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COMPARISON OF MiG-29 AND F-16 AIRCRAFT IN THE FIELD OF SUSCEPTIBILITY TO DESTRUCTION IN COMBAT

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Abstract. Because the Polish Air Force currently uses F-16 and MiG-29 aircraft, the aim of the study was to conduct a comparison of the susceptibility to destruction in combat of these two aircraft. The first part of the work concerned the analysis of individual critical components, such as: general characteristics of the airframe structure, aircraft engine, flight control system, fuel system, aircraft weapons, radar system. The index of susceptibility to destruction in combat was defined considering the listed critical components and the following types of enemy weapon: aircraft gun, air-to-air missile, anti-aircraft gun, surface-to-air missile. The analysis proved that the aircraft have similar susceptibility to damage in combat, a slight advantage of the F-16 aircraft in this respect was determined. The presented scheme can be used to analyze other aircraft. Proposals of aircraft modifications, directions of further actions, possibilities of using the described method were presented. The method can be used to making decisions by governments regarding the purchase aircraft for their fleets and identify aircraft critical components with high susceptibility to destruction in order to introduce appropriate modifications by military aircraft manufacturers.

Keywords: susceptibility to destruction, air combat, indicator method, military aircraft, MiG-29 aircraft, F-16 aircraft.

Introduction

Military aviation is one of the most important types of armed forces. The contemporary military aircraft is a modern weapon system combining achievements from such scientific fields as: structural analysis, aerodynamics, avionics, aircraft engines, armament. Analysis of completed conflicts and conducted air operations such as: the Korean War, Vietnam War, attack on Osirak reactor, attack on Bekka Valley, military operations: "Desert Storm", "Desert Fox", "Iraqi Freedom", indicate that the military aircraft plays a dominant role in terms of reconnaissance and combating enemy objects that are targets of attack. Conducting a successful military air operation requires adequate knowledge of the area in which it is to be conducted. The assessment to enable the selection of appropriate military aircraft to achieve the intended tactical or strategic objectives is also important. Carrying out an assessment concerning the selection of a suitable aircraft in terms of mission capability requires the analysis of its operational efficiency and, in particular, its survivability on the battlefield (Tomaszek & Wróblewski, 2001).

When conducting research related to the analysis of combat capabilities, operational efficiency, weapon system effectiveness of military aircraft, various methods are used to build models: preliminary assessment based on detailed analysis of systems of a given aircraft (Adamski, 2009), Monte Carlo method (Jaiswal, 1997; Zheng & Feiguo, 2017), methods of decision analysis (Hošková-Mayerová et al., 2018; Wang et al., 2008), advanced probabilistic models (Erlandsson, 2014), simulation experiments using a special platform or environment (Gao et al., 2020; Guo et al., 2017). Maximization of operational readiness in military aviation through optimization of flight planning and maintenance (Lee & Mitici, 2020; Verhoeff et al., 2015; Wazny & Wojtowicz, 2008) and safety analysis of the military aircraft crew taking into account the destructive action of the enemy (Stępień et al., 2017) are also important issues related to the operation of military aircraft. The safety of aircraft crew and passengers can also be considered in the context of emergency situations (Papis & Matyjewski, 2016) and during aircraft accident evaluation to eliminate accidents in the future (Makrygianni, 2018).

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The readiness assessment of technical facilities also plays an important role in aviation (Żurek et al., 2018).

Among the evaluation methods that may be universally applicable to military aircraft are methods for assessing the effectiveness of aerial armament and the operational efficiency of military aircraft. However, these methods usually require very detailed knowledge of aircraft specifications and the development of advanced models. In practice, qualitative methods and expert estimates made using systems analysis of a given aircraft are often of great importance. The aim of this work was a detailed analysis of the airframe structure and the most important aircraft systems (engine, flight control system, fuel system, radar system) and weaponry possessed. Accordingly, the index of a qualitative assessment of susceptibility to destruction in combat was defined to allow comparison of the two aircraft.

1. Characteristics of the F-16 and MiG-29 military aircraft

The description of individual systems (components) of the discussed military aircraft is presented in Table 1. Below table are the conclusions of the aircraft comparison. The analysis was performed for the following systems:

1. General characteristics of the airframe structure;
2. Aircraft engine;
3. Flight control system;
4. Fuel system;
5. Aircraft weapon;
6. Radar system.

