Notice of Proposed Amendment 2013-23

Additional airworthiness specifications for operations: Fire hazard in Class D cargo compartments

RMT.0070 (OLD 26.003) — 22/11/2013

EXECUTIVE SUMMARY

This Notice of Proposed Amendment (NPA) addresses a safety issue related to the Class D cargo compartments in aircraft.

There are three safety recommendations from the NTSB in the USA concerning Class D compartments: A-88-122, A-88-123 and A-97-056. They recommend requiring smoke detection and fire suppression systems for all Class D cargo compartments.

The specific objective of this task is to improve the protection of occupants on board large aeroplanes operated in commercial air transportation (CAT) by removing the risk of uncontrollable fire in Class D cargo compartments. This improvement could be reached by upgrading, on large aeroplanes used for CAT, the existing Class D cargo compartments to the current CS-25 standards for Class C or Class E cargo compartments.

Apart from 'no regulatory change', the option of mandating a retrofit was assessed. However, although a mandatory retrofit to upgrade the Class D cargo compartments to either Class C or E would have a limited safety benefit, the RIA shows that the subject risk is already declining, taking into account the effect of previous regulatory actions. On the other hand, the economic burden ensuing from retrofit is hence considered disproportionate in relation to the possible safety benefit.

In conclusion, the 'no regulatory change' option is recommended and no draft rules are proposed by this NPA.

Applicability		Process map	
Affected regulations and decisions:	Part-26 (CRD 2012-13) CS-26 (CRD 2012-13)	Terms of Reference:	17.09.2010
		Concept Paper:	No
		Rulemaking group:	No
Affected stakeholders:	Design Organisations, Production Organisations, Commercial Air Transport Operators	RIA type:	Light
		Technical consultation during NPA drafting:	No
Driver/origin:	Safety related	Duration of NPA consultation:	3 months
Reference:	Articles 5(5)(e)(vi) and 5(6) of the Basic Regulation (EC) No 216/2008 from 20 February 2008	Review group:	No
		Focussed consultation:	No
		Publication date of the CRD:	2014 Q3
		Publication date of the Opinion:	None
		Publication date of the Decision:	None

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1. Procedural information

1.1. The rule development procedure

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed this Notice of Proposed Amendment (NPA) in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2].

This rulemaking activity is included in the Agency's Rulemaking Programme 2013-2016[3] under RMT.0070 (former task number 26.003). The ToR have been published on 17 September 2010[4].

The text of this NPA has been developed by the Agency. It is hereby submitted for consultation of all interested parties[5].

The process map on the title page contains the major milestones of this rulemaking activity and provides an outlook of the timescale of the next steps.

1.2. The structure of this NPA and related documents

Chapter 1 of this NPA contains the procedural information related to this task. Chapter 2 (Explanatory Note) explains the core technical content. Chapter 3 contains the Regulatory Impact Assessment showing which options were considered and what impacts were identified, thereby providing the detailed justification for this NPA, where the option 'no regulatory change' is proposed.

1.3. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[6].

The deadline for submission of comments is **24 February 2014.**

1.4. The next steps in the procedure

Following the closing of the NPA public consultation period, the Agency will review all comments. The outcome and considerations of the NPA public consultation will be reflected in the respective Comment-Response Document (CRD).

Should stakeholders confirm that the option 'no regulatory action' is the preferred one, the CRD published by the Agency will be the last deliverable stemming this task.

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1 Regulation (EC) No 216/2008 of the European Parliament and the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1), as last amended by Commission Regulation (EU) No 6/2013 of 8 January 2013 (OJ L 4, 9.1.2013, p. 34).

2 The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See Management Board Decision concerning the procedure to be applied by the Agency for the issuing of Opinions, Certification Specifications and Guidance Material (Rulemaking Procedure), EASA MB Decision No 01-2012 of 13 March 2012.

3 http://www.easa.europa.eu/agency-measures/docs/agency-decisions/2012/2012-013-R/4-Year%20RMP%202013-2016.pdf

4 http://www.easa.europa.eu/rulemaking/docs/tor/26/EASA-ToR-26.003-01-17092010.pdf

5 In accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

6 In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

2. Explanatory Note

Fires in Class D compartments have been identified as a source of risk to aviation. This risk has increased after 1970 due to the change in the carried baggage and cargo.

Especially in the passenger baggage there was an increase of aerosol cans which often contained flammable materials and led to a longer and more intense duration of fires in the cargo compartments than experienced before 1970.

Class D cargo compartments were originally envisaged with neither active fire extinguishing means nor with detection equipment. This was justified by the limited amount of oxygen available for fires in such restricted spaces, which would lead to a self-starving fire in case the liners of the compartment withstand the fire long enough.

However, after 1970 the liners were seen as vulnerable to the changed composition of baggage and cargo carried. Therefore, Class D compartments became obsolete and no longer included in newly designed aircraft after 1990.

2.1. Overview of the issues to be addressed

The issue is that there are still aircraft in the current fleet which were built before the change eliminating Class D cargo compartments from the certification specifications for large aeroplanes (i.e. FAR-25, JAR-25 and now CS-25). These aircraft might prove more risky to operate. Hence, the issue is a possible mandatory retrofit of existing Class D compartments to upgrade them to Class C for passenger aircraft or to Class E for cargo aircraft. The safety benefit stemming from these possible mandatory retrofit has to be compared against the economic burden that operators of such 'old' aircraft would have to bear.

For more detailed analysis of the issues addressed by this proposal, please refer to the RIA section 3.1. 'Issues to be addressed'.

2.2. Objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in this Chapter 2.

The specific objective of this proposal is to improve the protection of occupants on board large aeroplanes operated in commercial air transport (CAT) by reducing the risk of uncontrollable fires in Class D compartments.

This improvement could be reached by upgrading, on large aeroplanes used for CAT, the existing Class D cargo compartments to the current CS-25 standards for Class C or Class E cargo compartments.

2.3. Summary of the Regulatory Impact Assessment (RIA)

The RIA compared the option for a mandatory retrofit to the default option of 'no regulatory change'. The 'no regulatory change' option will create no additional rules, since CSs have been amended more than 25 years ago, and let the progressive phase-out of 'old' aircraft resolve the issue on its own. A mandatory retrofit would cost EUR 49.1 million in 2013 present value for the industry and could avoid 0.07 accidents and save 5 lives.

The RIA concluded that no rulemaking action is required due to the large imbalance between the limited safety benefit and the associated large costs.

2.4. Overview of the proposed amendments

Neither amendments to existing rules nor additional rules are proposed by this NPA, in accordance with the result of the RIA.

3. Regulatory Impact Assessment (RIA)

3.1. Issues to be addressed

3.1.1. The hazard

When Class D cargo compartments were originally designed, they were envisioned to be small compartments of 1,000 ft^3 (28.3 m^3 or less), minimally ventilated and used in narrow-body commercial airplanes, such as e.g. Boeing B-707 and Mc Donnel-Douglas DC-8, which were successful products in the 1960s.

A Class D cargo compartment is defined as a compartment in which a fire would be completely contained without endangering the safety of the aeroplane or the occupants, and without being accessible to the crew members. These cargo compartments depend on oxygen deprivation to prevent and supress combustion, therefore the capability of liners to resist flame penetration is very important.

Although there is little or no airflow into a Class D compartment at the time a fire occurs, there is oxygen available from the air already contained in the compartment. In some instances, particularly when the compartment is larger or only partially filled, the oxygen already present in the compartment may be sufficient to support an intense fire, long enough to penetrate the liners. Once the integrity of the liners is compromised, there is an unlimited flow of air into the compartment, resulting in an uncontrollable fire that can quickly spread throughout the rest of the aeroplane.

The risk of an uncontained fire hence increased after 1970, with the entry into service of 'wide body' aeroplanes such as e.g. B-747, DC-10 and L-1011.

In the past decades there have been several fires in the cargo or baggage compartments of large aeroplanes involved in commercial air transport, some of which resulted in accidents and loss of life. Although actions have been taken in the past to improve the safety of these compartments by improving the fire resistance of liners, the relatively frequent occurrence of fires and the severity of the consequences of an uncontrolled fire resulted in a review of the entire cargo compartment Classification system.

3.1.2. Regulatory actions taken by the FAA and JAA/EASA following in-flight aeroplane fires

In-flight Passenger Aeroplane Fires

In 1980 a Saudi Arabian Airlines Lockheed L-1011 was destroyed after an uncontrollable fire occurred in a compartment which was Classified as Class D. 301 lives were lost and the aeroplane was totally damaged.

