AVIATION ACCIDENT – FIRE MODELLING USING PROGRAMME PATHFINDER IN RIGA AIRPORT LIABILITY AREA

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Abstract. The article will explore and collect information about the possible accidents with the Airbus 220-300 aircraft, which is the new and largest aircraft that can be serviced at Riga airport. Previously, such a large plane had not been serviced at Riga Airport, so the article will gather technical information about the characteristics of the Airbus 220-300 compared to previous model planes. As part of the work, passenger evacuation modelling will be carried out with the help of the Pathfinder program, which will be used for emergency simulation. The results of the study may be used to implement further improvements, as well as to ensure more efficient firefighting team work in emergencies in the Riga Airport liability area, as well as other airports serving the Airbus 220-300 aircraft. Reaching the aim will provide an opportunity to look at different variations in the evacuation of people depending on the composition of passengers, behaviour and location of escape exits.

Keywords: plane crash, fire, response.

Introduction

Nowadays, there is a growing interest from both passengers and airports in a quality, efficient and environmentally friendly aircraft that can not only meet the increasing passenger requirements but also make the flight safe. At present, only newer and more technologically advanced aircrafts are emerging in the aviation market, with increasing emphasis on safety and aircraft efficiency. In the event of an aeroplane emergency, it is essential to train flight crew personnel, who should be provided with a high level of preparedness to take effective action if necessary in the event of a potential emergency. This knowledge enables the effective use of aircraft equipment built to help save passengers' lives in the event of an emergency evacuation and minimise the harmful consequences that may occur in the event of an emergency. Aircraft personnel in the event of an emergency involving a fire shall be required to identify which emergency exits can be used for evacuation and which cannot, and after identification of the situation, ensure safe exits and the necessary opening of emergency doors as quickly as possible.

Aircraft evacuations are relatively rare in today's aviation sector, but this is an essential process from a safety point of view when an emergency occurs. From a logic point of view, one can always find an opportunity to make a real evacuation from the plane, but it comes with a variety of nuances, including money issues and the potential traumatism of the persons to be evacuated. A cost-effective solution offered by various scientists is to perform computer simulations to understand the dynamics of evacuation in the event of an emergency [1]. It is therefore important, as part of the study, to assess the emergency situation with a larger aeroplane, which can be carried out in the liability area of Riga airport, although without actually evacuating people, but using a computer simulation tool. This will help make more efficient use of existing resources by improving the life-saving algorithm and safety aspects at the scene of the accident and recognizing possible worst-case evacuation options.

Characteristics and technical parameters of Airbus A220

Today, energy prices are increasing faster, as well as thinking greener and more environmentally friendly, in 2012 Latvian national airline Air Baltic decided to expand and renew its air fleet with new, economic and modern aircrafts. A contract was signed with Canadian manufacturer Bombardier to buy ten CSeries 300 planes with the option of buying ten more aircrafts.

In the second half of 2016, Air Baltic was the first airline in the world to receive and start using CS300 aircrafts. According to the Air Baltic CEO Martin Gauss: We are excited to welcome our first CS300 plane and be the first airline in the world to receive and launch commercial flights using CS300, the most advanced plane in terms of both innovation and technology [2].

In 2017, Latvian airline Air Baltic received seven new Bombardier CS300 planes and had carried more than 635,250 passengers to 60 destinations. The CS300 was recognised as the first environmentally friendly aircraft which life-cycle environmental impact is completely transparent.

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When Bombardier announced the firm's breakdown, the order was transferred to Boeing/Airbus. The production of the aircraft ordered for Latvia was continued by Airbus and the previous model Bombardier CS300 was renamed the Airbus A220-300. After the partnership was approved in July 2018, Air Baltic was supplied with the first A220 aircraft which had its brand name changed to A220-300 (Airbus A220-300, 2022).