Table 1. Aircraft comparison of the F-16 and MiG-29

F-16	MiG-29
general characteristics of the airframe structure	
A single-engine, light fighter aircraft. It was built in a classic mid-wing configuration with a single vertical stabilizer of mixed construction with a predominance of aluminum alloys. Its basic dimensions are: wingspan 9.8 m, aircraft length 14.8 m, wing area: 27.87 m^2. The airfoil is trapezoidal in outline, with straight leading and trailing edges. Eleven-spar wing with five ribs. Upper and lower covers integral, one-piece, joined to the structure by riveting. Front flaps and flaps of sandwich construction. At the ends of the wings there are guides for air-to-air missiles, which act as anti-flatter masses. The fuselage has a semi-monocoque construction with covering densely supported by frames and half frames (Matusiak, 1996; Wasilewski, 2004).	A supersonic fighter aircraft, built in an upper-wing configuration with banded wings and a double vertical tailplane. The structure of the aircraft is metal with a small share of composite materials. Its basic dimensions are: wingspan 11.36 m, aircraft length 17.32 m, wing area: 38 m^2. The basic structure of the airframe was made in a semi-monocoque system. The wings have a tri-spar construction. In the front part of the wing a three-segment front flap of dural semi-monocoque construction is attached to the lower edge of the auxiliary spar. Attached to the rear auxiliary spar are wing flaps and ailerons of sandwich structure. The single-slot flaps and ailerons are suspended at three points, which are swung by hydraulic systems (Gretzyngier, 1992).
propulsion systems – engines	
The power unit (single-engine) of the F-16 aircraft consists of a Pratt & Whitney F100-PW-229 engine with 79.13 kN and 128.91 kN thrust with afterburning. It is a two-flow engine with a hydraulically regulated nozzle. It has a modular structure. The low-pressure compressor has three stages and the high-pressure compressor has ten stages. Annular combustion chamber. Both turbines are two-stage. The turbine blades are cooled. Engine weight – 1,370 kg (Wasilewski, 2004).	The power unit consists of two two-flow RD-33 twin-shaft turbine engines. The engine consists of the following modules: 4-stage low pressure compressor, 9-stage high pressure compressor, 2-stage turbine with cooled high pressure turbine blades (first stage), afterburner, supersonic adjustable nozzle. Each engine with a thrust of 49.9 kN (with the afterburner – min. 54.9 kN, max. 81.4 kN), weight – 1055 kg (Grzegorzewski, 2002).
flight control systems	
A fly-by-wire control system based on the Lear Siegler flight parameters computer, which uses data, among others from yoke (control column), control surface position transmitters, accelerometers, gyroscopes, angle of attack and slide transmitters, aerodynamic data computer. Moreover, the system includes hydraulic actuators of control surfaces (Matusiak, 1996).	Control system for all versions of serial aircraft – mechanical with hydraulic actuators. Airplane control can be manual or automatic. When approaching an angle of attack of 28 degrees, the system that acts upon the control stick turns on. The control system consists of the control subsystems: ailerons, stabilizers, rudders, flaps, air brake (Grzegorzewski, 2002).
fuel systems	
The F-16 engine is supplied with fuel from five fuselage tanks and two wing tanks with a total capacity of 3,986 l. The fuel tanks have a self-sealing design. An additional fuel tank with a capacity of 1135 l can be mounted on the central sub-fuselage node, while tanks with a capacity of 1400 or 2270 l can be suspended on the sub-wing nodes. Two conformal fuel tanks with a capacity of 1864 l each can be mounted on the fuselage (Wasilewski, 2004).	On MiG-29 (type "9-12"), MiG-29SD and MiG29UB aircraft, fuel is contained in 5 fuselage and 2 wing tanks with a total capacity of 4,300 l. The capacity of the fuselage tanks is 650, 870 310 l respectively, and the two wing tanks – 660 l. An additional drop tank of 1500 l can be suspended under the fuselage. The total amount of fuel is 5800 l. On MiG-29 (type "9-13"), MiG-29S and MiG-29SE fighters after upgrades the total possible capacity of fuel tanks is 8340 l (Grzegorzewski, 2002).