The growing concern over this and other reports of cargo or baggage compartment fires led to the amendment of large transport aeroplane certification standards (FAR Part 25 Amendment 25-60 in May 1986, JAR 25 Change 12 in May 1988). In addition to establishing a maximum volume of 1,000 ft^3 for Class D compartments, this amendment also established new standards for liners with greater resistance to flame penetration for use in Class C and D compartments. However, these improvements addressed only the type certification (TC) of newly designed large transport aeroplanes.

In respect to the in-service aeroplanes, operators were required to install liners that met the new standards introduced in the FAR Part 25/JAR-25, through respectively FAA Part 121 Amendment 121-202 and Part 135 Amendment 135-31, dated February 1989, and JAR 26 first issue dated July 1998. However, unlike the upgraded FAR Part 25/JAR 25, these amendments did not establish a maximum volume for Class D compartments. In addition, the new FAR Part 25/JAR-25 standards apply to all Class C or D compartments regardless of size, while Amendments 121-202 and 135-31 and JAR-26 requirements apply only to compartments greater than 200 ft^3.

The safety benefits that could be gained by replacing existing liners in compartments smaller than 200 ft^3 were not considered sufficient to justify the cost of doing so. Meanwhile, the subsequent appearance of consumer aerosol cans with highly flammable propellants has introduced a hazard that did not exist at that time.

In September 1983, a Boeing-737 operated by Gulf Air was destroyed as a result of an inflight fire in a Class D compartment. The fire, which resulted in 112 casualties, was attributed to an incendiary device.

In February 1988, a fire occurred in the Class D compartment of an American Airlines McDonnell Douglas MD-83[7]. Although there was no loss of lives, the fire severely damaged the cabin floor above the compartment. As a result, the FAA initiated a review of service experience and existing regulations, policies and procedures pertaining to the certification of aeroplanes with Class D compartments.

Since the time the review of Class D compartments was completed there have also been seven additional known instances of fires occurring in those compartments. Most of them resulted in no injuries and little or no damage to the aeroplane, with one exception: the fire that occurred in May 1996 in the Class D compartment of a McDonnell Douglas DC-9[8] operated by ValuJet Airlines. Although the fire involved the carriage of undeclared hazardous materials (as in the case of American Airlines MD-83 fire), it resulted in the destruction of the aeroplane with a loss of 110 lives. It must be noted that this undeclared carriage occurred in spite of existing prohibitions concerning such goods.

In order to remove the risk of uncontrollable fire in Class D compartments, the FAA issued on 19 March 1998 final rules FAR Part 25 Amdt 25-93 and FAR Part 121 Amdt 121-269 based on NPRM 97-10. These amendments provided the following upgrades:

a. Elimination of Class D cargo or baggage compartment as an option for future type certification of transport category aeroplanes;

b. Class D compartments in certain transport category aeroplanes already in service and used in passenger service must meet the fire or smoke detection and fire suppressions standards for Class C compartments;

c. Class D compartments in certain transport category aeroplanes already in-service and used only for the carriage of cargo must meet the standards for Class C compartments or the corresponding standards for Class E compartments.

[7] Type entered into service in 1985.
[8] Type entered into service in 1965.

In 2001, the JAA published NPA 25D-320 and NPA 26B-15 which were similar to FAA NPRM 97-10. In 2003, the Agency was established and continued the work initiated by the JAA.

In December 2005, the Agency published NPA 04/2006 which led to the Amendment 3 of CS- 25 in September 2007, incorporating similar changes as the FAA Amdt 25-93 to FAR Part 25.

However, retroactive action to address in-service aeroplanes has not yet been mandated by the Agency.

A summary of the rulemaking actions related to Class D cargo compartments taken by the FAA and the corresponding JAA/EASA initiatives is presented in Table 6 on p. 23.

In-flight Cargo Aeroplane Fires

In February 2006 a McDonnell Douglas DC-8[9] operated by United Parcel Service (UPS) was substantially damaged after it landed at Philadelphia International Airport following a cargo smoke indication reported by the crew. Although the aeroplane was substantially damaged, the crew suffered only minor injuries.

On 3 September 2010 a Boeing 747-400F[10] operated by UPS crashed inside an Emirates army post, 9 miles from Dubai International Airport, after the flight crew encountered a 'Fire Main Deck' (i.e. Class E cargo compartment) warning. The crew was fatally injured and the aeroplane destroyed by the impact and post-crash fire.

On 28 July 2011 a Boeing 747-400F operated by Asiana Cargo crashed about 70 miles from the Jeju Island, Republic of Korea, after the flight crew declared an emergency due to a cargo fire. Both flight crew were fatally injured and the aeroplane totally destroyed.

The investigation reports (i.e. for the two latter accidents) revealed an important delay between the actual time when warning is given to the pilots and the start of the fire in the cargo compartment and therefore exceeding the time prescribed by the current FAA and EASA regulations (i.e. 1 minute).

Further FAA experiments have suggested that passive fire suppression systems by oxygen deprivation in large cargo compartments might not be effective. However, it was decided not to take any rulemaking action (i.e. to install active fire suppression like the ones in Class C cargo compartments) after the FAA conducted a cost-benefit analysis.

With respect to the previously mentioned accidents, the National Transportation Safety Board (NTSB) has made the following recommendations to the FAA:

a. Develop and implement fire detection systems capable of early detection of fires originating in the cargo containers;

b. Ensure that cargo containers materials meet the same flammability requirements of the cargo compartment materials;

c. Require the installation of active fire suppression systems in all aeroplanes cargo compartments and/or containers.

3.1.3. Conclusion

To date there have not been any EU registered aeroplanes involved in accidents or serious incidents indicating as a cause a fire occurred in a Class D cargo compartment.

9 Type entered into service in 1959.
10 B747-400 entered service in 1985, one year before amendment of FAR 25 for Class D compartments.

Furthermore, all the accidents mentioned above concern aircraft types designed before 1986 (i.e. first improvements of the design standards for Class D cargo compartments).

Fires occurring in Class E cargo compartments are out of the scope of the present rulemaking task.

3.1.4. Safety risk assessment

Among the reported Class D fire events, the rate of catastrophic and hazardous occurrences was 4 out of 16 events (Table 7), meaning 1 in 4 events resulted in major damage to aircraft or personnel.

3.1.5. Who is affected?

Affected by possible mandatory retrofit are air operators of aircraft equipped with Class D compartments. Design Organisations holding the relevant type certificates could be affected if requested by the operators to design the necessary modifications.

The FAA eliminated Class D cargo compartments from new TC and also, through retrofit, from the fleet, through rules issue between 1986 and 1998. Although these rules where applicable only to organisations under FAA jurisdiction, nevertheless they produced effect all over the world, as made evident from statements made by Boeing[11], according to which the Boeing models 717, 747, 757, 767, 777 and MD-11 do not carry Class D compartments.

The fleet of aircraft of European operators that might potentially carry Class D compartments is estimated in 2013, the initial year for forecasting future evolution, to be maximum 787 aircraft (Table 10).

3.1.6. How could the issue/problem evolve?

The Agency[12] has established a general retirement curve based on the age of aircraft and applicable in principle to estimate the progressive effect of any amendment to CS-25. The retirement curve is based on the formula $y = \frac{1}{1+0.7968^{(25-x)}}$, where x is aircraft age and y is the share of aircraft still in service. The formula is based on historical data on the age of aircraft at the time of their retirement from service.

Assuming that operators have to comply with the new rule by 2017, Table 11 shows the estimated number of aircraft in service fitted with Class D cargo compartments, and the risk of a catastrophic fire. Out of the 787 aircraft in service in 2013, 255 are not expected to comply with the new rule because they will have retired by 2017. The last aircraft of the affected fleet of 532 aircraft is expected to retire in 2041.

The current average aircraft age of 22.1 years is going to gradually increase to 50.0 by 2043. Average annual hours and average annual departures show strong correlation with aircraft age (Table 8 and Table 9), and this correlation was taken into account when forecasting future flight hours and departures.

The probability of a fire occurring in a Class D cargo compartment per departure was estimated based on the FAA final rule publishing amendments 25-93 and 121-269 (extract reproduced in Appendix 2 below).

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11 http://www.boeing.com/commercial/aeromagazine/aero_06/textonly/s03txt.html.
12 EASA RIA bulletin issue 6 of 16 January 2013. Extract in Appendix 1.

The FAA concluded that the event rate for fires occurring in Class D and Class C compartments is approximately 0.085 per million departures, which is slightly better than $1x10^{-7}$ per departure.