Technical parameters:

1. Overall length: 38.7 m
2. Cabin length: 27.5 m
3. Maximum diameter of the fuel tank: 3.5 m
4. Maximum cab width: 3.28 m
5. Wing width: 35.1 m
6. Height: 11.5 m

Capacity:

1. Maximum seating capacity: 160
2. Number of 2-class seats: 120-150 [3].

These aircrafts are characterised by advanced applications of various innovative materials, including composite materials for the wing part of the aircraft, in the front and rear fuselage. This helped reduce the overall weight of the aircraft and increased corrosion resistance. This has resulted in better efficiency and maintenance provision. The use of the modern and innovative materials of the Airbus A220-100 accounted for around 40% of all usable materials, providing weight savings to reduce fuel consumption, with an additional reduction of up to 25% CO2 and up to 50% of NO_x emissions [4].

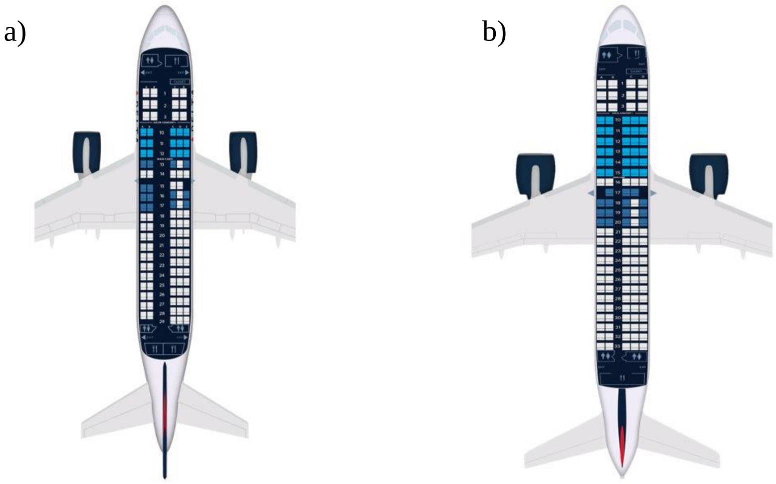

Fig. 1. **Comparison between Airbus A220-100 and A220-300 aircrafts [5]:** a – A220-100; b – A220-300

As it can be seen from Figure 1, when comparing Airbus A220-100 and Airbus A220-300 aircrafts, the Airbus A220-300 has larger engines, the tail part of the aircraft has become more compact, and the number of seats has been increased. This has generally made it possible to increase the aircraft capacity as well as improve various technological and safety solutions. In addition, it provides an opportunity to ensure more efficient and faster possible evacuation of aircraft passengers, fire extinguishing and risk of accident mitigation.

However, despite modern technical solutions and capabilities, Airbus aircrafts are also experiencing various accidents in different parts of the aircraft. Various technical improvements in aircrafts operated today have significantly reduced the trend of accidents.

Evacuation characteristics and assessment of the time required

In this part of the article assessment of the passenger evacuation measures taking into account the type of aircraft, which in this case is the Airbus A220-300 and the possible adverse impact factor, the fire, will be carried out.

The greatest danger to passengers is caused by fires occurring during an emergency landing when damage to the plane fuel tank occurs and its tightness is lost. If spilled, aviation fuel catches fire, the fire usually surrounds the fuselage of the aircraft and blocks part of the escape exits. The burning fuel combustion temperature and strong heat flow of aviation fuel warms the fuselage of the aeroplane very quickly, resulting in the loss of strength of the materials in the skin of the aeroplane and the loss of tightness of the fuselage casing, as well as the result of heat radiation causes a rapid increase in the temperature in the cabin due to insufficient ventilation, and temperatures in the cabin reaching 500-600 C, resulting in a self-inflammation of hand luggage and trim materials inside the cabin, which rapidly increases the fire area.