End of Table 1

F-16	MiG-29
weapons	
The primary weaponry is the General Electric M61 A1 six-barrel cannon (20 mm caliber). Suspended armament: medium-range AIM-120 AMRAAM air-to-air missiles, LAU-114 launchers for firing short-range Sidewinder and medium-range AMRAAM air-to-air missiles. It is possible to suspend two armament beams under each wing. Guided air-to-ground armament consists of AGM-65A/B/D/G Maverick and AS30L missiles, AGM-88 HARM and AGM-45 Shrike anti-radiation guided missiles, AGM-84 Harpoon or AGM-119 Penguin Mk 3 air-to-air guided missiles. Unguided missiles of 70 mm caliber can be fired from LAU-68 and LAU-88 multi-barrel launchers. The aircraft's bombarding armament consists of Paveway II series guided bombs. The aircraft is also adapted to carry B43 nuclear bombs (Adamski, 2009; Davis, 2014; Tomaszek & Wróblewski, 2001).	The weaponry of the MiG-29 aircraft, with a total weight of up to 2,000 kg, can be suspended on six nodes under the wings. In the air combat variant, the aircraft is armed with 6 self-guided R-73 short-range missiles and 2 self-guided R-27R1 medium-range missiles. The alternative air combat armament variant consists of 6 R-60T or R-60MK (AA-8 Aphid) self-guided short-range infrared rockets and two R-27R1 rockets. In the ground combat variant the MiG-29 aircraft can be armed with 8 unguided main target bombs, bomb hoppers KMGU-2, incendiary tanks ZB-500, unguided missiles S-8 fired from the B-8M1 launcher, missiles S-13 fired from the B-13Ł launcher and missiles S-24. The aircraft is armed with one GSz-301 barrel air cannon fixed in the fuselage. The aircraft is also adapted to carry RN-40 tactical nuclear bombs (Tomaszek & Wróblewski, 2001).
radar systems	
A common radar used in F-16 aircraft is the Westinghouse AN/APG-68(V)5 (AN.APG-68 in older versions of the F-16C), operating in the I/J waveband. The (V)5 variant added an SA (Situation Awareness) module to warn the pilot of a threat. Starting with Block 50/52, a DTS digital map projector was added. Under ideal conditions the maximum detection range for large targets (bomber) at high altitude is 270 km. For small targets it decreases to about 170 km. Against a ground background the analogous values are 230/130 km respectively. The radar can start tracking a target at a distance equal to about 60% of the detection distance. It is possible to track up to 10 targets simultaneously. The situation as seen by the radar is presented on multifunctional Honeywell indicators (the screen also shows targets that are not tracked, but their flight parameters are not measured). The targets tracked by the station are also presented on the GEC-Arconi wide-angle head-up display (HUD), which displays information on the basic flight parameters and selected targets. The AN/APG-68 radar prepares data necessary for air-to-air and air-to-ground missiles (Matusiak, 1996). The latest versions of the radar dedicated for F-16 are the AN/APG-80 and AN/APG-83, which can track more targets simultaneously.	A common radar used in MiG-29 aircraft is the N-019 Rubin pulse-doppler radar, capable of detecting, tracking and recognizing targets flying at altitudes from 30 to 23,000 m at distances up to 100 km, in the front or rear hemisphere. Up to 10 targets can be observed simultaneously, and the radar selects the most dangerous one. Additionally, observation can be carried out with the use of KOLS quantum-optical laser station, providing automatic search and tracking of targets in the infrared range and distance measurement to airborne and ground targets. The station consists of a thermal sight with a range of 15 km and a laser rangefinder, effective to about 5–6 km. Marking a target visually under air combat conditions can be carried out using the Szz3-ZUM helmet-mounted sight and display. The coordinates of the target are calculated by the targeting complex based on data on the position of the head of the pilot observing the target through the sight (NWU-2) and transmitted to short-range infrared guided missiles. An important element connected with the radar system is also the targeting-navigation system. It collects and processes, with the use of digital processors, data on the flight situation and (with the help of the integrated information system) provides pilot-navigation and combat information through projection on the glass (Gretzyngier, 1992).