Four incidents with casualties or substantial damages during 224.5 million flights result in a 1.7817×10^{-8} per departure risk of a catastrophic fire event. The cumulative accident risk of the affected fleet during its whole service life from 2013 is 0.134[13] accidents (Table 11 on p27).

3.2. Objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation.

The specific objective of this proposal is to improve the protection of occupants on board large aeroplanes operated in commercial air transport (CAT) by reducing the risk of uncontrollable fires in Class D compartments, leading to catastrophic events, to a probability of 10^{-9} per flight hour, or even less.

This improvement would be reached by upgrading, on large aeroplanes used for CAT, the existing Class D cargo compartments to the current CS-25 standards for Class C or Class E cargo compartments.

3.3. Policy options

Table 1: Selected policy options

Option No	Short title	Description
0	**'No regulatory change'**	Baseline option (no change in rules; risks would evolve as estimated in paragraph 3.1.6).
1	**Retrofit**	Take retroactive rulemaking action for in-service Large Aeroplanes used for commercial air transportation. It requires European Operators to modify Class D compartments so as to meet the Class C standards of CS 25.857(c) and 25.858, or the Class E standards of CS 25.857(e) if the aeroplane is operated in an all-cargo configuration.

3.4. Methodology and data

This assessment analyses relevant aircraft operated by EASA Member States. The Republic of Croatia joined the European Union on 1 July 2013, after the commencement of this Regulatory Impact Assessment. For this reason, aircraft operated by Croatian airlines were not included in this analysis.

3.4.1. Multi-criteria analysis

The term multi-criteria analysis (MCA) covers a wide range of techniques that share the aim of combining a range of positive and negative impacts into a single framework to allow

[13] In real life the number of accidents, fatalities or injuries can only be a whole number and not a fraction (either an accident occurs or it doesn't). However, using whole numbers for infrequent/extremely improbable events could result significantly misleading results, therefore it is appropriate to use fractions for greater accuracy.

easier comparison of scenarios. Essentially, it applies cost benefit thinking to cases where there is a need to present impacts that are a mixture of qualitative, quantitative and monetary data, and where there are varying degrees of certainty.

Key steps of an MCA generally include:

1. Establishing criteria to be used to compare the options (these criteria must be measurable, at least in qualitative terms);
2. Assigning weights to each criterion to reflect its relative importance in the decision;
3. Scoring how well each option meets the criteria; the scoring needs to be relative to the baseline scenario;
4. Ranking the options by combining their respective weights and scores;
5. Perform sensitivity analysis on the scoring so as to test the robustness of the ranking.

The objective for this rulemaking activity has been outlined in paragraph 3. The options have been described above and will be analysed in the following chapter for each of the assessment areas. The criteria used to compare the options were derived from the Basic Regulation and the guidelines for Regulatory Impact Assessment developed by the European Commission. The principal objective of the Agency is to 'establish and maintain a high uniform level of safety' [Art. 2 (1)]. As additional objectives the Basic Regulation identifies environmental, economic, proportionality and harmonisation aspects, which are reflected below.

This table also shows the weights that were assigned to the individual groups of criteria. Based on the above considerations and the mandate of the Agency, safety received highest weight of 3. Environmental impacts are attributed with a weight of 2 as the Agency has certain specific responsibilities in this area related to noise and emissions. For the same reason impacts on the other assessment areas are attributed with a weight of 1 since these areas are to be duly considered when developing the implementing rules. Each option developed below will be assessed based on the above criteria. Scores are used to show the degree to which each of the options achieves the assessment criteria. The scoring is performed on a scale between -5 and +5.

Table 2: Assessment criteria for the multi-criteria analysis

Overall Objectives	Specific Objectives and assessment criteria	
	Weight	**Description**
Safety	3	Maintain or improve the level of safety
Economic	1	Ensure cost-effective aviation safety rules Ensure "level playing field"
Environment	2	Avoid negative effects on the environment
Social	1	Avoid negative effects on social issues Promote high quality jobs in the private sector for aviation
Equality and proportionality	1	Ensure proportionate rules for Small and Medium sized Enterprises (SMEs)/General aviation/Business Aviation
Regulatory harmonisation	1	Ensure full consistency with EU laws and regulations Ensure compliance with ICAO standards (if appropriate) Achieve the maximum appropriate degree of harmonisation with the FAA/TCCA equivalent rules for commercial aviation

Table 3 gives an overview of the scores and their interpretation.

Table 3: Scores for the multi-criteria analysis

Score	Descriptions	Example for scoring options
+5	Highly positive impact	Highly positive safety, social or environmental protection impact. Savings of more than 5% of annual turnover for any single firm; Total annual savings of more than 100 million euros
+3	Medium positive impact	Medium positive social, safety or environmental protection impact. Savings of 1% - 5% of annual turnover for any single firm; Total annual savings of 10-100 million euros
+1	Low positive impact	Low positive safety, social or environmental protection impact. Savings of less than 1% of annual turnover for any single firm; Total annual savings of less than 10 million euros
0	No impact	
-1	Low negative impact	Low negative safety, social or environmental protection impact. Costs of less than 1% of annual turnover for any single firm; Total annual costs of less than 10 million euros
-3	Medium negative impact	Medium negative safety, social or environmental protection impact. Costs of 1% - 5% of annual turnover for any single firm; Total annual costs of 10-100 million euros
-5	Highly negative impact	Highly negative safety, social or environmental protection impact. Costs of more than 5% of annual turnover for any single firm; Total annual costs of more than 100 million euros

3.4.2. Cost-effectiveness analysis

Complementing the MCA, we used cost-effectiveness analysis to calculate the cost associated to preventing one fatality. Cost-effectiveness analysis ranks regulatory options based on ‘cost per unit of effectiveness’, i.e. cost per fatalities avoided.

In order to avoid a result that concentrates only on a single type of benefit (i.e. the number of fatalities avoided), the net cost of each option was calculated, which takes into account the benefit of avoided aeroplane damage and airport delays and diversions.

To make results comparable, all monetary values are expressed in 2013 euros. For future costs and benefits, a standard discount rate of 4% was applied and past costs were inflated with the same value. Discounted euro values are marked with the PV (present value) abbreviation in columns right from the undiscounted figures.

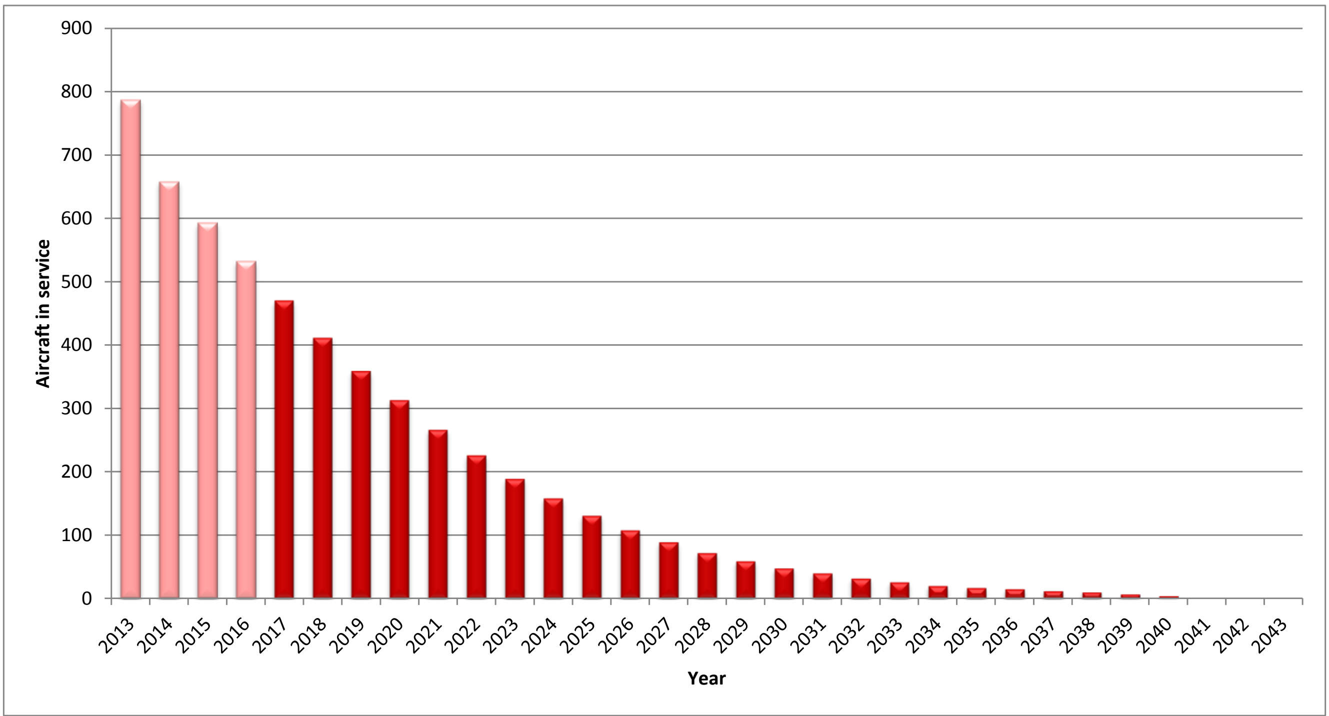
The benefits are accrued during the period while the aircraft with updated cargo compartments are in service (2017–2041), and the costs of installation are incurred in the last year of the transitionary period, 2016. Operating costs are parallel with the benefits (2017–2041).

