Topic area A1
Topic Area: SIG-8 (Air Transport Research Society) Session Track

12th WORLD CONFERENCE ON TRANSPORT RESEARCH

THE IMPACTS OF AIRCRAFT INCIDENT ON THE UNIT OPERATING COSTS OF CIVIL AIRCRAFT

Olja Cokorilo
MSc, BSc in Air Transport Engineering, Doctoral student
oljav@sf.bg.ac.rs
Slobodan Gvozdenovic
PhD, MSc, BSc in Air Transport Engineering, Professor
dean@sf.bg.ac.rs
Petar Mirosavljevic
MSc, BSc in Air Transport Engineering, Doctoral student
airperami1@yahoo.com
The Faculty for Traffic and Transport Engineering,
Vojvode Stepe 305, 11000 Belgrade, Republic of Serbia, Europe
Phone: ++381 11 3091 233, ++381 63 77 32 568, Fax: ++381 11 3976 017
Natasa Babacev
MSc, BSc in Mathematics, Doctoral student
natasa@etf.rs
The Faculty of Electrical Engineering,
Bulevar Kralja Aleksandra 73, 11000 Belgrade, Republic of Serbia, Europe

Abstract

Over the years, increasing attention has been paid to the aircraft accident and incident prevention. Of all the consequences generated from commercial flights, aircraft accidents and incidents have significant impacts on humans, aircraft damage, third part damages and infrastructure. However, the impacts of aircraft accidents and incidents are a world-wide issue and have drawn significant attention in the global community.

This research aims to evaluate the impacts of aircraft incident, based on the estimation of incident costs, on aircraft operating costs, involving European regional flight routes for civil aircraft. The paper firstly presents the method of assessing the aircraft unit operating costs. The aircraft incidents have impacts on unit costs, which are shown on example of aircraft landing stage, with point in landing gear failure. The incident costs of aircraft vary by value of spare type and aircraft category, depending on the caused damages. The implications of aircraft incident costs (due to landing gear failure) on the corresponding effects on unit operating costs were measured, involving regional aircraft B737-300. Paper presents originally developed mathematical model that is applied to simulate aircraft annual utilization by considering the incident costs effects on aircraft unit operating costs. It was found that the aircraft incident costs have influence on process of optimal range of the aircraft unit operating costs determination, depending on the route distance, aircraft types and the forecasted annual utilization.

Keywords: Aircraft unit operating costs; Incident costs; Annual utilization;

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1. Introduction

Over the years, increasing attention has been paid to the aircraft accident and incident prevention. Of all the consequences generated from commercial flights, aircraft accidents and incidents have significant impacts on humans, aircraft damage, third part damages and infrastructure. However, the impacts of aircraft accidents and incidents are a world-wide issue and have drawn significant attention in the global community.

According to (ICAO, 2001) incident is an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation, whilst serious incident is an incident involving circumstances indicating that an accident nearly occurred. The difference between an accident and a serious incident lies only in the result. The same source defined different types of aircraft incidents of main interest as it is shown below:

- Engine failure. Failures of more than one engine on the same aircraft and failures which are not confined to the engine, excluding compressor blade and turbine bucket failures.
- Fires. Fires which occur in flight including those engine fires which are not contained in the engine.
- Terrain and obstacle clearance incidents. Occurrences which result in danger of collision or actual collision with terrain or obstacles.
- Flight control and stability problems. Occurrences which have caused difficulties in controlling the aircraft, e.g. aircraft system failures, weather phenomena, operation outside the approved flight envelope.
- Take-off and landing incidents. Incidents such as undershooting, overrunning, running off the side of runways, wheels-up landing.
- Flight crew incapacitation. Inability of any required flight crew member to perform prescribed flight duties as a result of reduced medical fitness.
- Decompression. Decompression resulting in emergency descent.
- Near collisions and other air traffic incidents. Near collisions and other hazardous air traffic incidents including faulty procedures or equipment failures.