The main conclusions of the aircraft comparison are as follows:

1. Due to the similar purpose of the aircraft, the designs are similar. It is worth noting that the MIG-29 was designed specifically for combat against the F-16 and F-15 (Baker, 2017). Both aircraft have a semi-monocoque airframe construction. The F-16 is a smaller aircraft, but the differences in dimensions are not very high;
2. In propulsion systems aspect, the MiG-29 aircraft gains the advantage of having two engines. Although the destruction of one engine makes it impossible to complete the mission, it gives the crew a chance of survival. Moreover, the MiG-29, due to its higher total thrust value of the propulsion unit, has a better chance of survival on the battlefield (Kozakiewicz, 2009) – especially in combat at a short distance;
3. The fly-by-wire system makes it possible to achieve optimized flight mechanics. F-16 due to this system has the ability to perform advanced manoeuvres within the air combat. Electric fly-by-wire control system was designed in such a way as to eliminate pilot errors resulting from steering which threatens stall or lack of coordination which threatens loss of stability of the aircraft (Milkiewicz, 2002);
4. The capacity of fuel tanks of both planes is similar, in both cases it is also possible to use additional fuel tanks. It is worth noting that the additional fuel tanks of an aircraft during a battle can work against it (a hit with a fuel tank with a very high probability will end with the total destruction of the aircraft (Ball, 2003).
5. The weapon of both aircraft may differ depending on the aircraft variant, and alternative armament variants are also possible. Both aircraft can be equipped with missile and bomb armament. The F-16 can be also equipped with more types of

special equipment, e.g. LANTIRN. In the proposed method, the susceptibility to destruction in combat will be analyzed, considering the weapon of the enemy aircraft (aircraft gun, air-to-air missile) and in the surface-to-air variants (anti-aircraft gun, surface-to-air missile);

6. The advantage of the MiG-29 over the F-16 becomes apparent in short-range combat, among other things due to its greater maneuverability at low speeds and its KOLS laser station with passive thermal sight. Missiles for targets within 90 degrees of the flight direction can be fired earlier compared to the F-16. More distant targets must be guided from a ground station. A limited number of MiG-29 electronic systems can be considered like a small advantage, but also the main drawback of the aircraft. MiG-29 is not equipped with the LINK-16 tactical system which is used in NATO countries. F-16 is equipped with a better radar station. This allows it to detect the target earlier and receive information about it. As a result, it becomes more independent and autonomous, and has more time to maneuver and prepare the attack. The passive defense system against missile attack is also more effective (Adamski, 2009; Kalwat, 2017).

2. Qualitative assessment of susceptibility to destruction in combat

2.1. Defining the index of susceptibility to destruction in combat

The index was defined to compare the two aircraft in terms of their susceptibility to destruction in combat:

$$Index_{SDC} = \frac{\sum_{j=1}^{4}(\sum_{k=1}^{4} i_{j,k})}{16}, \qquad (1)$$

where: $Index_{SDC}$ – index of susceptibility to destruction in combat; $i_{j,k}$ – partial index (destruction probability) for critical component j depending on the enemy weapon k.

The analysis will be conducted for 4 critical components of both aircraft and 4 enemy weapons used to destroy the aircraft. The possibility of an attempt to shoot down the aircraft by the other aircraft (aircraft weapons) as well as from the ground has been considered. The different components and weapon types are shown in Table 2.

The analysis assumes that the complete destruction of any component of the aircraft makes it impossible for it to continue its mission and with a high probability results in the consequent destruction of the entire aircraft.

In the next step of the analysis the radar system and armament as factors to counteract the increase in susceptibility can be considered. The corrected susceptibility index was determined from the following relationship:

$$Index'_{SDC} = a \cdot Index_{SDC}, \qquad (2)$$

where: $Index'_{SDC}$ – index of susceptibility to destruction in combat considering the impact of the radar system and armament; a – radar and weapon system impact factor, taking the following values: 0.8 – for very high impact to counteract the increase in susceptibility, 0.9 – for high impact, 1.0 – for medium impact, 1.1 – for low impact, 1.2 – for very low impact.

2.2. Estimation of partial indexes

In military aircraft design, it is important that critical components are arranged in such a way that none of them overlap with any other. Thus, only one critical component can be hit during attack (Ball, 2003).

Based on the anatomy of F-16 and MiG-29 aircraft (Table 1), the authors of the article conducted the assessment of susceptibility to destruction in combat considering selected critical components. A qualitative seven-point probability scale (negligible, very low, low, medium, high, very high, critical) was used. The estimated probabilities correspond to values on a scale of 0–1, as presented in Table 3. The value in the middle of the respective range was used for the final assessment. Table 3 will also be used to interpret the susceptibility to destruction in combat determined in accordance with relation (1).