3.5. Analysis of impacts

Option 0 (No regulatory change) would not establish in the EU rules on retrofit paralleling the existing FAA rules. The disharmonised situation would continue and the currently existing Class D compartments would remain in service until the aircraft are permanently retired from service with and European Operator (Figure 1). It is assumed that no new deliveries with Class D compartments take place.

Option 1: (Retrofit) could be mandated over the whole existing EU fleet, mirroring the FAAs Amdt 121-269 and associated rules in Part-121. Existing Class D cargo compartments would need to be upgraded to a Class C cargo compartment or in case of an all cargo aeroplane into a Class C or E cargo compartment. This could be regulated by amending Part-26 and CS-26. A transitionary period for the upgrade would end on 31 December 2016.

Figure 1: Number of aircraft in service with Class D cargo compartments[14]



[14] See Appendix 1 for calculation method of the retirements.

3.5.1. Safety impact

A conversion of Class D compartments to either Class C or E would aim at introducing earlier awareness of a fire in the cargo hold in the aircraft cockpit, thanks to installing fire detection systems. Earlier awareness, if achieved, would lead to a reduction of the severity of an event and therefore to a reduced risk for the aircraft and personnel.

However, the probability of a catastrophic fire event occurring in Class D cargo compartments, taking into account the declining number of fleet in service equipped in such a way, was forecasted to be 0.134, which means a 13.4% probability of a catastrophic event in the remaining service life of the affected fleet (see Table 11 on p27). If a retrofit were mandated in 2014, allowing a three-year transition period, the number of prevented accidents and fatalities from 2017 until all aircraft permanently retire would be 0.067 and 4.87 respectively.

Thus, while the severity would remain catastrophic, the probability of an event occurring in any given year is quickly evolving towards extremely improbable, so reducing the risk.

Furthermore, in 2012, the NTSB revising its recommendations A12-68 to 70[15] pointed out that smoke sensors do not necessarily significantly enhance safety in loaded cargo. The pallets, containers and similar object therein, can in fact obstruct and obscure the airflow in the compartment, so enlarging the warning time up to several minutes, until the moment that damage on the structure of the compartment is imminent. The NTSB therefore recommended further studies from the FAA, including the possibility of detecting fire or smoke not at the level of aircraft compartment, but at the level of container. These studies are not yet concluded at the present time, but it can already be stated that additional sensors in the aircraft cargo compartment could not significantly reduce the risk.

Highly loaded compartments also jeopardise the establishment of a saturation level of extinguishing agents, as introduced in Class C compartments.

The mandatory retrofit of Class D cargo compartments in option 1 would increase the awareness of the flight crew of possible fires therein, but possibly after several minutes. With the earlier awareness and fire extinguishing systems, where timely and effective, more options for reaction would be open and usually prove more effective in order to limit or prevent damage to aircraft or personnel. However, option 1 would not completely eliminate the risk of 0.067 catastrophic events in the period of 2017–2041, due to the limitations of the current systems, as highlighted by the mentioned NTSB assessment. It is therefore estimated to have a low positive safety impact (MCA score +1).

3.5.2. Environmental impact

The retrofit of aircraft from Class D towards a Class C or Class E compartment has only a minor impact on the environment through the fact that a retrofit will introduce a slight weight penalty for the aircraft. The average weight penalty per aircraft is in the range of 20 to 100 kg. This weight penalty will result in an associated greater consumption of fuel which would accumulate over the lifetime of the aircraft a significant amount of additional gaseous emissions.

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[15] http://www.ntsb.gov/doclib/recletters/2012/A-12-068-070.pdf.

In the estimation of the additional fuel burn we used an average aircraft MTOW of 55 tonnes, 50 kg of weight increase per airframe and 0.0132 US gallon additional fuel burn per flight hour and kilogram of added weight, which results in 0.6614 US gallon increase in fuel consumption per aircraft flight hour.

The affected fleet is projected to accumulate 4.7 million flight hours in the 2017–2041 period, which amounts to 3.2 million US gallon additional fuel consumption. Burning 3.2 million US gallon fuel creates 31 million tonnes of CO_2 emission (1 gallon creates 9.8 kg).

The method to calculate the environmental impact of the proposed amendment is based on the approach recommended by the European Commission financed HEATCO research project (Harmonised European Approach for Transport Costing). One of the main objectives of HEATCO is to create a consistent framework for monetary valuation and contribute to consistency with transport costing.

The costs due to the emission of greenhouse gases were calculated by multiplying the amount of CO_2 equivalents[16] emitted by a cost factor. The cost factor is based on the work of Watkiss et al (2005), which assumes that emissions in future years will have greater total impacts than emissions today (see Table 12 on page **Error! Bookmark not defined.**).

Since these aircraft and their flight hours represent a small and sharply decreasing share of the total annual traffic from 2017 to 2041, the environment impact is estimated to be low to negligible (MCA score -1).

3.5.3. Economic impact

Should a retrofit be mandated, the upgrade of Class D compartments to either Class C or E might lead to considerable cost for the operators implementing it. Depending on the legal solution for retrofit (i.e. mandated by rules), as well as on the possible regulatory transition time (assumed to be three years, i.e. 2014–2016 for this analysis), 532 out of 787 aircraft would need to be retrofitted (255 aircraft are retiring from service by the end of 2016).

The cost of the retrofit per aircraft would include around EUR 90 000 for the upgrade kit and installation per airframe. Because most operators would likely perform these retrofits during scheduled C-checks, there is no revenue lost due to time-out-of service during these conversions.

Multiplying this cost for the 532 large aeroplanes estimated to be affected, leads to a forecasted undiscounted cost for a fleet wide retrofit of EUR 42.6 million. The 2013 present value of the retrofit using a 4% discounting rate is EUR 37.8 million.

The discounted cost of additional fuel burn at a EUR 2.40 per gallon price is EUR 5.6 million in the 2017–2041 period (Table 14). During the forecasted 3.7 million departures in the 2017–2041 period we expect 165 false alarms[17] resulting in flight diversions with a cost of EUR 3.5 thousand each, amounting to EUR 0.4 million present value of additional costs. In

[16] In high altitudes other emissions from aircraft than CO_2 (water vapour, sulphate and soot aerosols, as well as nitrogen oxides) have a considerable climatic effect. To take into account the warming effect of other emissions than CO_2, we multiply high altitude CO_2 emissions by a factor of 2, as recommended by the HEATCO report based on recent research results.

[17] 44 false alarms per million departure.

the same period the maintenance cost of the system (annual EUR 200 per aircraft for the replacement of the fire bottles every five years) is EUR 0.5 million (PV) (Table 15).

The monetised benefits of avoiding a catastrophic accident include aircraft and ground damages avoided and accident investigation costs saved. The average resale value of an aircraft in the relevant fleet is EUR 3.1 million based on data from Ascend, the cost of accident investigation is estimated to be EUR 7.1 million in accordance with FAA values, and the avoided ground damage is EUR 0.5 million. These avoided costs were multiplied by the number of projected accidents in each year and then discounted to 2013 euro values (see Table 16 on page 32). The total present value of savings is EUR 0.5 million in the 2017–2041 period.

Table 4: Summary of benefits[18]

	Undiscounted	Discounted
Aircraft damage	€ 203 514	€ 150 821
Accident investigation	€ 472 692	€ 350 305
Ground damage	€ 33 361	€ 24 724
Total without VPF	€ 709 568	€ 525 850

Rule costs of option 1 are between EUR 10 and 50 million and are thus considered to be a medium negative impact (MCA score -3).

