - the probability of j-th group of states	0,57		-	0,43		-

Knowing the probability of occurrence of situations and the likelihood of falling into a dangerous situation from the model (3), we can determine the probability of passenger survival for the companies under consideration:

$$P_{survivors} = 0.66 \tag{7}$$

To estimate the probability of a passenger entering the AI with fire and their survival in it for the companies under consideration, we will determine the number of passengers transported per trip.

Total passengers trapped in the AI *with fire:* $N_{pass} = 7017$;

Number of *fires:* $N_{fire} = 112$.

It is obvious that the average number of passengers per flight who have fallen in the AI with fire.

$$N_{pass.} = \frac{\boldsymbol{N_{pass}}}{\boldsymbol{N_{fire}}} = \frac{\mathbf{7017}}{\mathbf{112}} = \mathbf{63} \text{ (aircraft type, close to the medium)}$$

Table 10.

The total number of flights of one airline per year [4.8]

Amount of one type aircraft, K	Average flight of one aircraft per year , N_i	Total number of flights per year , $N = K * N_i$
39	1300	50700

Then all airline passengers transported under consideration per year

$N_{pass} = 50700 * 63 = 3.2$ mil.pas./year

The number of passengers who find themselves in a situation with a fire (in a year):

$N^{fire}{}_{Pass} = \frac{\mathbf{7017}}{\mathbf{10}} = \mathbf{702}$ Pass. / Year

The probability of the passenger airlines get considered in the AI to fire (in a year)

$P^{fire.}{}_{Per\ year} = \frac{N^{pass} fire}{N^{allpass}} = \frac{702}{3.2*10^{6}} = \mathbf{2.2 * 10^{-4}}$

The probability of the passenger to be in AI with fire and die in it, for the given airlines a year, is equal to:

$P_{death} = P_{fall\ into\ the\ fire.} * (1-P_{to\ survive\ in\ a\ fire.})$

$P_{death} = 2.2 * 10^{-4} * 0,34 = 0,748*10^{-4}$

Regularly likely to be in the fire and death for people in case of fire of building constructions is 10^{-6} [6].

It can be seen that the passenger aircraft during the aviation accident with the fire on the ground (in a year), is 75 times more dangerous to the regulatory risk in the event of fire in the premises of building structures.

6. Conclusion

The proposed model makes it possible to assess the risk of the passengers killed in a fire situation on aircraft carriers and airlines and the compilation of the insurance fund for payments to the families of those killed and injured. In assessing, the level of risk of AI, we have to evaluate the exposure level of affecting factors on people in emergencies. With such a task may encounter expert, insurance companies and owners of companies. To assess the level of danger requires AI effects data, the number of casualties, economic damage. In fact, evaluation of the impact of factors affecting people and the aircraft comes down to the definition of two functions: the dependence of the number of fire hazards on the distance to the accident and the damage dependent on the number of factors.

The probability of survival at the AI with post-accident fire is lower than in a situation with a fire in civil engineering. Implementation of the developed model allows to quantitatively calculate the amount of fire hazards in the AI based on probabilistic method by direct processing of statistical data.

The resulting research evidence, increase the objectivity and probative conducted expert studies.

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