Information compiled by scientists Y.Liu et al., based on the National Transportation Safety Board report that provides information that 78% of all deaths in the planes occurred after the impact, 95.4% resulted from smoke inhalation and burns due to slow and ineffective evacuation, found that if survivors of the crash could be immediately evacuated after the impact, the survival rate would increase by 98.3% [6].

For a number of reasons, the time to evacuate passengers is always very limited and at best is around 180 seconds [7]. Other authors mention shorter evacuation times, determined in accordance with Part 25.803 of the Federal Aviation Board (FAA) Standard. New aircraft must meet multiple conditions, including the ‘90-second standard’. This condition requires that the maximum number of seats and aeroplane capacity, including crew members, should be evacuated from plane to ground within 90 seconds, provided that less than half of the emergency exits are available [8]. However, meeting this standard is a very challenging task, as the disembarking time required for evacuation is influenced by many factors such as the airframe (number, size and location of emergency exits, seat), passengers (age, health, gender, relationship and degree of panic) and the flight crew (level of skills and training) [8]. According to FAA Standard 14. 25 part, it is stated that during actual evacuation from plane the participants must be of normal health, 40% of whom are women and 35% of whom are over 50. The total evacuation time is determined when the last passenger reaches the ground using inflatable slides [1]. However, through an evacuation modelling, scientists such as Mr. Zhi-Ming and others found the following relationship that the time of the exit evacuation of each passenger in the event of a fire is longer than the condition without fire. The reason is that people tend to avoid fire, high temperatures and poor visibility will affect the movement route [9]. It can be observed that the modelling time and the actual passenger time in the stress situation will clearly be longer than the time that has been stated in the aircraft certification, where the people participating in the certification evacuation are ready to evacuate after the signal.

The topicality of the study is also complemented by the situation where aircraft certification does not adequately address the issue that some escape exits are blocked and evacuations occur in only one direction, which slows down the evacuation process. Nor are the issues of people being able to move in opposite direction addressed, it happens when members of the same family are located in different parts of the cabin of the plane. The composition of people in the cabin of the plane also affect evacuation processes. An additional barrier in the cabin may include, for example, luggage left in an aisle between chairs or hand luggage that fell during emergency landing, these restrictions could hinder the evacuation flow of passengers. Narrower aisle sizes increase congestion by reducing flow rate, thus making the evacuation process time longer [10]. In addition, other factors are also named, such as in actual aviation accidents due to panic some passengers may behave inappropriately, such as getting on a seat and conflicting with other passengers [6]. As part of the study, such behaviour is ignored in this modelling, and it is assumed that all passengers are trying to get out of the cabin as quickly as possible in a systematic order.

It can be noted that, due to the above factors, the real situation may differ significantly from that of the certification tests. Consequently, the evacuation time will also be different and will not always be within the 90 s regulatory framework. The circumstances in which aviation accidents occur with a fire in an airport area can vary widely.

Consequently, exits that are on the plane cannot always be considered equivalent because some of them, for example, are close to fuel tanks and are less safe.

Small suburban-sized aircraft up to a large narrow hull for planes are often equipped with Type III doors above the wing, which includes the Airbus 220-300. Unlike major types of exit doors, Type III exits require the passengers to manually remove the exit hatch themselves and, after removal, to place the hatch away from the exit port. Accident studies and experiments have shown that under the influence of emotional disorientation state of mind a passenger can throw a hatch inappropriately, which will hamper evacuation flow and a total exit time [11]. To help plane passengers make more efficient use of emergency exits, in China there is an obligation for flight crew personnel to help evacuate passengers in the event of an emergency. In accordance with the requirements of the Annex to Part 25 of the China Civil Aviation Regulations, during the 90-second emergency evacuation experiment, the crew is assigned the following duties: direct passengers to move quickly to the exit, direct the passenger to pick the right exit, follow the evacuation order and ensure safety of passengers [12].

Evacuation modelling

Passenger evacuation modelling programs provide more reliable data because it keeps aircraft manufacturers running in multiple trials, choose different strategies, and visualize scenarios where each passenger has different health and physiological condition. In this particulat study modelling was performed using the Pathfinder program.