3.5.4. General aviation and proportionality issues

The possible rulemaking action only concerns CAT. Hence, there is no impact on general aviation.

Proportionality issues may emerge for Small and Medium Enterprises (SMEs) each operating few 'old' aircraft of the types concerned by this rulemaking task. The cost of retrofit could potentially overburden small regional operators and therefore could be problematic for SMEs.

The proportionality impact of option 1 is considered to be a low negative impact (MCA score -1).

3.5.5. Impact on 'Better Regulation' and harmonisation

Class D cargo compartments are no longer allowed in new models of large aeroplanes by CS-25, but it is still possible to operate 'old' aircraft equipped with them.

In the USA mandatory retrofit to change Class D into Class C or E was mandated by March 2001, through a rule promulgated in 1998 (see Table 6).

EU rules therefore differ, in respect of the retrofit, from the FAA rules promulgated 15 years ago.

No operator has reported that this lack of harmonisation causes problems to its business.

[18] 2013 discounted, present values (PV).
Discount rate: 4 per cent.
Appraisal period: 2017–2041.
For more details see Table 16 on page 31.

As Option 1 would introduce a similar retrofit requirement as in the US and thus increase harmonisation between FAA and EASA (MCA score +1).

3.6. Comparison and conclusion

3.6.1. Comparison of options

The identified options can finally be compared using the multi-criteria analysis (MCA) and the cost-effectiveness indicator. An overview of the results can be found in Table 5 on page 18.

As far as cost-effectiveness is concerned, option one is estimated to generate costs of roughly EUR 10.5 million per fatality prevented. This compares of a standard figure of EUR 2 million per fatality, which is is considered a standard value for cost-benefit analysis of this kind. Based on this indicator, **option 1 is not considered cost-effective**.

MCA allows to consider the cost impacts at the same time as the non-monetised impacts and thus gives a broader picture. The low positive safety and regulatory harmonisation (MCA scores of +1) is compared against a medium negative economic impact (-3) induced by the total rule costs of EUR 65.6 million and a low negative impact on proportionality and the environment (-1). This results in an overall negative score for option 1 compared to option 0. Even if safety is allowed a higher weight, this result remains stable.

Table 5: Overview of impacts (EASA operators, 2017-2041)[19]

Criteria (weight)	Qualitative impacts	Quantified impacts		MCA score	
				Unweighted	Weighted
Safety (3×)	Significant reduction of risk of uncontrollable fires by upgrading aircraft flying with Class D cargo compartments to the current CS-25 standards for Class	Accidents avoided: Fatalities prevented: Reduction in accident costs (A):	0.07 4.87 € 525 850	1	3
Environment (2×)		Additional tonnes of fuel burn: Additional tonnes of CO2 emmission: Shadow price of CO2 emmission (B):	 30 972 € 2 674 076	-1	-2
Economic		Costs of installation (C): Recurring costs (D):	€ 42 565 146 € 6 558 750	-3	-3
Proportionality	Installation costs might disproportionately affect small regional operators			-1	-1
Reguralory harmonisation	FAA mandated a similar retrofit in 1998. An EASA retrofit would increase harmonisation.			1	1
Overall MCA score				**-3**	**-2**
Efficiency/cost effectiveness		**Total net costs ([B + C + D] - A):** **Net cost per fatality prevented:**	**€ 51 272 122** **€ 10 518 523**		

[19] MCA scores are relative to option 0, 'no regulatory change'.

All monetary values are 2013 euros (present values discounted with a 4 % rate). More details in Annex Tables.

The table shows no more than two decimals but calculations were made without rounding. Recurring costs (D) are the costs of additional fuel burn, diversions, and maintenance (hydrostatic tests and fire bottle recharges/replacements).

3.6.2. Conclusion

The result of the multi-criteria analysis as well as the cost-effectiveness analysis indicates that option 0 should be the preferred option.

Option 1 would marginally increase the level of safety, but it is neither considered cost-effective nor proportionate. It would not completely eliminate the risk of catastrophic accidents caused by fires in cargo compartments, while putting a significant burden on operators. Furthermore, it has a slight negative impact on the environment.

Therefore, the resources required for option 1 are considered to be more effective for safety if spend on other safety-related activities. The expected present value of the costs to lower the probability of a catastrophic accident from 14.8% to 8.4% is EUR 47.7 million.

Question:
The Agency is interested in knowing whether stakeholders share and support the conclusion that a mandatory retrofit is not justified, on the basis of the analysis presented.

4. References

4.1. Reference documents

FAR-26

FAR 121

Part-26 (CRD 2013-13)

CS-25 (Amendment 12)

5. Appendix 1: Retirement curves

How quick will a new safety requirement mandated by CS-25 and CS-26 spread in the fleet?

The speed at which a new technology is introduced into a fleet may have a strong effect on the success of a rulemaking task aimed at increasing safety (e.g. to reduce runway excursions). In order to understand how fast the share of compliant aircraft increases in different options, we have to build a model of the fleet evolution.

The two most important factors in the fleet evolutions are the permanent retirement of old aircraft and the deliveries of new ones. Using historical data of retirements, we managed to find a third degree polynomial curve that fits very well the past observations and can be used to predict future retirements as a function of aircraft age.

The retirement curve shows the share of 'surviving' aircraft, in other words the percentage of delivered fleet remaining in service at any given age.

A careful review of literature and a comprehensive analysis of data (30 years) shows that retirement patterns have remained remarkably stable. Although projections based on past data should always be interpreted cautiously, there is no indication that these trends would change in the coming years or decades.

Applying the retirement curve requires the following steps:

- the current fleet is broken down into age categories;
- we project the current number of aircraft in each age Class back to year zero of the retirement curve (e.g. if we have 131 24-year old aircraft and we know that 53.6% survive till age 24, then the original number of them was 131÷0.536=244);
- we apply the retirement curve to get the number of aircraft remaining in the fleet for the next year (if 48.1% survive till age 25, then we get 244×0.481=117).

Calculating the difference between the two years (131–117=14), we get the number of aircraft retired.

Long-term fleet forecasts by large commercial aircraft manufacturers are very similar in their growth predictions for Europe for the coming decades (around three per cent). In order to realise this increase in the number of aircraft:

- one part of the new deliveries are used the replace the retired old aircraft;
- another part of the new deliveries enter into service to maintain the forecasted average annual growth rate.

Putting this information together, we can predict for any analysis period the number of old aircraft not meeting the new requirement and the size of the fleet which meets the new requirement.

6. Appendix 2: Extract from FAA final rule publishing amendments 25-93 and 121-269

'The benefits of detection and suppression systems depend on the degree to which the systems enable an aeroplane to avert a catastrophic accident in the event a fire occurs in a cargo or baggage compartment. Measuring this benefit, however, is problematic since it is determined not only by the relative fire-protection capabilities of Class C and Class D compartments, but on the probability that a fire will occur. Amendments to regulations -- e.g. restrictions on the transportation of hazardous materials and more stringent burn through requirements for compartment liners-also impinge on this analysis. (It should be noted, however, that the improvement standards for liners apply equally to both Class C and Class D compartments.)

The expected (future) rate of fires occurring in cargo or baggage compartments is estimated using historical accident and incident data from the National Transportation Safety Board (NTSB), FAA, insurance underwriters, and foreign aviation authorities.

These records show that during the 20-year period between 1977 and 1996, there were 19 fires reported as having occurred worldwide in Class D and Class C compartments involving transport category aeroplanes while used in commercial service.

During this period, air-carriers worldwide (excluding domestic operations within the former Soviet Union, the Russian Federation, and the Commonwealth of Independent States) accumulated approximately 224.5 million departures in transport category aeroplanes having Class C or Class D compartments.

The event rate for fires occurring in Class D and Class C compartments is, therefore, approximately 0.085 per million departures. It must be noted that the event rate of 0.085 per million departures is based, for the most part, on service experience that occurred when consumer aerosol cans contained inert propellants. The current use of highly-flammable propellants in consumer aerosol cans presents an additional hazard.

The available evidence shows that in the majority of incidents, Class D compartments successfully contain fires. Of the 16 in-flight fires occurring in Class D compartments, only four were reported to have resulted in casualties or substantial damage to the aeroplane.

A precise estimate of the likelihood of injury or aeroplane damage in the event a fire occurs in a Class D compartment is difficult to compute, however, owing to the limitations of accident and incident information. In many cases, necessary details had to be estimated. Where the post-event condition of the aeroplane is unknown, it is assumed that there was no damage. Where fatalities and injuries are unreported, it is assumed that there were no casualties. Where necessary, the number of occupants is estimated by applying the average load factor for that year by the average passenger capacity for a given aeroplane model.