This list can be expanded further in accordance to the examples given in ICAO Annex 13 regarding the description of serious incidents.

2. Methodology for assessing aircraft unit operating costs

Cost benefit analysis presents most common approach in variety of aircraft operation field's evaluations. Therefore, incident consequences should be measured according to damage repair as well as for safety management system evaluation step due to incident prevention. According to the above approach, an aircraft cost evaluation is traditionally based primarily on one economical figure: the Direct Operating Costs, DOC. Also DOC takes account of criteria like weight, maintainability, reliability, and aircraft price, but DOC combine these separate parameters unambiguously by calculating their economical implications. Aircraft DOC methods have been defined e.g. by:

- the Air Transport Association of America, 1967 [ATA 67],
- the Association of European Airlines, 1989 [AEA 89a], [AEA 89b],
- NASA / American Airlines, 1977 [NASA 77],
- Airbus Industries [AIRBUS 88],
- Lufthansa [LUFTHANSA 82].

This paper is based on an operating cost model which was developed by AEA, using common operating cost components to calculate the cost of running an airline service along a route. According to (AEA, 2007) direct operating cost distribution could be presented as follows.

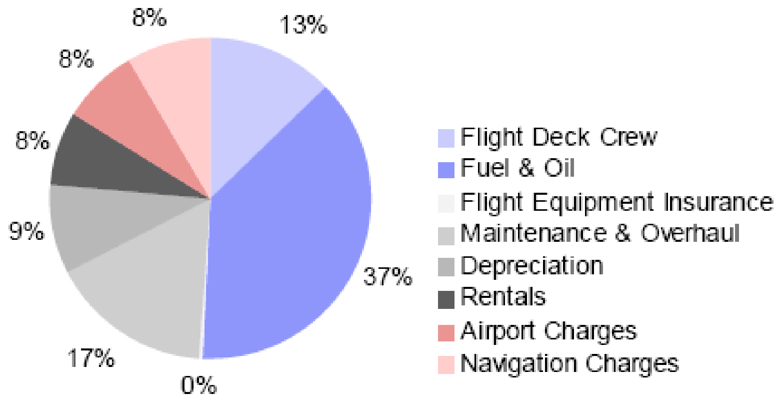

Fig 1 Cost distribution, % of total direct operating costs (2006)

For the purpose of this paper block time is described as the time period in hours from 'engine-on' to 'engine–off', taking into consideration the lost time as the aircraft is taking off and landing.

For the presented model, based on aircraft B737-300, the utilization period is considered daily and annually to calculate the direct operating costs. Annual utilization is a product of daily utilization and number of working weeks in a year, assumed to be an average of 48 weeks, while daily utilization has to be calculated from the block time and the ground handling time a day within usable operating hours as shown below:

$$U_d=VTT/(1+t_{po}/t_{bpr}) \quad (1)$$

(Stratford, 1973) suggests that for any given aircraft to be utilized efficiently, in a bid to spread out operating costs over its economic life, it will be in use for a maximum of 14 hours in any operating day, whether daytime or nighttime. Even though technology has changed over the years, the number of hours for which newer aircraft in the industry can operate on a flight is still at an average of 14 hrs for the long-haul 400-seater planes. This means the frequency of flights an aircraft can perform will be dictated by the usable hours in a day. Assumed number of usable hours in an operating day for B737-300 is 12. Annual aircraft utilization is given as:

$$U=n_p*7*U_d \quad (2)$$

Model Output

The model's output component calculates a range of cost indicators that are used to analyze the type of incident being provided on a sample of B737-300. For the DOC calculation it is important to identify cost components and systematize costs as it is shown in table 1. Since DOC are variable costs related to route distance, flight time and annual utilization, this sample analyses those parameters for average regional flight as a portion of fixed costs. The variable costs are those related to necessary maintenance period (reflected by aircraft utilization before and after incident occurrence).