As a general rule, modelling requires determining the location of the fire and determining the percentage of passengers to be evacuated, after which it is necessary to determine the modelling scenario. In general, modelling is carried out using the following parameters, which need to be followed in the modelling process to produce reliable results:

- demonstration must be carried out in the dark of night or simulated in the dark of night;
- aeroplane emergency lighting system can provide the only exit track and slide lighting;
- use a certain number of passengers “with normal health” as well as a percentage distribution of passengers from other groups;
- up to 50 per cent of emergency exits may be used [13].

Based on these criteria, the study identified the composition of the passenger group with normal health for which evacuation modelling will be carried out, the passenger composition is given in Table 1. A total number is 145 passengers and five crew members.

Table 1

Composition of passengers

No	Group		
	Composition	%	Movement speed, $m \cdot s^{-1}$
1.	Women	30	1.67
2.	Men	60	1.67
3.	Persons 60 y >	5	1.17
4.	Children up to 12 y.o.	5	1.00

The individual-flow model for simulating human movement will be used to determine the time of evacuation, as the modelling object is each individual person, allowing a more accurate reflection of the different behavioural factors present in the particular room. A computer simulation program, Pathfinder was selected for modelling, allowing the implementation of the individual-flow model and the assignment of its own behavioural model to each individual person [14]. The modelling identified different movement speeds for passengers depending on their age and gender. For men: if the age is between 20 and 40 years, their speed is assumed to be 1.67 $m \cdot s^{-1}$, if it is between 40 and 50 years then 1.17 $m \cdot s^{-1}$ and if between 50 and 70 years, then 1.0 $m \cdot s^{-1}$, similar to women 1.67 $m \cdot s^{-1}$, 1.17 $m \cdot s^{-1}$ and 1.0 $m \cdot s^{-1}$ respectively.

There are a total of 4 exits on the plane and two hatches above the wings, in the simulation the passenger tries to pick one of those exits where there are no hazard factors. During modelling, these exits may be open or closed, only 2 exits in front of the aeroplane are left open in the examined situation.

Based on a selected two exits, several evacuation models will be viewed and the evacuation time compared. Scenario 1, with only two front exits open and all people heading for an evacuation exit in one direction. Scenario 2, where two front exits are open but one person goes against the flow. An evacuation start time of 6 seconds is assumed for modelling. As well as a door permeability factor of 0.7, which helps slow down the flow at the exit required for a person to overcome fear before descending on an inflatable ladder.

As part of the simulation, the Pathfinder program builds a model airplane and distributes passengers and crew members, as pictured in Figure 2. The figure also shows the escape exits that were closed.

Fig. 2. **A220-300 model**

As part of the simulation, it is assumed that one of the members of the crew (from inside the cabin) opens emergency exits, the opening time is assumed to be 2 sec.

In the event of a situation in which a threat to human life and health may occur, crew personnel shall take into account the following factors when deciding to evacuate:

- nature of smoke spread (black or white smoke), open fire present,
- enough information has been received to make a decision.