The expected reduction in the proportion of occupants fatally injured in an accident resulting from a fire occurring in a Class D compartment is estimated as the ratio of fatalities to total occupants. Of the 1,411 individuals involved in the accidents cited above, 523 were fatally injured, representing approximately 37% of occupants.'

7. Appendix 3: Tables

Table 6: FAA and JAA/EASA rulemaking actions

No	FAA Rulemaking Action			JAA/EASA Rulemaking Action		
	Amendment	**Affected FAR**	**Applicability**	**Amendment**	**Affected JAR/ CS**	**Applicability**
1	Amendment 25-60 , May 1986	Part 25	TC of new large transport aeroplanes	Change 12, May 1988	JAR 25	TC of new large transport aeroplanes
2	Amendment 121-202, February 1989 Amendment 135-31, February 1989	Part 121 Part 135	retrofit to meet the requirements introduced by Amdt 25-60 to Part 25	Change, July 1998	JAR 26	retrofit to meet the requirements introduced by Amdt to JAR 26
3	Amendment 25-93, March 1998	Part 25	elimination of Class D cargo compartments for TC of new large transport aeroplanes	Amendment 3, September 2007	CS-25	elimination of Class D cargo compartments for TC of new large transport aeroplanes
	Amdt 121-269, March 1998	Part 121	retrofit of Class D cargo compartments to the requirement of either Class C or E cargo compartments	n/a	n/a	n/a

Table 7: Catastrophic and hazardous fire occurrences

Date	Carrier	Aircraft	Fatalities	Serious injuries	Notes
19/08/1980	Saudi Arabian Airlines (Flight 163)	Lockheed L-1011	301	0	Uncontrolled fire in the C-3 cargo compartment of the aircraft. Undetermined source of ignition.
23/09/1983	Gulf Air (Flight 771)	Boeing 737	112	0	Attributed to incindiary device
03/02/1988	American Airlines (Flight 132)	McDonnell Douglas MD-8:	0	13	Severe damage to cabin floor above compartments
11/05/1996	ValueJet (Flight 592)	McDonnell Douglas DC-9	110	0	Undeclared shipment of hazardous materials

Table 8: Correlation between aircraft age and annual flight hours

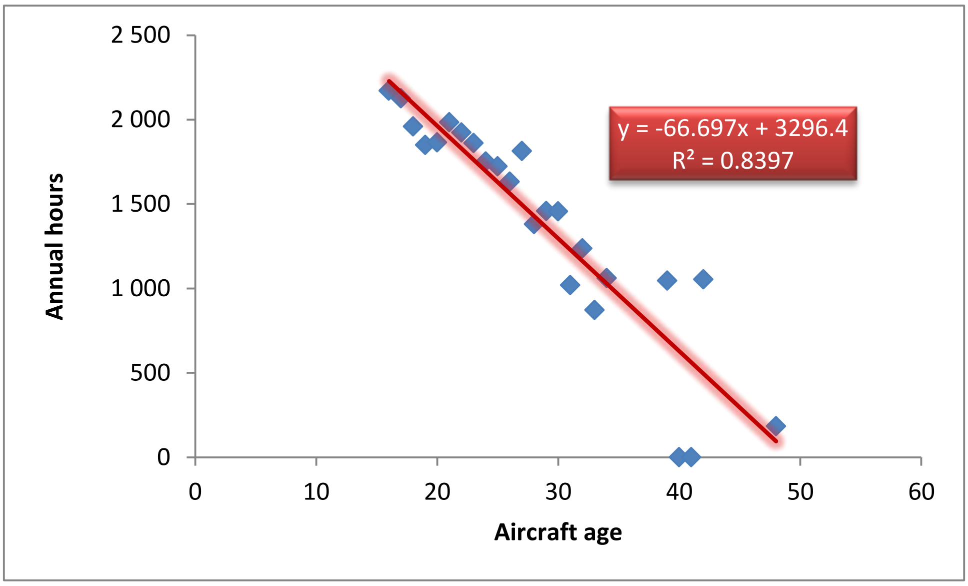

Table 9: Correlation between aircraft age and annual departures

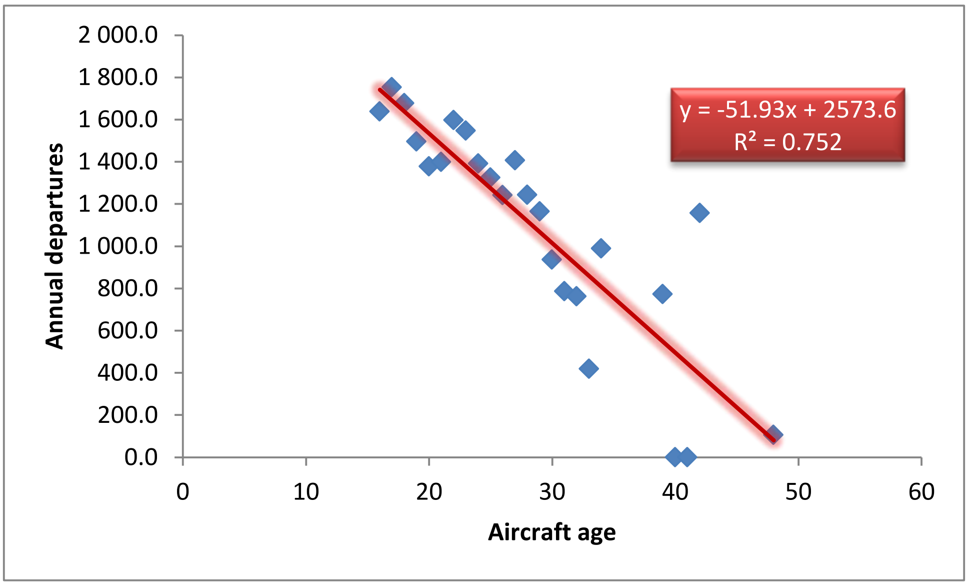

Table 10: 2013 European fleet with Class D cargo compartment[20]

Manufacturer	Type	Number of Aircraft	Average age
Airbus	A300	31	23.0
	A320	103	20.9
Antonov	An-12	1	48.0
	An-26	21	33.9
BAE SYSTEMS (Avro)	RJ Avroliner	58	18.0
BAE SYSTEMS (HS)	146	42	24.6
	748	1	42.0
	ATP	45	22.6
BAE SYSTEMS (Jetstream)	Jetstream 41	20	19.1
Boeing	727	3	30.3
	737 (CFMI)	255	21.8
	737 (JT8D)	7	34.0
	737 (NG)	3	16.0
Boeing (McDonnell-Douglas)	MD-80	70	24.9
Embraer	EMB-120 Brasilia	16	25.8
	ERJ-145	8	16.0
Fairchild/Dornier	328	16	18.6
Fokker	100	47	20.9
	70	35	17.5
	F.28	1	27.0
Lockheed	L-1011 TriStar	3	33.0
Tupolev	Tu-154	1	24.0
Total		787	22.1

[20] Some of the Airbus A320s operated by European airlines might have no Class D cargo compartment

Table 11: Estimated evolution of fleet and risk with Class D cargo compartments

Year	Aircraft with Class D cargo comp.	Average aircraft age	Average departures per aircraft	Total departures	Accidents	Fatalities
2013	787	22.1	1 426	1 122 262	0.020	1.461
2014	722	22.9	1 383	998 526	0.018	1.300
2015	658	23.7	1 341	882 378	0.016	1.149
2016	593	24.5	1 303	772 679	0.014	1.006
2017	**532**	25.3	1 258	669 256	0.012	0.871
2018	470	26.2	1 214	570 580	0.010	0.743
2019	411	27.0	1 170	480 870	0.009	0.626
2020	359	27.9	1 125	403 875	0.007	0.526
2021	313	28.8	1 078	337 414	0.006	0.439
2022	266	29.6	1 037	275 842	0.005	0.359
2023	226	30.5	990	223 740	0.004	0.291
2024	189	31.4	945	178 605	0.003	0.232
2025	158	32.2	902	142 516	0.003	0.186
2026	131	33.1	857	112 267	0.002	0.146
2027	108	34.0	808	87 264	0.002	0.114
2028	89	34.9	760	67 640	0.001	0.088
2029	72	35.8	716	51 552	0.001	0.067
2030	59	36.7	669	39 471	0.001	0.051
2031	48	37.6	621	29 808	0.001	0.039
2032	40	38.6	570	22 800	0.000	0.030
2033	32	39.5	522	16 704	0.000	0.022
2034	26	40.5	470	12 220	0.000	0.016
2035	20	41.7	411	8 220	0.000	0.011
2036	17	42.9	347	5 899	0.000	0.008
2037	15	44.1	285	4 275	0.000	0.006
2038	12	45.6	206	2 472	0.000	0.003
2039	10	47.4	112	1 120	0.000	0.001
2040	7	48.4	59	413	0.000	0.001
2041	4	50.0	0	0	0.000	0.000
2042	0	:	:	:	:	:
2043	0	:	:	:	:	:
2044	0	:	:	:	:	:
Total from 2013 to 2043				7 520 668	0.134	9.789
Total from 2017 to 2043				3 744 823	0.067	4.874