The assessment also depended on the type of weapon used to destroy the aircraft. Aircraft gun, air-to-air missile, anti-aircraft gun, surface-to-air missile (with proximity warhead) were considered. The results of the qualitative analysis carried out are presented in Tables 4 and 5. The expert estimates result from the data on both aircraft presented in Table 1 and the information contained in the literature on military aviation and weapons systems (Ball, 2003; Dougherty, 2019; Tomaszek & Wróblewski, 2001).

The above analysis indicates that the MiG-29 gains battlefield survival advantage by having two engines. The

Table 2. Critical components and weapons included in the analysis

j	critical component	*k*	weapon
1	airframe structure	1	aircraft gun
2	engine	2	air-to-air missile
3	flight control system	3	anti-aircraft gun
4	fuel system	4	surface-to-air missile

Table 3. Descriptive scale adopted for qualitative susceptibility assessment

descriptive scale of probability	numerical interval	mean value
critical	0.901–1	0.95
very high	0.801–0.9	0.85
high	0.601–0.8	0.7
medium	0.401–0.6	0.5
low	0.201–0.4	0.3
very low	0.101–0.2	0.15
negligible	0–0.10	0.05

Table 4. Estimation of susceptibility to destruction in combat for MiG-29

critical component	aircraft gun	air-to-air missile	anti-aircraft gun	surface-to-air missile
airframe structure	low	high	low	high
engine	medium	very high	low	high
flight control system	low	very high	high	high
fuel system	very low	very high	low	medium

Table 5. Estimation of susceptibility to destruction in combat for F-16

critical component	aircraft gun	air-to-air missile	anti-aircraft gun	surface-to-air missile
airframe structure	low	high	low	high
engine	very high	critical	medium	very high
flight control system	very low	very high	medium	medium
fuel system	very low	very high	low	medium

F-16, on the other hand, gains advantage by having digital solutions for the flight control system.

2.3. Results of the analysis

Tables 6 and 7 show results of the analysis with the mean values from Table 3 for the estimates of susceptibility to destruction in combat for MiG-29 and F-16 and calculations based on relations (1) and (2).

Considering the information contained in Table 1 (parts: *weapons*, *radar systems*) and the presented conclusions the factor a = 0.9 can be assumed for F-16 and a = 1.0 for MiG-29. This is because the weapons and radar systems of the aircraft under consideration give them advantages at various ranges (F-16 gains advantage in combat at long range, MiG-29 at short range). Moreover, it should be considering that the lack of some equipment in MiG-29 can affects the situational awareness, safety and the success of combat mission (Kalwat, 2017).

Table 6. The assessment of susceptibility to destruction in combat for MiG-29

$i_{j,k}$	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$(\sum_{k=1}^{4} i_{j,k})/4$
$j = 1$	0.3	0.7	0.3	0.7	0.5
$j = 2$	0.5	0.85	0.3	0.7	0.5875
$j = 3$	0.3	0.85	0.7	0.7	0.6375
$j = 4$	0.15	0.85	0.3	0.5	0.45
$Index_{SDC}$					0.54
$Index'_{SDC}$					0.54

Table 7. The assessment of susceptibility to destruction in combat for F-16

$i_{j,k}$	$k = 1$	$k = 2$	$k = 3$	$k = 4$	$(\sum_{k=1}^{4} i_{j,k})/4$
$j = 1$	0.3	0.7	0.3	0.7	0.5
$j = 2$	0.85	0.95	0.5	0.85	0.7875
$j = 3$	0.15	0.85	0.5	0.5	0.5
$j = 4$	0.15	0.85	0.3	0.5	0.45
$Index_{SDC}$					**0.56**
$Index'_{SDC}$					**0.50**

It can be noted that both aircraft have similar susceptibility to destruction in combat. The conducted analysis indicates that the MiG-29 gains battlefield survival advantage by having two engines (a chance to survival after the destruction of one engine, higher total thrust). The F-16 gains advantage by digital solutions for the flight control system and better radar station. Minimal advantage of MiG-29 aircraft in the first part of analysis may result from the way of calculations and accepted expert estimations. In the case of both aircrafts the highest indicators were assigned to the critical components: engine and flight control system. It is possible to carry out modifications in these areas in order to increase the level of safety during military operations.