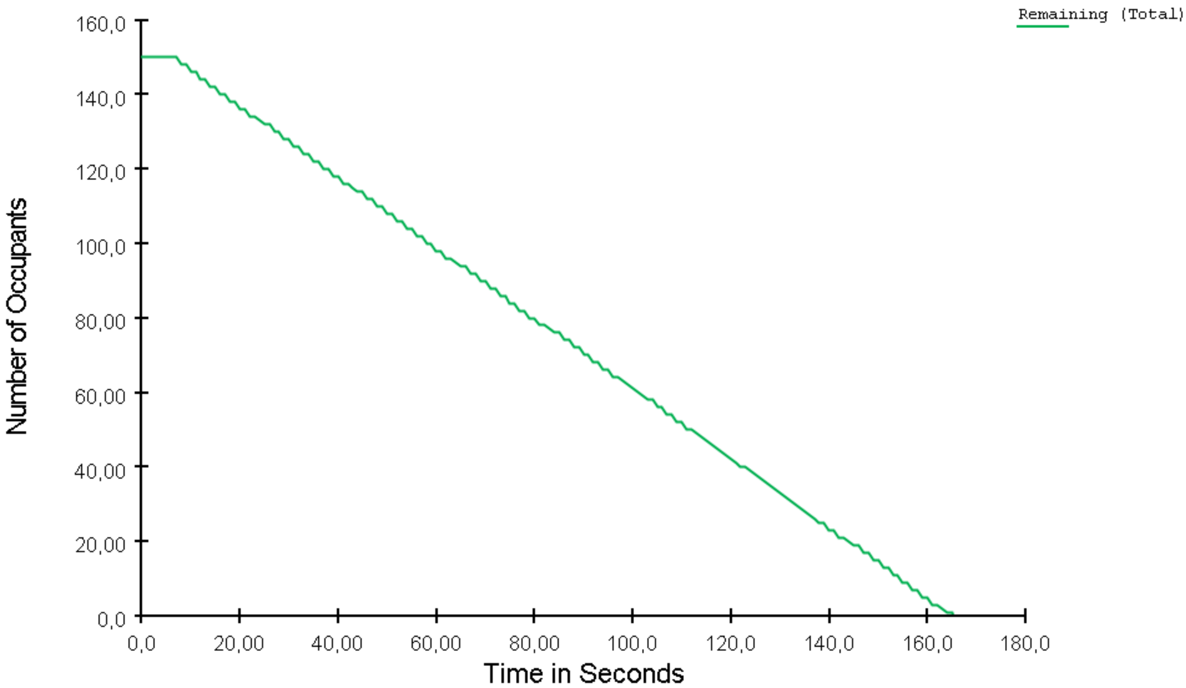

Fig. 3. **Scenario 1, total evacuation time**

The total evacuation time for scenario 1 was 164 seconds, Figure 3 provides an evacuation diagram from the Pathfinder program.

Emergency exits are usually opened by one of the members of the crew (from inside the cab) or by one rescuer (from outside) without the use of keys and tools. In the areas of emergency exits leading to the wing surface, the passageways between the chairs are enlarged and do not interfere with the opening of hatches and the evacuation of passengers through them, but the study modelling assumed that these exits could not be used.

The total evacuation time for scenario 2 was 167.4 seconds. Figure 4 provides an evacuation diagram, this is because one person went against the flow and the evacuation time increased, but the overall increase is not too great, yet in a real situation this time could be even greater, as such behaviour would also cause additional emotional stress and frustration among passengers.