Table 12: Shadow prices per tonne of CO_2 equivalent emitted (EUR)

Year of emission	Central guidance
2000-2009	22
2010-2019	26
2020-2029	32
2030-2039	40
2040-2049	55
2050-	83

Table 13: Shadow prices of emission with climatic effect[21]

Year	Aircraft with Class D cargo comp.	Average aircraft age	Annual flight hours per aircraft	Total annual flight hours	Additional fuel burn (US gallon)	Additional CO2 emission (9.8kg/US gallon)	Shadow price of high altitude emission (per tonne)	HEATCO shadow price of greenhouse gas emission (undiscounted)	HEATCO shadow price of greenhouse gas emission (PV)
2013	787	22.1	1 822	1 433 914	:	:	€ 52	:	:
2014	722	22.9	1 768	1 276 496	:	:	€ 52	:	:
2015	658	23.7	1 714	1 127 812	:	:	€ 52	:	:
2016	593	24.5	1 665	987 345	:	:	€ 52	:	:
2017	**532**	25.3	1 607	854 924	565 435	5 543 601	€ 52	€ 576 534	€ 492 824
2018	470	26.2	1 550	728 500	481 820	4 723 827	€ 52	€ 491 278	€ 403 795
2019	411	27.0	1 493	613 623	405 842	3 978 928	€ 52	€ 413 809	€ 327 039
2020	359	27.9	1 435	515 165	340 723	3 340 495	€ 64	€ 427 583	€ 324 928
2021	313	28.8	1 375	430 375	284 644	2 790 689	€ 64	€ 357 208	€ 261 009
2022	266	29.6	1 323	351 918	232 754	2 281 949	€ 64	€ 292 089	€ 205 218
2023	226	30.5	1 262	285 212	188 635	1 849 406	€ 64	€ 236 724	€ 159 922
2024	189	31.4	1 205	227 745	150 628	1 476 771	€ 64	€ 189 027	€ 122 788
2025	158	32.2	1 149	181 542	120 069	1 177 176	€ 64	€ 150 679	€ 94 113
2026	131	33.1	1 092	143 052	94 613	927 595	€ 64	€ 118 732	€ 71 307
2027	108	34.0	1 029	111 132	73 501	720 615	€ 64	€ 92 239	€ 53 266
2028	89	34.9	967	86 063	56 921	558 060	€ 64	€ 71 432	€ 39 663
2029	72	35.8	910	65 520	43 334	424 853	€ 64	€ 54 381	€ 29 035
2030	59	36.7	850	50 150	33 169	325 189	€ 80	€ 52 030	€ 26 711
2031	48	37.6	788	37 824	25 016	245 263	€ 80	€ 39 242	€ 19 371
2032	40	38.6	724	28 960	19 154	187 786	€ 80	€ 30 046	€ 14 261
2033	32	39.5	662	21 184	14 011	137 364	€ 80	€ 21 978	€ 10 031
2034	26	40.5	595	15 470	10 232	100 312	€ 80	€ 16 050	€ 7 043
2035	20	41.7	518	10 360	6 852	67 178	€ 80	€ 10 748	€ 4 535
2036	17	42.9	436	7 412	4 902	48 062	€ 80	€ 7 690	€ 3 120
2037	15	44.1	357	5 355	3 542	34 724	€ 80	€ 5 556	€ 2 167
2038	12	45.6	256	3 072	2 032	19 920	€ 80	€ 3 187	€ 1 196
2039	10	47.4	135	1 350	893	8 754	€ 80	€ 1 401	€ 505
2040	7	48.4	66	462	306	2 996	€ 110	€ 659	€ 229
2041	4	50.0	0	0	0	0	€ 110	€ 0	€ 0
2042	:	:	:	:	:	:	:	:	:
2043	:	:	:	:	:	:	:	:	:
2044	:	:	:	:	:	:	:	:	:
Total from 2013 to 2043				9 601 937	3 159 028	30 971 512		€ 3 660 302	€ 2 674 076
Total from 2017 to 2043				4 776 370	3 159 028	30 971 512		€ 3 660 302	€ 2 674 076

[21] Present values are discounted values expressed in 2013 euros.
Discount rate: 4 per cent.
Appraisal period: 2017–2041.

Table 14: Cost of additional fuel burn[22]

Year	Aircraft with Class D cargo comp.	Average aircraft age	Annual flight hours per aircraft	Total annual flight hours	Additional fuel burn (US gallon)	Cost of additional fuel burn (undiscounted)	Cost of additional fuel burn (PV)
2013	787	22.1	1 822	1 433 914	:	:	:
2014	722	22.9	1 768	1 276 496	:	:	:
2015	658	23.7	1 714	1 127 812	:	:	:
2016	593	24.5	1 665	987 345	:	:	:
2017	**532**	25.3	1 607	854 924	565 435	€ 1 355 496	€ 1 158 684
2018	470	26.2	1 550	728 500	481 820	€ 1 155 049	€ 949 366
2019	411	27.0	1 493	613 623	405 842	€ 972 909	€ 768 904
2020	359	27.9	1 435	515 165	340 723	€ 816 802	€ 620 703
2021	313	28.8	1 375	430 375	284 644	€ 682 367	€ 498 599
2022	266	29.6	1 323	351 918	232 754	€ 557 972	€ 392 024
2023	226	30.5	1 262	285 212	188 635	€ 452 208	€ 305 496
2024	189	31.4	1 205	227 745	150 628	€ 361 093	€ 234 559
2025	158	32.2	1 149	181 542	120 069	€ 287 838	€ 179 783
2026	131	33.1	1 092	143 052	94 613	€ 226 811	€ 136 217
2027	108	34.0	1 029	111 132	73 501	€ 176 202	€ 101 752
2028	89	34.9	967	86 063	56 921	€ 136 454	€ 75 768
2029	72	35.8	910	65 520	43 334	€ 103 883	€ 55 464
2030	59	36.7	850	50 150	33 169	€ 79 514	€ 40 820
2031	48	37.6	788	37 824	25 016	€ 59 971	€ 29 603
2032	40	38.6	724	28 960	19 154	€ 45 917	€ 21 794
2033	32	39.5	662	21 184	14 011	€ 33 588	€ 15 329
2034	26	40.5	595	15 470	10 232	€ 24 528	€ 10 764
2035	20	41.7	518	10 360	6 852	€ 16 426	€ 6 931
2036	17	42.9	436	7 412	4 902	€ 11 752	€ 4 768
2037	15	44.1	357	5 355	3 542	€ 8 490	€ 3 312
2038	12	45.6	256	3 072	2 032	€ 4 871	€ 1 827
2039	10	47.4	135	1 350	893	€ 2 140	€ 772
2040	7	48.4	66	462	306	€ 733	€ 254
2041	4	50.0	0	0	0	€ 0	€ 0
2042	:	:	:	:	:	:	:
2043	:	:	:	:	:	:	:
2044	:	:	:	:	:	:	:
Total from 2013 to 2043				9 601 937	3 159 028	€ 7 573 012	€ 5 613 492
Total from 2017 to 2043				4 776 370	3 159 028	€ 7 573 012	€ 5 613 492

[22] Present values are discounted values expressed in 2013 euros.
Discount rate: 4 per cent.
Appraisal period: 2017–2041.