After accounting for the impact of the radar system and armament as factors to counteract the increase in susceptibility slight advantage of F-16 can be noticed. The scheme of proceedings presented in the article may constitute the first stage of the analysis of the combat capabilities of military aircraft.

3. Discussion

The presented study included a detailed analysis of individual critical aircraft components in terms of susceptibility to destruction by various enemy weapons. The effect of radar system and aircraft weapon on the estimated susceptibility index was also considered. The developed author's method allows for a structured analysis of the combat capabilities of military aircraft, assigning them appropriate tasks, missions, a battle strategy and formulating proposals for modifications to improve their capabilities.

It should be noted that the conducted analysis assumes that both aircraft are airworthy. Issues related to ease of maintenance and its cost were not considered. The procedure proposed in this paper serves only as a preliminary, qualitative comparison of susceptibility to destruction in combat. However, it should be noted, that these matters, while not the focus of this study, are very important. These issues are often considered as early as the aircraft design stage. For example, in the F-16 aircraft, access to the interior of the structure is possible in all service areas. On the surface of the aircraft there are about 300 hatches and access doors. Elements which need to be inspected or serviced on a regular basis are located in the lower parts of the airframe. It results in shortening the time of service and maintenance and increases safety (Królik, 2011).

The main objective of maintenance planning is to achieve maximum availability of the airplane. Each aircraft must undergo a routine maintenance check every specified period depending on a number of flight hours. In recent years, the defence policy of governments is often the result of a trade-off between increased operational workload and financial capacity. Aircraft stay in service longer than planned, maintenance costs rise, obtaining spare parts can be difficult. System costing indicates that expenses on sustainment and support functions (including staff training expenses) are higher than production and development of a military aircraft system (Kozanidis et al., 2010).

Conclusions

Results of the conducted analyses concerning susceptibility to destruction in combat indicate that MiG-29 and F-16 aircraft have equal chances in air combat. It is worth emphasising that the F-16 is a versatile attack aircraft capable of long-range ground attack missions, while the MiG-29 is a typical fighter aircraft. A slight advantage of F-16 aircraft can be noticed, however, it may also result from indexes values assumed by the expert method.

The qualitative analysis carried out allows to formulate conclusions regarding the expected modifications of the aircraft designs in order to reduce their susceptibility to destruction in combat. In terms of further development of the F-16 and MiG-29 aircraft designs, the following modifications can be expected:

1. Equipping the F-16 with an engine having better parameters (including thrust);
2. Equipping the MiG-29 with digital avionics (control systems, weapon systems);
3. Subjecting the MiG-29 to modifications whereby will perform the function of a fighter attack aircraft. Using guided air-to-ground missiles would make it possible, as well as modifications enabling an increase in range - conformal tanks or deep modernization connected with increasing the capacity of tanks while optimizing the fuel system and engine operation;
4. Development of the F-16 through the application of hybrid modifications, e.g. equipment enabling effective electronic combat in the standard mission for fighting ground targets and artificial intelligence solutions supporting the pilot's actions or replacing him.

The research carried out concerned qualitative analyses of the susceptibility to destruction in combat of aircraft widely used in the Polish Armed Forces, among others. In this study, the susceptibility index was defined using contractual numerical scales. The main features of the proposed author's method are its universality and simplicity. It can be used for preliminary analysis of combat aircraft capabilities without the need for expensive and detailed analyses and simulations. The presented scheme can be used to analyze the combat susceptibility of the other military aircraft. This can be used, among other things, to making decisions by governments regarding the purchase aircraft for their fleets. It is also possible to use the method to identify aircraft components with high susceptibility to destruction and to introduce appropriate modifications by military aircraft manufacturers.

Further analyses are planned to analyze direct aircraft air combat scenarios using simulation methods. These will allow for analyses and comparisons of a quantitative nature.

Author contributions

Both authors were responsible for a general literature review on the methods used, expert estimates and development of conclusions. MP was also responsible for developing the assumptions of the indicator method and the final version of the article, TK for the review of aircraft specifications.

Disclosure statement

Authors have no competing financial, professional, or personal interests from other parties.

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