Operating costs assumptions - normal operations		
The mean distance per route *Dpr*	340	nm
Block time coefficient *a*	0,149	Fhr
Block time coefficient *b*	0,002	Fhr/nm
The mean block time per route *tbpr*	0,943	Bhr
Aircraft service time *VTT*	12	Hrs
Aircraft ground handling time *tpo*	0,5	Hrs
Aircraft daily utilization *Ud*	7,84	Bhrs
Working weeks in a year for comercial aircraft service *np*	48	
Aircraft annual utilization *U*	2634,96	Bhrs
Working weeks in a year before an incident *nbi*	20	
Aircraft utilization before an incident *Ubi*	1097,90	Bhrs
Number of weeks in year when aircraft is not in service due to damage repair *np*	8	
Working weeks in year when aircraft is in service after damage repair *nai*	20	
Aircraft utilization after demage repair *Uai*	1097,90	Bhrs
Total annual aircraft utilization including time repair *Ur*	2195,80	Bhrs
Incident related costs		
Costs of additional flight on route AAA-BBB due to passengers transportation after incident *Tdl*	8355,34	USD$
Costs of new material for aircraft system/subsystem damage repair *Tms*	250000,00	USD$
Man hour due to aircraft structure maintenance *VRS*	25,00	USD$/Mhr
Working hours for damage repair after aircraft incident *PRS*	150	Mhr
Test flight costs *Tpl*	2947,72	USD$
Total incident related costs *TOO*	265053,06	USD$
Unit incident related costs t10	120,71	USD$/Bhr

Table 1 Costs breakdown due to normal operations/incident

3. Case study: landing gear failure

According to statistical data (EUROCONTROL, 2007) of total number of aircraft operating in controlled airspace in Europe, by aircraft type, B737 has been the most operated aircraft by the number of 1442 aircraft or 10.1%. This paper considers landing gear failure accident of this aircraft type. Demonstrated accident/incident reports show that the landing phase is the most hazardous phase no matter by which factors is been affected. Standard procedure in normal operations requires plenty of crew actions and systematic approach for safety landing. Planning for the landing should start before takeoff (FSF, 2009). Risks can be reduced by selecting a runway that either has a precision approach or other means of vertical guidance and provides the most favorable overall performance. At critical airports (e.g., those with contaminated runways, short runways, adverse wind conditions, etc.), consideration should be given to not scheduling aircraft with inoperative braking systems (e.g., wheels brakes, anti-skid, spoilers, thrust reversers), and extra weight (e.g., tanked fuel) should be minimized. Accurate weather information and timely runway condition information are essential for landing phase. Crews should carefully review all aircraft performance computations and be alert for FMS data entry errors (e.g., weights, speeds, runway length, etc.). The effects of all environmental conditions on aircraft performance must be evaluated (e.g., temperature, pressure, wind, runway contamination and slope, obstacles, etc.), and the effects of inoperative aircraft systems (e.g., wheel brakes, anti-skid, thrust reversers, spoilers) must be considered. Adequate landing performance safety margins should be applied.

This paper shows that aircraft incident influences based on landing gear failure on annual utilization, as well as on unit operating costs. Calculation is done based on assumptions provided in table 1 and results are presented in table 2. The second column in table 2 presents case where the aircraft achieves maximal annual utilization without any failure which is referred to 48 working weeks per year. Other cases presented in table below are related to unit operating costs based on aircraft cancelation from service due to repair period from 1.5 to 8 weeks during the year. Table 2 also shows the increase of total DOC per flight related to aircraft state out of service caused by landing gear failure. The results provided below are the costs, calculated according to (ICAO, 2007) for operating a number of aircraft model B737 per hour.