Table 15: Cost of false alarms and fire bottle replacement[23]

Year	Aircraft with Class D cargo comp.	Average aircraft age	Departures per aircraft	Total departures	False alarms resulting in diversions	Diversion costs (undiscounted)	Diversion costs (PV)	Fire bottle replacement cost (undiscounted)	Fire bottle replacement cost (PV)
2013	787	22.1	1 426	1 122 262	:	:	:	:	:
2014	722	22.9	1 383	998 526	:	:	:	:	:
2015	658	23.7	1 341	882 378	:	:	:	:	:
2016	593	24.5	1 303	772 679	:	:	:	:	:
2017	**532**	25.3	1 258	669 256	29.4	€ 103 065	€ 88 101	€ 106 400	€ 90 951
2018	470	26.2	1 214	570 580	25.1	€ 87 869	€ 72 222	€ 94 000	€ 77 261
2019	411	27.0	1 170	480 870	21.2	€ 74 054	€ 58 526	€ 82 200	€ 64 964
2020	359	27.9	1 125	403 875	17.8	€ 62 197	€ 47 264	€ 71 800	€ 54 562
2021	313	28.8	1 078	337 414	14.8	€ 51 962	€ 37 968	€ 62 600	€ 45 741
2022	266	29.6	1 037	275 842	12.1	€ 42 480	€ 29 846	€ 53 200	€ 37 378
2023	226	30.5	990	223 740	9.8	€ 34 456	€ 23 277	€ 45 200	€ 30 536
2024	189	31.4	945	178 605	7.9	€ 27 505	€ 17 867	€ 37 800	€ 24 554
2025	158	32.2	902	142 516	6.3	€ 21 947	€ 13 708	€ 31 600	€ 19 737
2026	131	33.1	857	112 267	4.9	€ 17 289	€ 10 383	€ 26 200	€ 15 735
2027	108	34.0	808	87 264	3.8	€ 13 439	€ 7 760	€ 21 600	€ 12 473
2028	89	34.9	760	67 640	3.0	€ 10 417	€ 5 784	€ 17 800	€ 9 884
2029	72	35.8	716	51 552	2.3	€ 7 939	€ 4 239	€ 14 400	€ 7 688
2030	59	36.7	669	39 471	1.7	€ 6 079	€ 3 121	€ 11 800	€ 6 058
2031	48	37.6	621	29 808	1.3	€ 4 590	€ 2 266	€ 9 600	€ 4 739
2032	40	38.6	570	22 800	1.0	€ 3 511	€ 1 667	€ 8 000	€ 3 797
2033	32	39.5	522	16 704	0.7	€ 2 572	€ 1 174	€ 6 400	€ 2 921
2034	26	40.5	470	12 220	0.5	€ 1 882	€ 826	€ 5 200	€ 2 282
2035	20	41.7	411	8 220	0.4	€ 1 266	€ 534	€ 4 000	€ 1 688
2036	17	42.9	347	5 899	0.3	€ 908	€ 369	€ 3 400	€ 1 379
2037	15	44.1	285	4 275	0.2	€ 658	€ 257	€ 3 000	€ 1 170
2038	12	45.6	206	2 472	0.1	€ 381	€ 143	€ 2 400	€ 900
2039	10	47.4	112	1 120	0.0	€ 172	€ 62	€ 2 000	€ 721
2040	7	48.4	59	413	0.0	€ 64	€ 22	€ 1 400	€ 486
2041	4	50.0	0	0	0.0	€ 0	€ 0	€ 800	€ 267
2042	:	:	:	:	:	:	:	:	:
2043	:	:	:	:	:	:	:	:	:
2044	:	:	:	:	:	:	:	:	:
Total from 2013 to 2043				7 520 668	165	€ 576 703	€ 427 385	€ 722 800	€ 517 873
Total from 2017 to 2043				3 744 823	165	€ 576 703	€ 427 385	€ 722 800	€ 517 873

[23] Present values are discounted values expressed in 2013 euros.
Discount rate: 4 per cent.
Appraisal period: 2017–2041.

Table 16: Benefits of accidents avoided[24]

Year	Aircraft with Class D cargo comp.	Average aircraft age	Departures per aircraft	Total departures	Accidents	Aircraft damages (undiscounted)	Aircraft damages (PV)	Investigation costs (undiscounted)	Investigation costs (PV)	Ground property damage (undiscounted)	Ground property damage (PV)
2013	787	22.1	1 426	1 122 262	0.020	€ 60 990	€ 60 990	€ 141 658	€ 141 658	€ 9 998	€ 9 998
2014	722	22.9	1 383	998 526	0.018	€ 54 265	€ 52 178	€ 126 039	€ 121 192	€ 8 896	€ 8 553
2015	658	23.7	1 341	882 378	0.016	€ 47 953	€ 44 336	€ 111 379	€ 102 976	€ 7 861	€ 7 268
2016	593	24.5	1 303	772 679	0.014	€ 41 992	€ 37 330	€ 97 532	€ 86 705	€ 6 884	€ 6 119
2017	**532**	25.3	1 258	669 256	0.012	€ 36 371	€ 31 090	€ 84 477	€ 72 211	€ 5 962	€ 5 097
2018	470	26.2	1 214	570 580	0.010	€ 31 008	€ 25 487	€ 72 022	€ 59 197	€ 5 083	€ 4 178
2019	411	27.0	1 170	480 870	0.009	€ 26 133	€ 20 653	€ 60 698	€ 47 971	€ 4 284	€ 3 386
2020	359	27.9	1 125	403 875	0.007	€ 21 949	€ 16 679	€ 50 979	€ 38 740	€ 3 598	€ 2 734
2021	313	28.8	1 078	337 414	0.006	€ 18 337	€ 13 399	€ 42 590	€ 31 120	€ 3 006	€ 2 196
2022	266	29.6	1 037	275 842	0.005	€ 14 991	€ 10 532	€ 34 818	€ 24 463	€ 2 457	€ 1 727
2023	226	30.5	990	223 740	0.004	€ 12 159	€ 8 214	€ 28 242	€ 19 079	€ 1 993	€ 1 347
2024	189	31.4	945	178 605	0.003	€ 9 706	€ 6 305	€ 22 545	€ 14 644	€ 1 591	€ 1 034
2025	158	32.2	902	142 516	0.003	€ 7 745	€ 4 838	€ 17 989	€ 11 236	€ 1 270	€ 793
2026	131	33.1	857	112 267	0.002	€ 6 101	€ 3 664	€ 14 171	€ 8 511	€ 1 000	€ 601
2027	108	34.0	808	87 264	0.002	€ 4 742	€ 2 739	€ 11 015	€ 6 361	€ 777	€ 449
2028	89	34.9	760	67 640	0.001	€ 3 676	€ 2 041	€ 8 538	€ 4 741	€ 603	€ 335
2029	72	35.8	716	51 552	0.001	€ 2 802	€ 1 496	€ 6 507	€ 3 474	€ 459	€ 245
2030	59	36.7	669	39 471	0.001	€ 2 145	€ 1 101	€ 4 982	€ 2 558	€ 352	€ 181
2031	48	37.6	621	29 808	0.001	€ 1 620	€ 800	€ 3 763	€ 1 857	€ 266	€ 131
2032	40	38.6	570	22 800	0.000	€ 1 239	€ 588	€ 2 878	€ 1 366	€ 203	€ 96
2033	32	39.5	522	16 704	0.000	€ 908	€ 414	€ 2 108	€ 962	€ 149	€ 68
2034	26	40.5	470	12 220	0.000	€ 664	€ 291	€ 1 542	€ 677	€ 109	€ 48
2035	20	41.7	411	8 220	0.000	€ 447	€ 188	€ 1 038	€ 438	€ 73	€ 31
2036	17	42.9	347	5 899	0.000	€ 321	€ 130	€ 745	€ 302	€ 53	€ 21
2037	15	44.1	285	4 275	0.000	€ 232	€ 91	€ 540	€ 211	€ 38	€ 15
2038	12	45.6	206	2 472	0.000	€ 134	€ 50	€ 312	€ 117	€ 22	€ 8
2039	10	47.4	112	1 120	0.000	€ 61	€ 22	€ 141	€ 51	€ 10	€ 4
2040	7	48.4	59	413	0.000	€ 22	€ 8	€ 52	€ 18	€ 4	€ 1
2041	4	50.0	0	0	0.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
2042	:	:	:	:	:	:	:	:	:	:	:
2043	:	:	:	:	:	:	:	:	:	:	:
2044	:	:	:	:	:	:	:	:	:	:	:
Total from 2013 to 2043				7 520 668	0.134	€ 408 715	€ 345 656	€ 949 300	€ 802 836	€ 66 999	€ 56 662
Total from 2017 to 2043				3 744 823	0.067	€ 203 514	€ 150 821	€ 472 692	€ 350 305	€ 33 361	€ 24 724

[24] Present values are discounted values expressed in 2013 euros.
Discount rate: 4 per cent.
Appraisal period: 2017–2041.