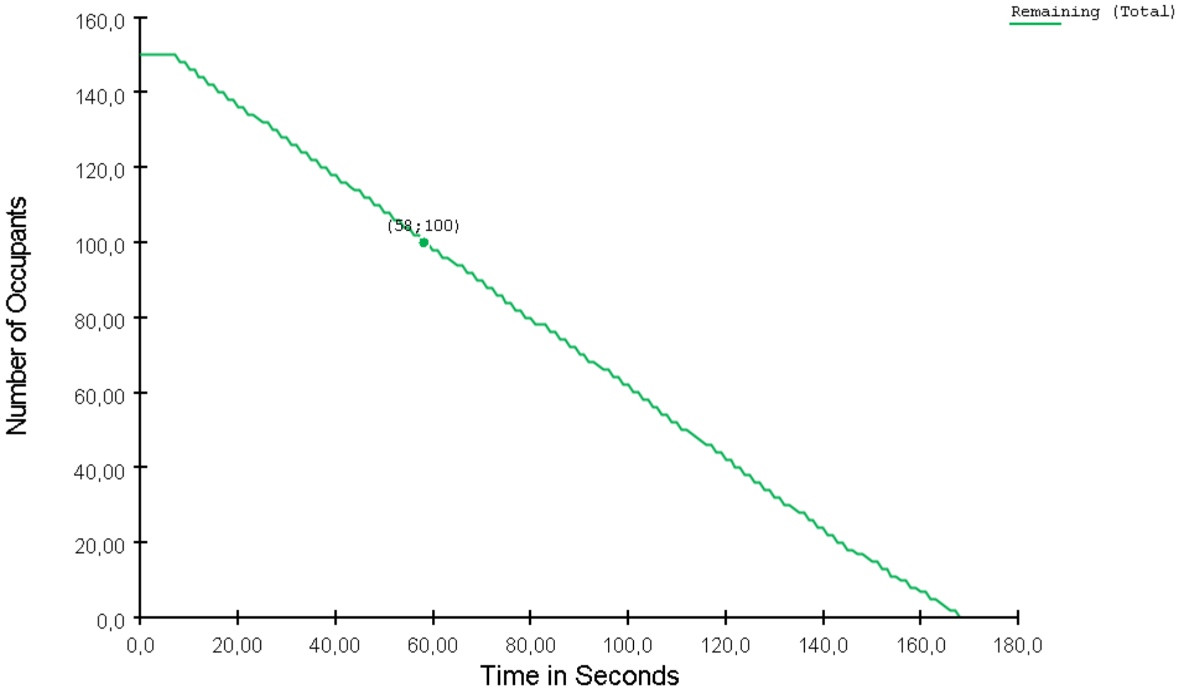

Fig. 4. **Scenario 2, total evacuation time**

The distribution of group 1 people on the plane is shown in Figure 5.

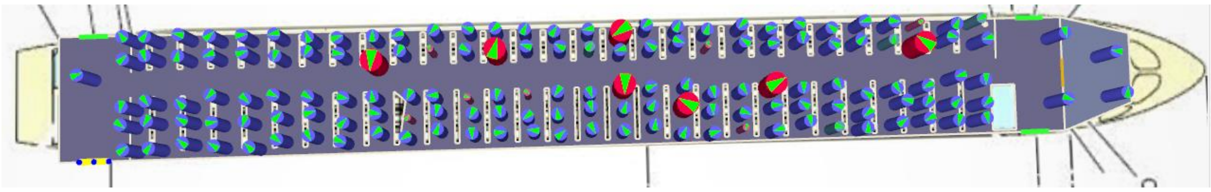

Fig. 5. **Distribution of passengers**

The results of the study provide information that safe evacuation of passengers using two front exits is not ensured and the evacuation time exceeds the 90 second norm. As a solution to scenario 2, in order to reduce the evacuation time, it would be necessary to place members of one family together or very close to one another, thus reducing unnecessary movements of passengers against the flow, which increases stress among passengers in the event of an emergency.

Modelling scenarios showed that for the most common accident fires on the plane, passengers would only have access to two exits.

Conclusions

The survival of passengers in aviation accidents in the airport area shows that, while in the cabin of a burning plane, they can only survive if there is a timely evacuation while leaving to a safe zone. The main evacuation task of passengers and the crew is to carry it out as quickly as possible to preserve people's chances of survival. The fire location affects the flow of people and how many exits will be available to passengers, as well as the distances to the exit, which can increase the evacuation time.

Using a simulation model, evacuating passengers from an airplane, the computer environment allows to effectively predict human behavior in the event of evacuation in different scenarios of its development. Computer simulation of the evacuation process proved that if a passenger moves against the evacuation flow, then the evacuation time extends. An approbation of the particular model showed that the time necessary to leave the crashed plane did not comply with the 90 second regulatory framework. This confirms that in the event of an emergency landing, not all passengers and crew members of the plane will be able to leave the plane until critical conditions in the cabin of the plane occur.

Author contributions

All the authors have contributed equally to creation of this article.

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