No of weeks when aircraft is out of service due to landing gear failure	0	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8
Utilization - U (Bhrs)	2635	2552,16	2525,17	2497,72	2470,27	2442,82	2415,38	2387,93	2360,48	2333,03	2305,59	2278,14	2250,69	2223,29	2195,8
DOC (USD)	8355,34	8664,15	8708,17	8753,88	8800,61	8848,39	8897,24	8945,63	8998,38	9050,72	9104,31	9159,21	9215,44	9272,96	9332,1
Unit operating costs - t_1(USD/Bhr)	4573,97	4743,02	4767,12	4792,14	4817,72	4843,88	4870,62	4887,11	4925,99	4954,64	4983,98	5014,03	5044,81	5076,3	5108,67
Increase of DOC due to landing gear failure (%)	0,00	3,70	4,22	4,77	5,33	5,90	6,49	7,06	7,70	8,32	8,96	9,62	10,29	10,98	11,69

Table 2 Unit operating costs variation due to annual utilization determined by aircraft incident during the landing phase

To locate the number of aircraft annual utilization for which the trend of unit operating costs *t1* starts to decrease with reduced speed, we need to locate the inflection point of the function that gives dependence of unit operating costs on the variable aircraft annual utilization. From the graphical interpretation (Fig 2) of the data we can locate the inflection point in the interval [2360.48, 2442.82]. For the calculation of the inflection point we used the Lagrange Interpolating Polynomial and its second derivative. Taking in count that annual utilization is an integer, we get that the inflection point is 2407 Bhr. Given result shows that for regional flight realization, aircraft B737 (according to data given in table 1) should achieve annual utilization more than 2407Bhr for having slow increase of unit operating costs in case of landing gear failure occurrences. Annual utilization less than 2407Bhr could provide unit operating costs jump according to assumptions described in table 1. Get inflection point determined optimal annual utilization (breakeven point) which could guarantee successful aircraft operations in a manner of optimal unit cost increase in case of landing gear failure safety occurrences.

Figure 2 presents get inflection point for B737-300, where *x-axle* presents annual utilization (Bhr); and *y-axle* presents unit operating costs (USD/Bhr).

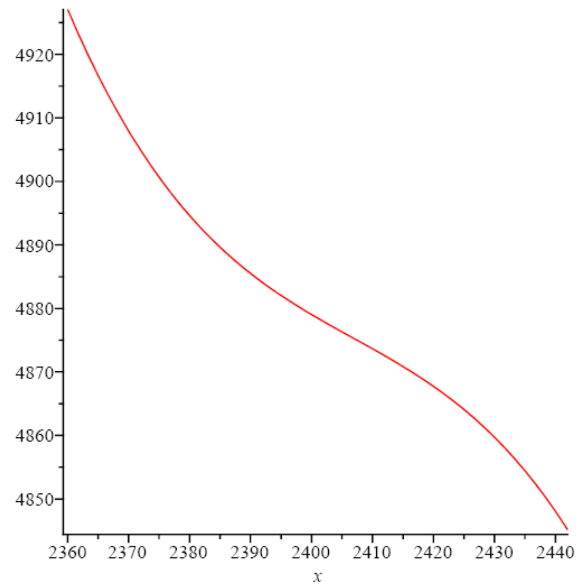

Fig 2 Unit operating costs function due to annual utilization (*x*) influenced by aircraft incident

Presented methodology allows determined optimal annual utilization affected by aircraft incident causes. Demonstrated cost benefit analysis could be provided for certain aircraft type, as it is described for B737-300, or for the whole airline fleet. Besides, model inputs could be provided more over detailed, for each route and different aircraft types. Sensitive analysis of get results would give parameters for risk assessment in safety management process. Furthermore, other incidents during the landing phase should be treated in the same manner.

4. Conclusion

According to (Boeing, 2006) accidents caused by landing gear failure have occurred in 12.5% of safety related occurrences during the landing phase, mostly in scheduled flight services. Almost 55% of accidents caused serious landing gear damage, 44% total damage and 3% minor damages. Therefore, special attention should be given to landing gear failure issues. Paper presents originally developed mathematical model that is applied to simulate aircraft annual utilization by considering the incident costs effects on aircraft unit operating costs. It was found that the aircraft incident costs have influence on determined optimal range of the aircraft unit operating costs, depending on the route distance, aircraft types and the forecasted annual utilization.

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